Survey of the types of stowage used in refrigerated containers for the transport of export fresh fruit

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Abstract

The maintenance of cold chain and temperature uniformity during transport of fresh fruit are critical factors to extend shelf life and maintain quality to reach distant international markets. The types of load patterns in a full load 12-m refrigerated containers using the stowage plans recommended by 5 top ten shipping lines and a new pattern were investigated. The container internal loading areas, type and size of pallets, and corners thickness were measured. The dimensions of 3 types of pallets used by the fruit industry were measured: 1016×1220 (American), 1000×1200 (Metric) and 800×1200 mm (Euro). The free area generated in the container floor cargo area was calculated considering the difference of total load area of the container and the areas occupied by the loaded pallets, including corners. The most common stowage plans were "9×11" and "Blocks of 4" with some modifications. Results show that the load area occupancy and the free area generated in the container floor vary depending mainly on the types of pallets used. Moreover, the free area in the container floor of a same pallet dimension varies depending of the type of dunnage used, and in most of the shipping companies is overlooked and not considered. Free areas in different positions of the container could be generated from incorrect installation of cardboard covering the free T-floor and the different openings where the air can escape, especially in areas close to the refrigeration unit, generating short cycles, decreasing the air circulation close to the door area, affecting the proper air temperature throughout the container. A more efficient stowage pattern is presented.

Keywords: stowage plan, reefer, pallet

INTRODUCTION

An efficient postharvest cold chain is essential to preserve the quality of fresh produce and to extend its shelf life in order to reduce food losses (Thompson et al., 2000; Defraeye et al., 2016). Sea transport accounts for 94% of the long distance fresh produce export system from Chile to over 100 countries in the world. In the last 10 years it has become the main fresh commodity exporter of the southern hemisphere, reaching 4.6 billion dollars value (SNA, 2012). From Valparaiso (Chile) to Tokyo (Japan), transport may take 34 days (CCNI, 2012). Accurate loading and control systems in reefer containers are essential to maintain fruit quality to markets. Containers are equipped with a bottom-air delivery system. Air from the refrigeration unit flows first to the floor, up through the load, horizontally across the top of the load, and then back to the refrigeration unit air return opening (Thompson et al., 2000).

In reefer containers, the so called "short air circulating cycle" may occur, near the refrigeration area where cool air comes out, while in the other side of the container, the doors area, the cold air flow is lower. Consequently, the air temperature at the door area is higher than the rest of the container.

If the floor and pallet openings are not completely covered, refrigerated air will short-cycle back to the refrigeration unit and bypass most of the load (Thompson et al., 2000). More integrated evaluation of cold chain performance is key for developing a more resource-

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efficient, energy-smart food supply chain (Defraeye et al., 2016). Transport operations have received less attention, despite being a critical link in the cold chain (Gac, 2002; James et al., 2006).

To obtain the maximum working efficiency of the reefer container, detailed placement of the fruit load and the additional material to fill unwanted spaces must be considered (Thompson et al., 2000). So, it becomes essential to consider all the components sizes and dimensions: the area to be loaded, the pallet, correct loading of boxes, and thickness of corners, ventilation area, and the utilization of material to cover floors free air spaces. All these factors mentioned are present in any reefer container to transport export fruit, and the correct use and placement of the additional elements to direct the correct cool air circulation in all the areas of the container is essential. So, the objective of this work, was to study the dimensions of all material used in the reefer container utilized to accommodate fruit load to export and verify the correct fitting to avoid loss of air circulation efficiency.

MATERIALS AND METHODS

Refrigerated containers

Inner dimensions for 12 m (40 foot) reefer containers were obtained at official web sites, from two different High Cube refrigerated manufacturers: Shangai CIMC Reefers Containers (CCNI, 2012) and Maersk Container Industry Qingdao (Maersk Line, 2011). To verify this information, on site measurements were made on 20 containers, 10 for each manufacturer, at the SITRANS store plant in Valparaíso (Chile). The useful surface cargo area was obtained from wall to wall total inner width by the length of the T bar floor only.

The stowage pattern was obtained from 5 top ten worldwide shipping companies (through website or technical brochures), and one developed by Luchsinger and used by many export companies in Chile and Perú, since 2000.

Pallets

Fifty measurements (in mm for accuracy) were made to each of the three types of wooden pallets commonly used by the fruit industry around the world: American Pallet (1016×1220 mm, 40×48 in), Metric Pallet (1000×1200 mm), and Euro Pallet (800×1200 mm). The area (m^2) was calculated for each one of them.

Corners (deck boards)

This element used in the corners of the boxes and pallet to secure verticality and impede the sliding of boxes over each other on the pallet load. For this purpose, 100 cardboard corners of 2,39 m height used for High Cube box staking were measured and the thickness (mm) of both sides was determined using a digital caliper.

Free area of the container floor

Two different analyses were performed:

- First, the free area of the containers for each type of pallet was determined, measuring containers for both manufacturers, the three types of pallets, and the thickness of the corners. Then the T-floor area and the loading area for the full load of each type of pallet was calculated, and by difference, the free floor area of the container.
- Second, the free area of each loading plan, used by different companies was evaluated, for the same type of pallet, in which the free area generated by the T-floor was calculated.

Statistical analysis

The design used, was a complete randomized design, where the experimental unit was the container. The treatments were the manufacturer or the type of staking used, each one with 10 repetitions. An ANDEVA with Tukey test (5%) was used to determine the difference between treatments.

RESULTS AND DISCUSSION

The informed and measured on-site floor cargo areas for the two manufacturers are shown in Table 1. No significant difference was observed among them, with values from 26.14 to 26.58 m^2. In order to simplify the calculations in this paper, the average area of the two-measured manufacturers was used (26.17 m^2, an average length of 11.43 m and a width of 2.29 m).

Table 1. Informed and measured floor cargo area for two different 12-m (40 foot) reefer manufacture containers.

Manufacturer	Floor area (m^2)	
	Informed	Measured
Maersk	26.34 a	26.14 a
CIMC	26.58 a	26.19 a

Values with the same letter are not statistical significantly different between treatments, according to Tukey test at 5%.

The pallet areas for each type of pallet are shown in Table 2. The American pallet (1.24 m^2) and the Metric (1.20 m^2) one are quite similar in area but with statistically significant differences. The Euro pallet has the lowest area (0.96 m^2). When adding the corner thickness into the pallet dimensions, the pallet areas are slightly increased (Table 3).

Table 2. Mean measured dimensions and pallet area for different types of pallet used in 12-m refrigerated containers.

Pallet dimension (mm)	Width (mm)	SD[1]	Length (mm)	SD	Area (m^2)	SD
1016×1220 - American	1014 a[2]	0,002	1219 a	0,004	1.24 a	0,005
1000×1200 - Metric	1001 b	0,002	1202 b	0,003	1.20 b	0,004
800×1200 - Euro	799 c	0,002	1199 b	0,002	0.96 c	0,003

[1]SD = standard deviation.
[2]Values with the same letter are not statistical significantly different between treatments, according to Tukey test at 5%.

Table 3. Pallet area (including corners), number of pallets and total cargo area at full load for different types of pallets used in 12-m refrigerated containers.

Pallet dimensions (mm)	Load dimensions				
	Width[1] (mm)	Length[1] (mm)	Pallet area[1] (m^2)	Number of pallets	Total cargo area[1] (m^2)
1016×1220 - American	1024 a[2]	1228 a	1.26 a	20	25.15 a
1000×1200 - Metric	1008 b	1208 b	1.22 b	20	24.35 b
800×1200 - Euro	808 c	1208 b	0.98 c	23	22.45 c

[1]Including corners.
[2]Values with the same letter are not statistical significantly different between treatments, according to Tukey test at 5%.

The pallet area gives different numbers of pallets that can be stowed in a container. For a 12-m full load refrigerated container, both American and Metric pallets hold 20 pallets, and 23 for the Euro pallet (Table 3; Figure 1). Therefore, each pallet area multiplied by the total number of pallets gives the total cargo area. As seen in Table 3, the largest total cargo area is with 20 American pallets, with a value of 25.15 m^2, followed by 20 Metric pallets with 24.35 m^2, and the lowest is the Euro pallet with 22.45 m^2, even though a fully loaded container holds 23 pallets.

To determine the free floor area, the total cargo area for each type of pallet was subtracted from the average floor cargo area of 26.17 m^2 (Table 4). Since the American pallet has the largest pallet area (Table 3), obviously this gives the lowest free floor area (1.02 m^2 and 3.90%). Even though the Metric pallet is not that different in pallet area, the differences in free floor area are very significant (0.80 m^2 and 3.05%). A fully loaded container with

Euro pallet presents the largest free floor area (3.72 m^2 and 14.21%), even with 23 pallets.

To obtain the maximum working efficiency of the reefer container, detailed placement of the fruit load and the additional material to fill unwanted spaces must be considered (Thompson et al., 2000). The larger the free floor area, the larger the probabilities to make mistakes when covering the T-floor, therefore increasing the possibilities of losing air causing short cycles.

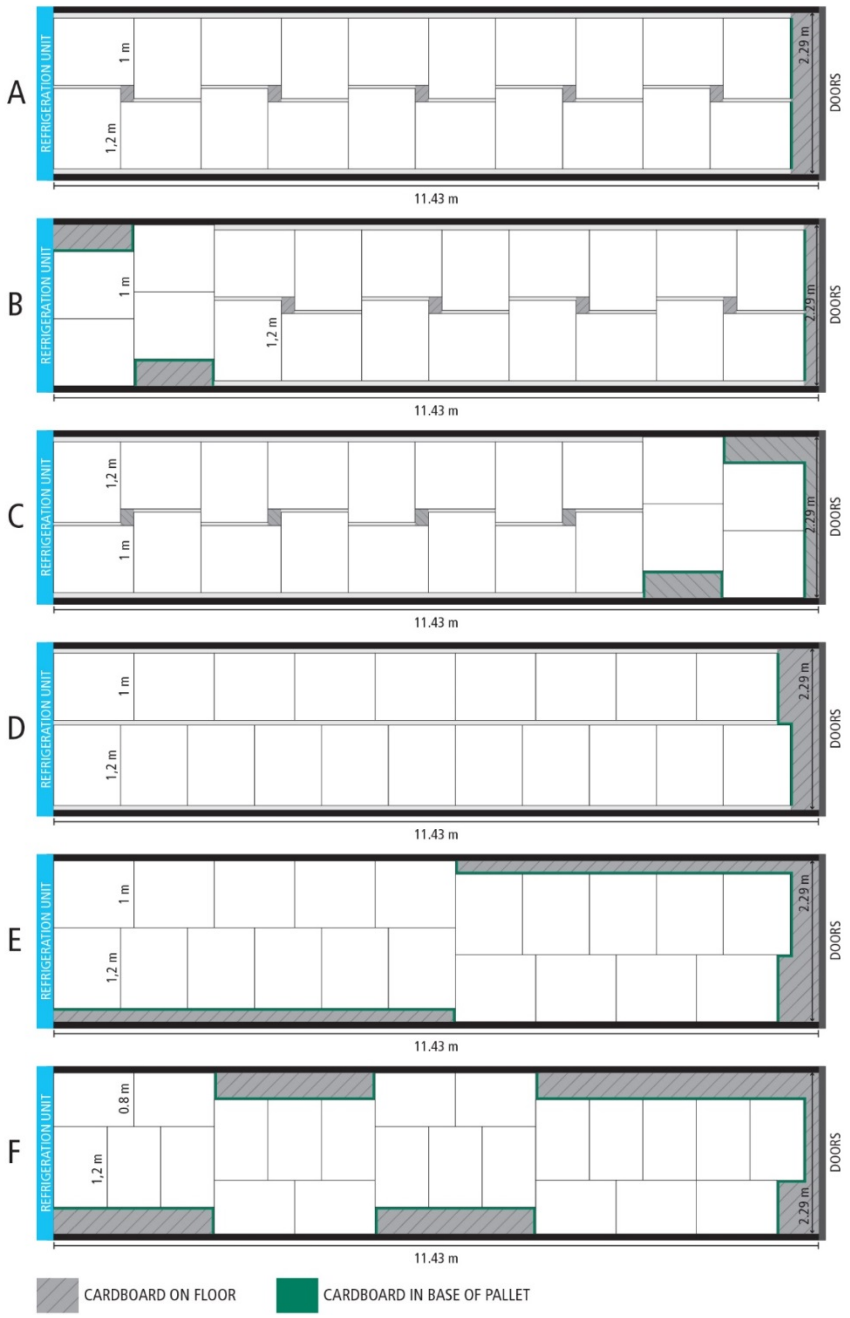

Figure 1. Most common stowage pattern used in 12 m refrigerated containers. A) five blocks of 4; B) start with 2 similar pairs of pallets, then four blocks of 4; C) start with four blocks of 4 and end with 2 similar pairs of pallets; D) patter 9×11; E) pattern 9×11 modified by Luchsinger; F) Euro pallet pattern.

Table 4. Total average floor area, total cargo area and free floor area (m² and %) at full load for different types of pallets (including corners) used in 12-m refrigerated containers.

Pallet dimension (mm)	Total floor area (m²)	Total cargo area (m²)	Free floor area (m²)	Free floor area (%)
1016×1220 - American	26.17	25.15 a	1.02 c	3.90 c
1000×1200 - Metric	26.17	24.35 b	1.82 b	6.95 b
800×1200 - Euro	26.17	22.45 c	3.72 a	14.21 a

Values with the same letter are not statistical significantly different between treatments, according to Tukey test at 5%.

Since a fully loaded container with Euro pallet has less cargo area (Table 4), it will be able to load just 92% of the load in comparison with the American or Metric pallet (Table 5). Therefore the cost for transport of a fully loaded 12-m container will be 8% higher than the other types of pallets, even though a container can carry only 20 pallets. In fact, Euro pallets are uncommon nowadays, also because they are more complicated to load and cover the free floor spaces.

Table 5. Comparison of the cargo efficiency (number of boxes) in American or Metric, with the Euro pallets in a 12-m refrigerated containers, for a box of 30×40×11 cm.

Pallet type	N° pallets	Boxes per layer	N° of layers	N° of boxes per pallet	N° of boxes per container	Cargo efficiency (%)
American or Metric	20	10	18	180	3600	100
Euro	23	8	18	144	3312	92

When taking a detailed look at the different loading patterns, it can be observed that in patterns A, B, C and D (Figure 1), not all free floor spaces are covered by cardboard or similar material, since small spaces are overlooked, a common error in the container transportation industry. Due to the length restriction in this paper, the floor area not covered for each stowage pattern will be shown only for the metric pallet, including corners (Table 6); a similar pattern can be concluded for the American pallet. The ones that present the highest uncovered floor areas are pattern A and D, with 45%. Patterns B and C are similar, with 36.3% uncovered free floor spaces. The only patterns that consider the full cover of the free floor spaces are E and F; therefore, the uncovered floor area is zero. Since pattern F is a more complicated one, and also less cost efficient as already explained, the more efficient and simple option is patter E. In commercial uses, this pattern performs with a more homogeneous temperature when comparing front (refrigeration unit) and rear section (doors) temperatures (data not showed), which will be presented in a coming paper.

Table 6. Total free floor area, cover and uncover areas (m² and %) at full load, for metric pallets (including corners) used in 12-m refrigerated containers.

Stowage pattern	N° of pallets	Total free floor area (m²)	Free floor area covered at cargo section (m²)	Free floor area covered at door section (m²)	Uncovered floor area (m²) (%)	
					(m²)	(%)
A - five blocks of 4	20	1.82	0.20	0.80	0.82	45.1
B - start with two parallel pallets, then four blocks of 4	20	1.82	0.82	0.34	0.66	36.3
C - start with four blocks of 4 and end with two parallel pallets	20	1.82	0.82	0.34	0.66	36.3
D - 9×11	20	1.82	0.00	1.00	0.82	45.1
E - 9×11 modified by Luchsinger	20	1.82	0.82	1.00	0.00	0.0
F - euro pallet	23	3.72	3.09	0.63	0.00	0.0

CONCLUSIONS

There are two major conclusions that can be drawn from this study:

I. The following variabilities are not significant for the purpose of maintaining an efficient cool air circulation:
   - Small variability in size of internal areas, of actual 12 m (40 foot) containers, nevertheless is considered standard;
   - Variability in different sizes in pallets and corners material;
   - Different stowage planning is consequence of distributing the loading of different type of pallet within the container.

II. There are factors that are overlooked and are of essential importance to maintain homogeneous and efficient temperature within the full reefer container during transit:
   - With the exception of pattern E and F, all the stowage planning reviewed in this research, do not consider the “free circulating areas of cool air” that occurs in different points of the reefer container. When this free space occurs close to the refrigeration unit, generates strong “short cycles of cool air circulation”;
   - The efficiency of cooling is directly influenced by the proper placement of materials that covers free T-bar floors and base of pallets opening to impede the free cold air circulation and to force the air to go thru the cargo.

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