AGROTECHNOLOGY & FOOD SCIENCES GROUP
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Sixth Quest Regular Trial Shipment

Pineapples from Panama to the Netherlands and the U.K.

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Report 737

Colophon

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Abstract

The “Quest regular” system has been developed to reduce power consumption of reefer containers. The Quest Regular concept and corresponding CCPC software was tested in a (sixth) real-life shipment of pineapples from Panama to the Netherlands and the U.K. in September/October 2006. The goal of the trial shipment was to test the software and compare the power usage and temperature distribution of two Quest test containers to those of two reference containers, which were shipped simultaneously at original settings. Also, product quality of pineapples from one reference container was compared to that of one reference container.

The reference containers had a mean power usage of 5.2 kW, this was 2.4 kW for the Quest containers, a 54% saving.

The supply air of the Quest containers fluctuates in time, but with such a high frequency, that the fluctuations are hardly visible in the carton temperature data (measured with a 30 min period).

The carton temperatures in the Quest container were satisfactory and quite close to the setpoint and the temperatures in the reference container. The Quest container cartons were 0.1°C further from the setpoint, while the bandwidth was 0.7°C larger.

In the Quest container more internal glassiness was found than in the Reference container. Although the level of glassiness was very low, it can be an indication of slight chilling injury. It may have been caused by the half a day of an (erroneous) low constant temperature setting. For the other quality indicators the Quest regime did not change quality output compared to normal regime.

Acknowledgements

This sixth real-life Quest trial was largely organized and performed by Maersk Line. Most of the data and information in this report was provided by Maersk employees. We especially would like to thank Mr. Lindhardt and Mr. Nielsen of Maersk's Centre Reefer Management, Mr Hofmann of Maersk's Reefer Management Great Britain, Mr Selsig of Maersk's Claims Rotterdam and Mr. Perez and Fernandes of Maersk Panama.

We also thank Carrier Transicold for providing the necessary CCPC software for the trial and the unit data-files that were made from the unit downloads. We especially would like to thank Mr. Griffin, Mr. Dudly, Mr. Duraisamy, Mr. McIntosh, Mr. Whyte, Mr. Smith, Mr. Hernandez and Mr. Bretherton.

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We are indebted to our A&F colleagues Mr. van den Boogaard, Mr. Boerrigter and Mrs. Otma for their help during the organisation of the trial and its preparations as well as the product quality assessments.

Finally, our thanks go to Panama Golden Packer and Fyffes, whose fruit was transported and who made quality inspection possible before and after transport.

Contents

1 Introduction

The "Quest regular" system has been developed to reduce power consumption of reefer containers. As a follow-up of the first real-life Quest trial with mangoes and the second trail with apples and mandarins, it has been tested for bananas, melons and pineapples in September 2006. In order to exactly determine the amount of power reduction, a comparison was made with two standard controlled reefer containers. All four 40 ft. containers were loaded with pineapples and were transported on two vessels (Maersk Dunafare for test1 and ref1 and Jeppesen Maersk for test2 and ref2). The shipment was from Panama (Balboa) to the Netherlands (Rotterdam) and the U.K. (Felixstowe). The transport time was 15 days to Rotterdam (with the Dunafare) and 18 days to Felixstowe (with the Jeppesen).

The test containers (MWCU6726193, Pineapple test 1 and MWCU6748628 Pineapple test 2 were equipped with and controlled by the "Quest Regular" software, also referred to as CCPC (Compressor-Cycle Perishable Cooling). The containers DAYU6705320, Pineapple ref 1 and MWCU6726193, Pineapple ref 2 served as reference containers. During the shipment power consumption of all containers was measured using externally added KWH-meters. The temperature distribution was measured using 18 sensors per container and logging the actual temperature every 30 minutes. Fruit samples for quality evaluation (12 cartons) were taken from 5 pallets of the test1 and ref1 containers (see scheme and location of the temperature sensors). All of these test cartons contained a temperature sensor (Tiny Tag) to be able to compare the temperature distributions of both containers. With these readings it would be possible to determine correlations between local temperatures and quality development of the fruits. Upon arrival in the Netherlands a first quality inspection of the pineapples was carried out. The quality evaluation was extended by a shelf life treatment of the test samples using the experimental facilities of AFSG in Wageningen, The Netherlands.

A precise quality evaluation was necessary as the Quest Regular mode operation allows the supply air to have a low value during specific interval times. This value is lower than the value that is commonly considered a chilling temperature. The idea behind this is that chilling will be avoided by cycling, as the supplied air is only on this low level for short periods. Product temperature and internal metabolic processes do not follow these quick changes of the temperature settings i.e. chilling will not occur. The energy saving method is only of value when product i.e. pineapple quality is not harmed by it.

2 Material and methods

2.1 Product

The pineapples (variety MD2) originated from two growers in Panama. The produce used for shelf life tests originated from Panama Golden Packer from La Chorrera. The initial temperature of the pineapple was 8°C.

Figure 1 Pineapple

Figure 2 Pineapple open

2.2 Packaging and stowage

The pineapples are packed in cardboard boxes, seven pineapples per box. The box size is 600x400 mm, stacked 15 boxes high (5 on a layer). In total 4 containers with 1500 cartons are packed, placed on 20 pallets. The pallets used were wooden industrial pallets size 1200x1000 mm. 20 pallets were fitted in the container cross stacked (see also Figure 5).

2.3 Unit settings

The containers used were fitted with Carrier Thinline refrigeration units. The CCPC program (v. 9576) was installed on all units, using a microlink 3 card or a microlink 2/3 adapter. The reference containers were running in normal mode with settings as usual for pineapple. For these, the CCPC software was only used to enable additional data logging. The Quest containers were running in CCPC mode.

The reference container settings were:

◊ Supply setpoint	6.5 °C = 43.7 F
◊ Fan setting	High
◊ Vent setting	10 m^3/hr

The CCPC settings were:

◊ Supply setpoint	4.5 °C = 40.1 F
◊ Return Air Pulldown Low Limit	6.5 °C = 43.7 F
◊ Return Air Low Limit	6.5 °C = 43.7 F
◊ Return Air High Limit	7.5 °C = 45.5 F

◊ Fan setting Alternating
◊ Vent setting 10 m³/hr

Defrost interval: was set to automatic and Humidity, Dehumidification and Bulb Mode were all set to OFF.

2.4 Voyage schedule

On September 19th and September 22nd the containers were loaded with pineapples. Subsequently, the containers were taken to the harbour of Balboa. The setup is shown in Table 2.

Table 2 Container setup

Container nr	Setup mode	Stuffing date	Commodity	Grower
MWCU 674 862 8	Quest 2	22/9/2006	Pineapple	-
MWCU 682 195 0	Ref 2	22/9/2006	Pineapple	-
DAYU 670 532 0	Ref 1	19/9/2006	Pineapple	Panama Golden Packers
MWCU 672 619 3	Quest 1	19/9/2006	Pineapple	Panama Golden Packers

Two containers were loaded on the vessel (Maersk Dunafare) during the night of September 21st and two containers were loaded on the vessel (Jepessen Maersk) during September 23rd.

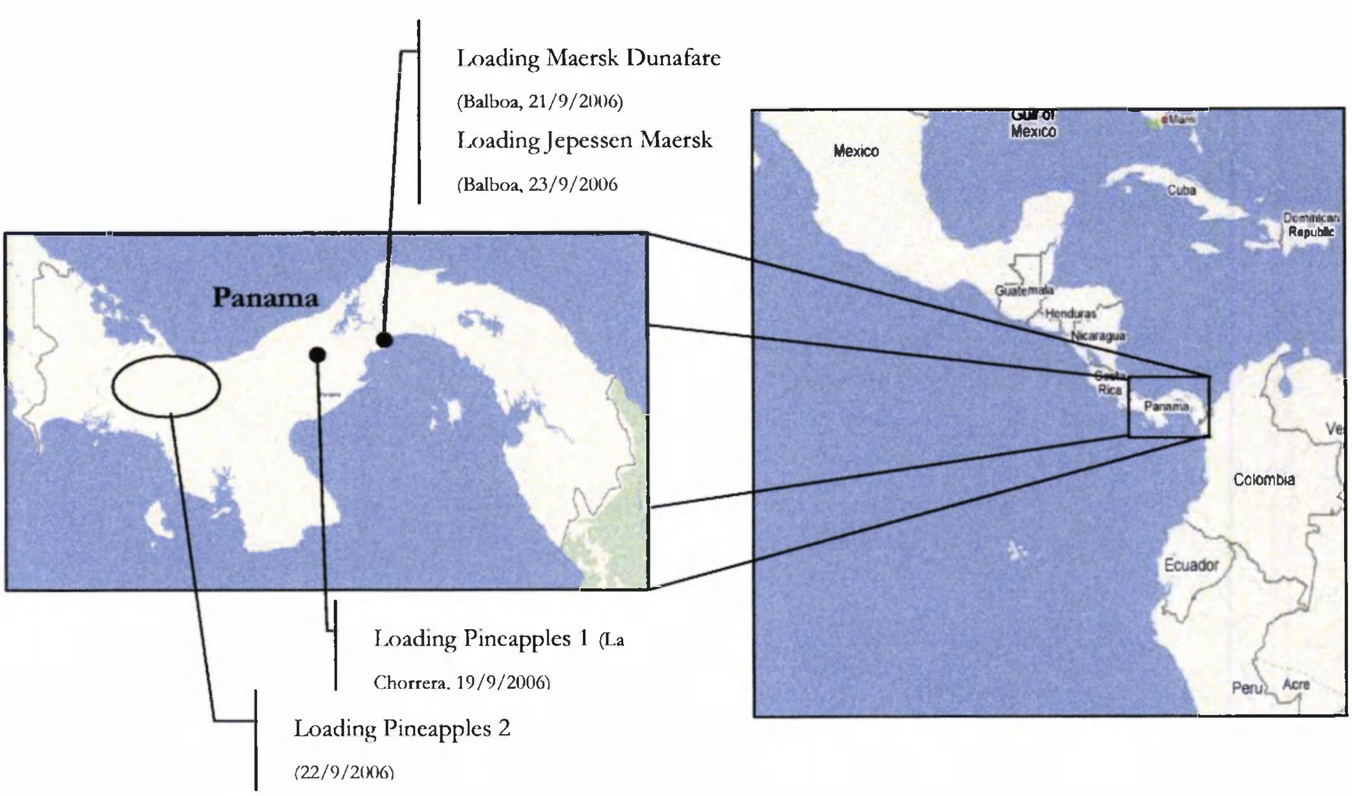


Figure 3 Map of loading and departure locations

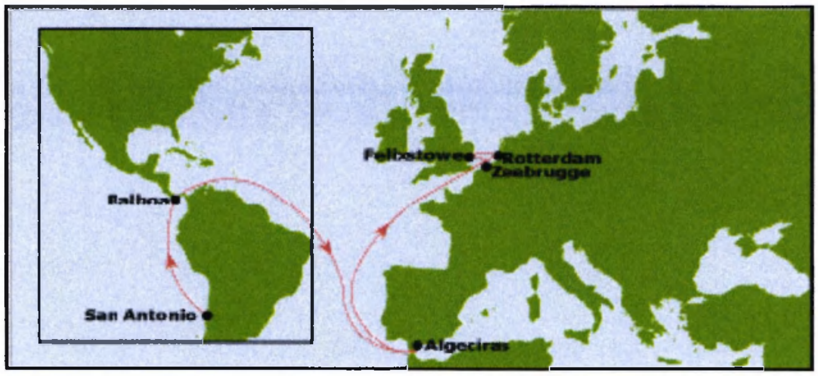


Figure 4 Map of the vessel route

The containers arrived in Zeebrugge (Belgium) on October 6th and in Felixstowe (U.K.) on October 8th. Figure 14 and Figure 15 in the appendix depict the mean temperature and relative humidity in October for such a trip.

2.5 Unit and climate measurements

External KWh meters were attached to all units. The CCPC software installed on the containers included additional data logging, storing elaborate unit information every hour. Temperatures were measured by 4 USDA probes and 18 Tiny tags inside the containers. In order to measure the temperature reaction of the fruit to the software system the Tiny Tags data loggers were placed next to the fruit to the sidewall of each carton. Data recording had been pre-set for every 30 minutes. Such instruments were placed in 6 pallets at the bottom and ¾ in height.

Figure 5 shows the stowage of the pallets in the containers. The yellow marked pallets were fitted with temperature, relative humidity and gas decomposition sensors. These are also the pallets from which samples for shelf live testing were taken. The green marked pallets were fitted with USDA-probes (on the bottom layer), measuring product temperature. Probe 1 was installed in pallet 1, Probe 2 was installed in pallet 2 and Probe 3 and 4 were installed in pallet 19 and 20.

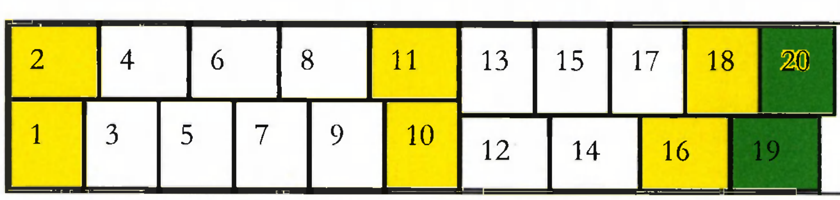


Figure 5 Container layout

2.6 Quality measurements

Pineapple pallets contained 15 layers of boxes. From pallets 1 and 2 (see Figure 5) boxes from layers 1 and 2 (bottom layer and layer above bottom layer) were taken. From pallet 11 boxes from layer 1, 2, 12 and 13 were taken. From pallet 16 and 18 boxes from layers 12 and 13 were taken as sample boxes. In total 12 boxes per container. The pineapples were transported from the place of delivery in the Netherlands to Wageningen by car. At arrival in Wageningen colour of all fruits was determined according to a colour scale of 1 – 6 (see Table 1).

Table 3 Colour scale for pineapples, individual fruits (www.fintrac.com)

CS1:	all eyes green, no traces of yellow
CS2:	5 to 20% of eyes yellow
CS3:	20 to 40% of eyes yellow
CS4:	40 to 80% of eyes yellow
CS5:	90% of eyes yellow, 5 to 20% reddish brown
CS6:	20 to 100% of eyes reddish brown

CS=colour stage

The following external quality indicators were determined as well:

- fungal growth on the stem/cutting area
- glassiness
- rot.

At arrival no internal quality parameters were determined.

The pineapples were stored at 18°C/75% relative humidity (RH) as a simulation of shelf life. After a 7.5 days' shelf life simulation the same external quality indicators were determined again. Furthermore, each pineapple was cut through and determined on:

- "internal glassiness"
- "internal browning"

The scale for internal quality judgement of pineapples is presented in Table 2.

Table 4 Scale for internal quality judgement of pineapples, individual fruits

	Internal glassiness / browning (area %)
class 0	0%
class 1	0-5%
class 2	5-10%
class 3	10-25%
class 4	25-50%
class 5	50-75%
class 6	>75%

3 Temperatures

Figure 6 and Figure 7 show the Tiny Tag data for the coolest and warmest cartons, as well as the mean temperature of all cartons. This gives an overview of all carton temperature readings, which are shown in Figure 16 and Figure 17 in the appendix. Time instance September 19th 23:00 is defined as t=0 for pineapple 1 and time instance September 22nd 14:00 is defined as t=0 for pineapple 2. To get a good impression of the spatial distributions of the carton temperatures and how these change in time, see the movies on the accompanying cd.

3.1 Temperature readings at the start of the trip

The initial temperature readings of the cartons in the test and reference containers are comparable, mostly between 5 and 8°C (see Figure 16 and Figure 17 in the appendix). Pulp temperature readings are comparable and lie between 6.5 and 7.5°C (see Figure 18 through Figure 21 in the appendix).

3.2 Temperature readings during pull down

The Pineapple 1 containers ran for 2 days in normal mode on normal setpoint before they were switched to CCPC mode. After 2 days the setpoint was lowered and the CCPC mode was turned on.

During day 3, CCPC Mode was turned off on unit Quest test 1 and the unit was (mistakably) set to cool continuously on the low Quest setpoint of 4.5°C. This causes an additional cool down of the product during the subsequent day, which is not part of normal Quest Regular operation. This was corrected on the vessel. Carton temperatures thus pull up again during day 4.

3.3 Temperature readings during Quest Regular Mode

The supply air of the Quest containers fluctuates in time, but with such a high frequency, that the fluctuations are hardly visible in the carton temperature data (measured with a 30 min period).

The temperature data for the Quest Regular period (September 23rd 0:00 until October 8th 0:00, t=80 – 465 h for pineapple 1 containers and September 25th 0:00 until October 10th 0:00, t=100 – 447 h) have been summarized in Table 5 through Table 9. The tables contain information on the temperatures of the coolest and warmest cartons as well as the mean temperature of all cartons combined during the time the containers were running in CCPC mode.

First of all, the deviation from the given setpoint is important (see column 3 of Table 6 and Table 7). The mean carton temperature of the Quest containers is 6.8°C. The mean carton temperature of the reference containers is 6.7°C. Thus, the reference containers are 0.1°C closer to the setpoint of 6.5°C than the Quest containers.

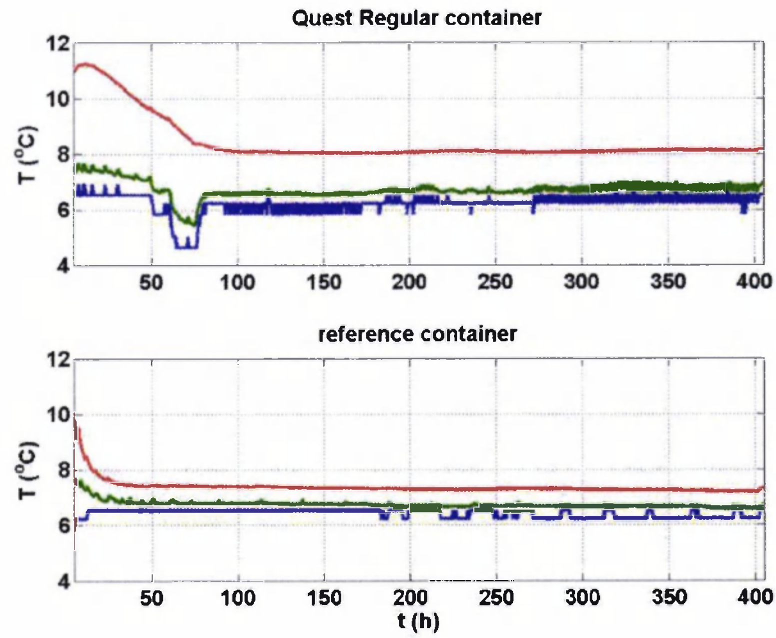


Figure 6 Temperature readings of Tiny Tags in cartons, coolest (-) and warmest (-) carton, as well as mean temperature for all cartons (-), for both Pineapple 1 containers

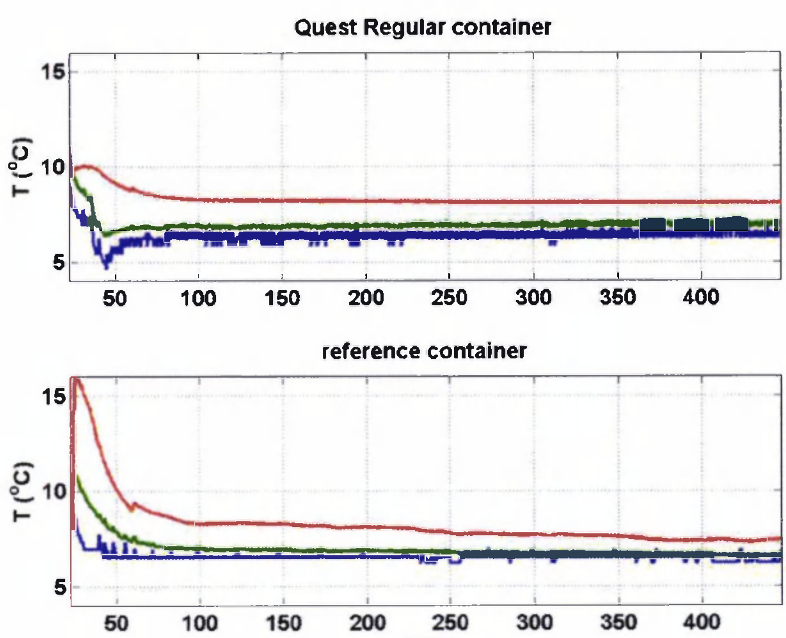


Figure 7 Temperature readings of Tiny Tags in cartons, coolest (-) and warmest (-) carton, as well as mean temperature for all cartons (-), for both Pineapple 2 containers

Secondly, the maximum bandwidth of the carton temperatures is considered (see Table 5, column 2 and 4). Looking at the lowest and highest temperatures measured in the cartons, the maximum temperature difference between the coolest and warmest cartons was 2.5°C in the Quest containers and 1.7°C in the reference containers. Thus, in the most extreme situation, the Quest containers had a 0.8°C larger maximum temperature bandwidth than the reference containers.

Thirdly, the mean bandwidth of the carton temperatures is considered (see Table 6, column 2 and 4). Looking at the mean of the carton temperatures in time, the temperature difference between the coolest and warmest cartons was 1.8°C in the Quest containers and 1.1°C in the reference containers. Thus, on average, the Quest containers had a 0.7°C larger temperature bandwidth than the reference container.

Fourthly, the time-averaged deviation of the coolest carton from the given setpoint is important (see column 2 of Table 8 and Table 9). The coolest cartons of the Quest containers were 0.2°C below setpoint. The coolest cartons of the reference containers are 0.1°C below setpoint. Thus, the coolest cartons of the Quest containers are 0.1°C further from the setpoint then the reference containers.

Finally, the time-averaged deviation of the warmest cartons from the given setpoint is important (see column 4 of Table 8 and Table 9). The warmest cartons of the Quest containers are 1.6°C above setpoint. The warmest cartons of the reference containers are 1.1°C above setpoint. Thus, the warmest cartons of the Quest containers are 0.5°C further from the setpoint then the reference containers.

Overall, carton temperatures in the Quest container were satisfactory and quite close to the setpoint and the temperatures in the reference container. The Quest container cartons were 0.1°C further from the setpoint, while the bandwidth was 0.7°C larger. The coolest cartons were 0.1°C further and the warmest cartons 0.5°C further from the setpoint.

Pulp temperature USDA readings lie between 7.7 and 8.5°C in the reference containers and between 7 and 9.7°C in the test containers see Figure 18 through Figure 21 in the appendix. Temperatures in the Quest containers are comparable to those of the containers, with the exception that one USDA reading shows a high temperature (approximately 8-13°C) in ref 2.

3.4 Temperatures at the end of the trip

Figure 8 and Figure 9 show a snapshot of the carton temperatures near the end of the trip. They show that carton temperatures of the reference containers lie somewhat closer to setpoint then in the Quest containers. Also, they give an indication of the temperature distributions over the various locations inside the containers.

Table 5 The ranges of the minimum, maximum and mean carton temperature readings (from September 23rd to October 8th for pineapple)

	min carton T (℃)	mean carton T (℃)	max carton T (℃)
Quest container 1	5.8 to 6.9	6.4 to 7.2	8.0 to 8.3
Quest container 2	5.8 to 6.9	6.7 to 7.3	8.0 to 8.2
reference cont. 1	6.2 to 6.5	6.6 to 6.9	7.1 to 7.5
reference cont. 2	6.2 to 6.9	6.5 to 7.0	7.3 to 8.3

Table 6 The mean of the minimum, maximum and mean carton temperature readings

	mean min carton T (℃)	mean mean carton T (℃)	mean max carton T (℃)
Quest container 1	6.3	6.7	8.1
Quest container 2	6.4	6.9	8.1
reference cont. 1	6.4	6.7	7.3
reference cont. 2	6.5	6.8	7.8

Table 7 The deviations from setpoint for the minimum, maximum and mean carton temperature readings

	dev min carton T (℃)	dev mean carton T (℃)	dev max carton T (℃)
Quest container 1	-0.7 to 0.4	-0.1 to 0.7	1.5 to 1.8
Quest container 2	-0.7 to 0.4	0.2 to 0.8	1.5 to 1.7
reference cont. 1	-0.3 to 0.0	0.1 to 0.4	0.6 to 1.0
reference cont. 2	-0.3 to 0.4	0.0 to 0.5	0.8 to 1.8

Table 8 The deviations from setpoint for the mean of the minimum, maximum and mean carton temperature readings

	dev mean min carton T (℃)	dev mean mean carton T (℃)	dev mean max carton T (℃)
Quest container 1	-0.2	0.2	1.6
Quest container 2	-0.1	0.4	1.6
reference cont. 1	-0.1	0.2	0.8
reference cont. 2	0.0	0.3	1.3

Table 9 The difference in deviation from setpoint for the Quest container compared to the reference container, for the coolest, mean and warmest carton

	ΔT coolest carton (℃)	ΔT mean carton (℃)	ΔT warmest carton (℃)
Quest 1 – ref 1	-0.1	0.0	-0.8
Quest 2 – ref 2	-0.1	-0.1	-0.3

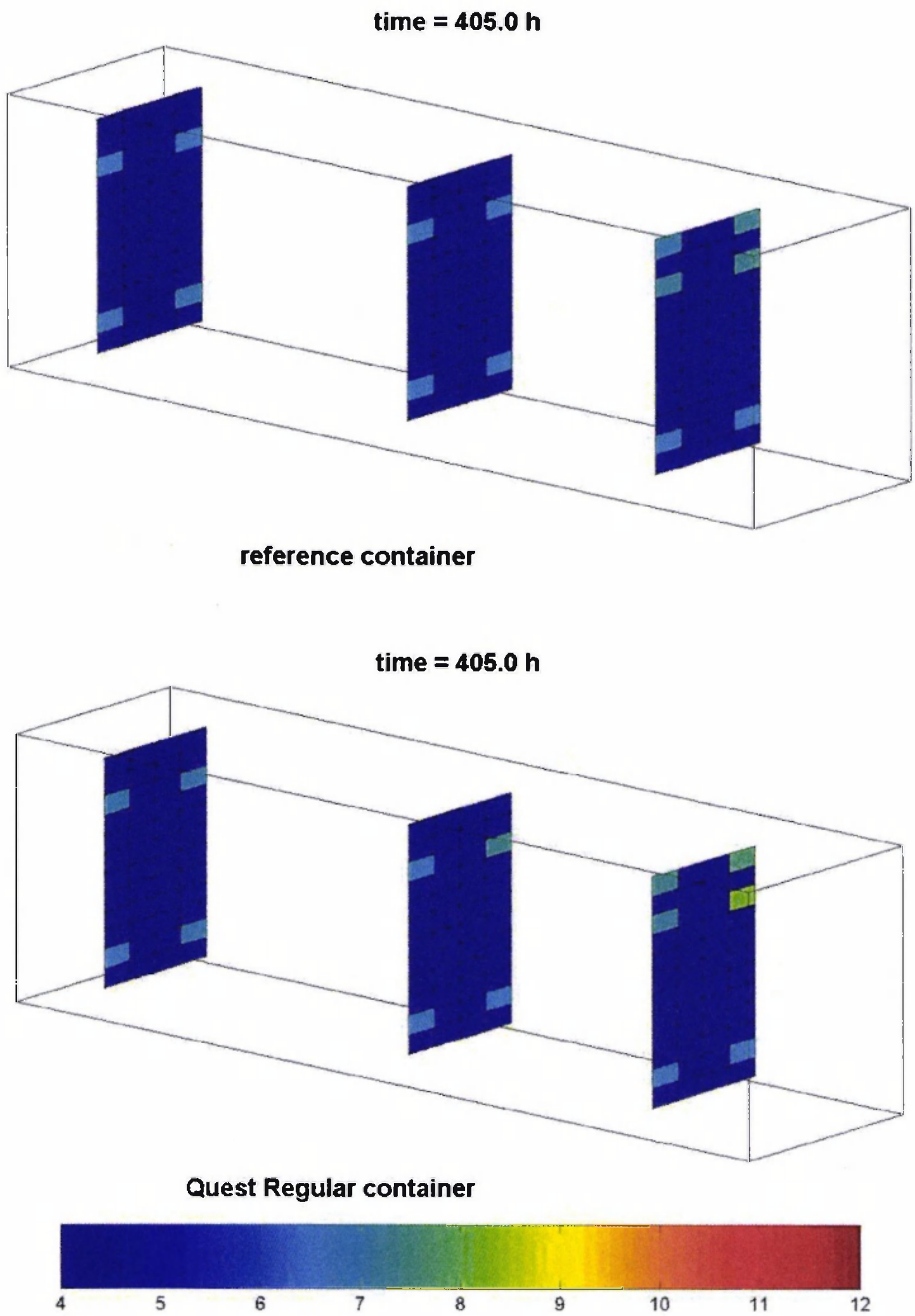


Figure 8 Tiny Tag readings of the carton temperatures near the end of the trip, on October 6th, Pineapple 1

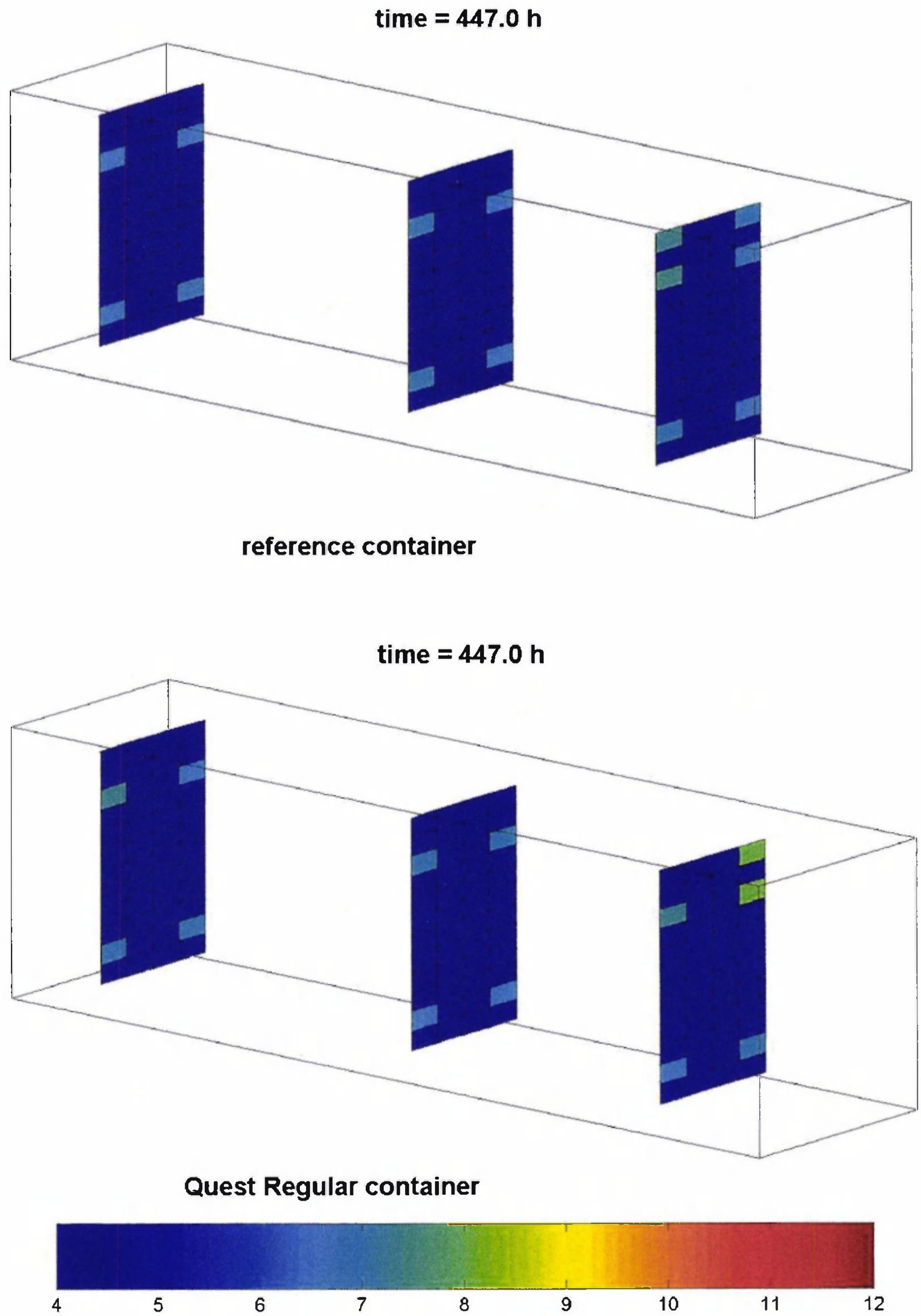


Figure 9 Tiny Tag readings of the carton temperatures near the end of the trip, on October 10th, Pineapple 2

4 Power Consumption

Power consumption data were read from the kWh meters by Maersk employees twice a day during the sea voyage. Time and energy data were taken from the kWh meters, see Figure 10. Time axis is such that t = 0 starts at September 19th 23:00 for pineapple 1 and September 22nd 14:00 for pineapple 2.

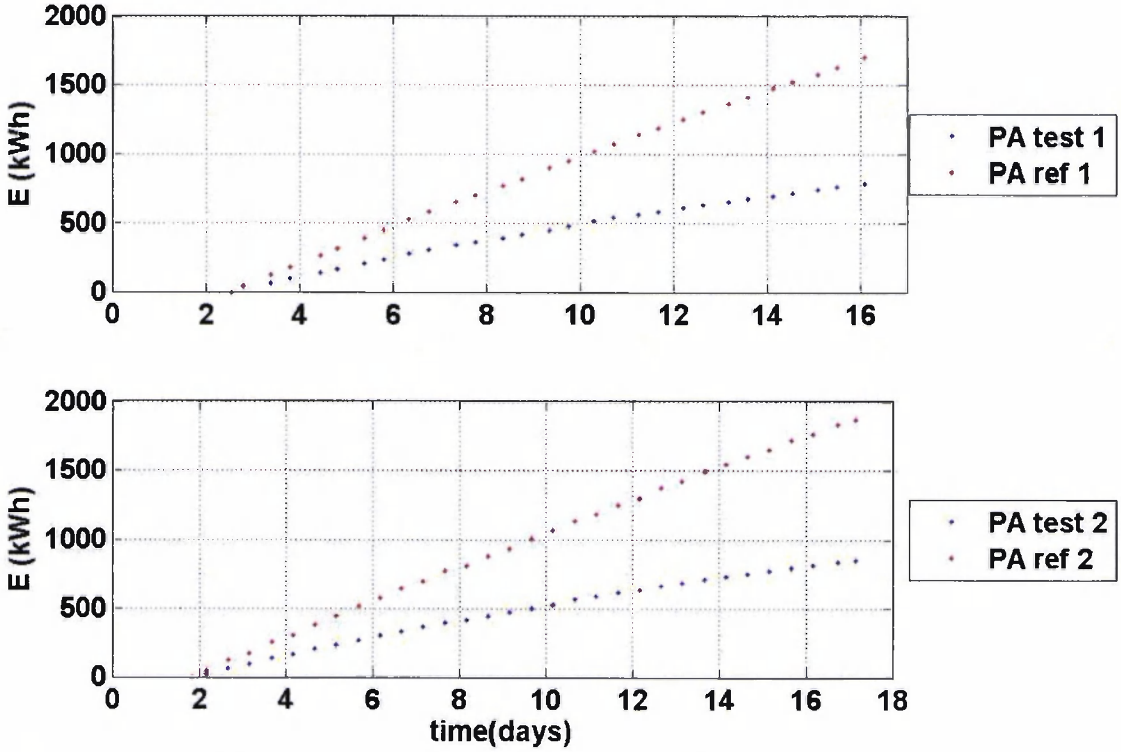


Figure 10 Energy readings as a function of time for both container sets

The reference containers used 1698 kWh in 325 h and 1868 kWh in 368 h, a mean power usage of 5.2 and 5.1 kW. The Quest containers used 790 and 852 kWh in the same periods, a mean power usage of 2.4 and 2.3 kW, which is 53 and 54% less compared to the reference containers. The power and savings per day are shown in Figure 11 and Figure 12. Mean savings are 54%.

The power savings are largely due to the periods that the compressor is turned off during cycling, the length of which can be seen in Figure 32 through Figure 34 in the appendix. (For comparison, also the active hours and defrost time of the units are shown.) Compressor off time intervals last approximately 50 - 100 minutes, about 2 – 4 times as long as the compressor-on time intervals. The compressor off periods become somewhat shorter when ambient temperature is higher. Other factors of influence are defrost intervals, the reduced fan speed during compressor-off time intervals and the somewhat reduced amount of ventilation during low fan speed/compressor off periods.

Defrost setting is AUTO, leaving the unit to learn from its measurement data how often a defrost action is necessary. Both reference units defrost about once a day, whereas the test containers defrost period increases to about once every 4 days. The defrost actions take approximately 18 minutes. These small values indicate that little ice was present on the coil. The reduced amount of defrost actions for the Quest containers is due to the reduction in compressor run hours (approximately 1/2nd to 1/4th).

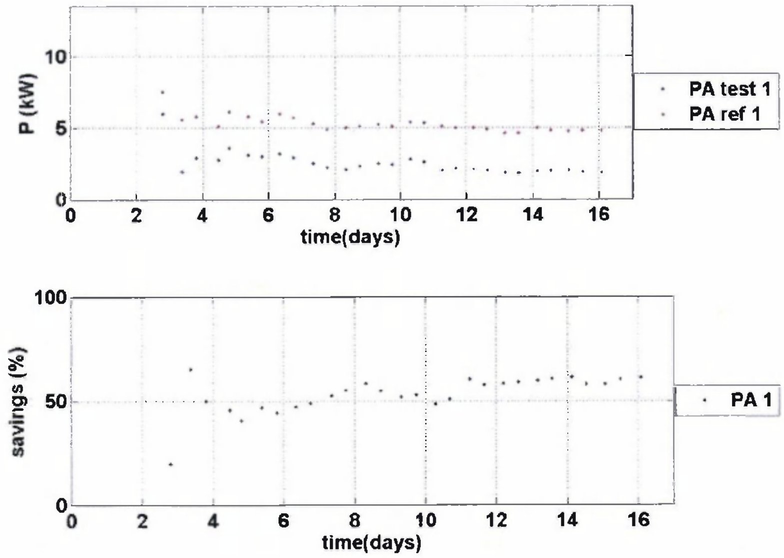


Figure 11 Power and savings as a function of time for container set 1

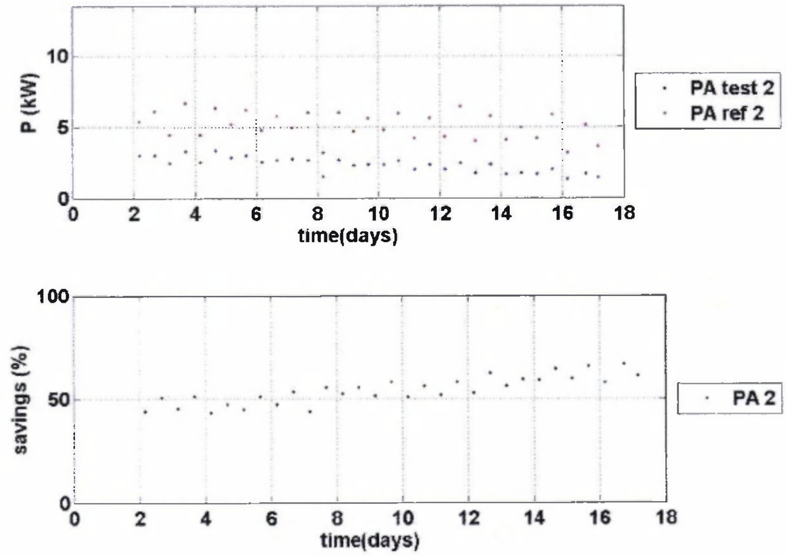


Figure 12 Power and savings as a function of time for container set 2

5 Evaluation of fruit quality

5.1 General remarks

According to the first impressions at arrival from Fyffes the quality of the pineapples was good. Product specialists from AFSG described the average quality of the pineapples as good. No rotten fruits were found, and no fungal infection was observed.

For analysis of effects of *pallet number* and *layer* the data from the pallets 1, 2, 11, 16 and 18 were used (10 boxes), because from 4 boxes the exact origin was unclear (of which 2 boxes had been placed in a Reference container and 2 boxes in a Quest container).

5.2 External quality

Table 10 shows that some colour development during shelf life occurred (see also Table 3). After 7.5 days of shelf life minor fungal growth was observed at the cutting area (stem) of almost all the pineapples. Crowns were dried in, and deviations were observed on the leaves of almost all pineapples (see Figure 13).

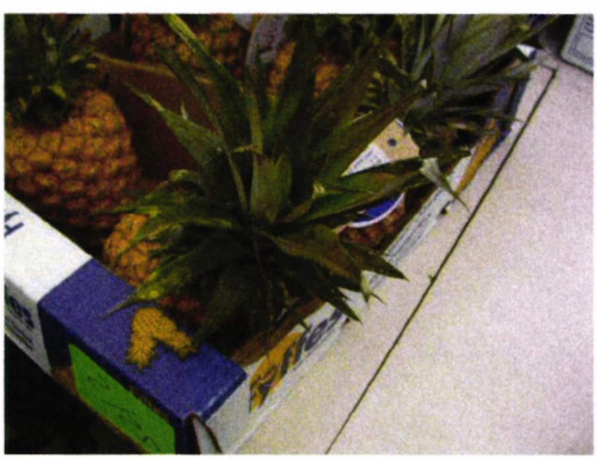


Figure 13 Deviations on pineapple leaves after shelf life period, origin not clear.

Table 10 External quality

	Reference container		Quest container	
Day of shelf life	Day 0	Day 7.5	Day 0	Day 7.5
Colour stage	3.9	5.8	3.8	5.6
Glassiness	No	no	no	no
Rot	No	no	no	no

After 7.5 days of shelf life simulation the difference in colour was significant, but very small. This difference cannot be explained by the temperature in the container ("Temperature and quality"). Table 11 shows the colour development, due to the location in the containers.

Table 11 Colour of Pineapples from different locations in two containers. Within the same column data with one or more the same letters do not differ significantly; N.S. = no significant difference.

	Reference container		Quest container	
Location	Day 0	Day 7.5	Day 0	Day 7.5
Pallet 1, layers 1 and 2	4.0 b	5.9		
Pallet 2, layers 1 and 2	3.9 b	6.0	3.6 a	4.9 a
Pallet 11, layers 1, 2, 12 and 13	4.0 b	5.8	3.7 a	5.6 b
Pallet 16, layers 12 and 13			3.9 ab	6.0 c
Pallet 18, layers 12 and 13	3.5 a	5.7	4.1 b	5.9 bc
		N.S.		

Table 11 shows that the colour depends on the location in the container. In the Reference container the pineapples from the top layers of pallet 18 were a bit greener than the ones from the other locations. This is an unexpected result, because average – and minimum temperatures on this location were higher than on other locations in this container, which should cause more yellow pineapples instead of greener ones. After 7.5 days of shelf life simulation no differences were found (see also "Temperature and quality"). In the Quest container the pineapples from the top layers of pallet 18 were more yellow than the ones from the lowest layers of pallet 2, and this was still the case after 7.5 days of shelf life simulation. This corresponds with the expectation that a higher temperature causes faster ripening (yellowing) of the fruits (see also "Temperature and quality").

5.3 Internal quality

After 7.5 days of shelf life simulation the fruits were cut through and internal browning and glassiness were determined. The average results are shown in Table 12.

Table 12 Internal quality

	Reference container		Quest container	
Day of shelf life	Day 0	Day 7.5	Day 0	Day 7.5
Glassiness	n.d.	0.16	n.d.	0.60
Browning	n.d.	0.16	n.d.	0.04

n.d.=not determined.

Internal browning was not very serious and no effect of the container was found.
Glassiness was found more in pineapples from the Quest container, but he level of glassiness was very low. In most pineapples glassiness did not exceed 5% of the surface. See also "Temperature and quality".

5.4 Temperature and quality

Table 13 shows average temperatures, minimum temperatures and fruit colour at day 0 and after 7.5 days of shelf life simulation.

Table 13 Locations, average temperature, minimum temperature and fruit colour after 7.5 days of shelf life simulation, in both containers.

Pallet	Layer	Reference container				Quest container			
		Tmean	Tmin	Colour		Tmean	Tmin	Colour	
		[°C]	[°C]	Day 0	Day 7.5	[°C]	[°C]	Day 0	Day 7.5
1	1	6.5	6.5	4.0	5.9				
1	2			4.0	6.0				
2	1	6.8	6.6	3.9	6.0	6.6	5.1	3.6	5.0
2	2			4.0	6.0			3.7	4.9
11	1	6.5	6.2	4.1	5.7	6.2	4.6	4.0	5.4
11	2			4.3	6.0			4.0	5.9
11	12	6.6	6.5	3.7	5.6	6.8	5.8	2.9	5.3
11	13			4.0	5.9			4.0	5.9
16	12					6.7	5.4	4.0	6.0
16	13							3.9	6.0
18	12	7.3	7.1	4.3	5.7	8.1	8.0	4.1	6.0
18	13			2.7	5.7			4.1	5.9
Mean colour in all boxes				**3.9**	**5.8**			**3.8**	**5.6**
Mean colour in boxes on same locations				**3.9**	**5.8**			**3.8**	**5.5**

Table 13 shows that the greenest pineapples were not coming from the coldest spots in the containers: in the Reference container the greenest pineapples came from pallet 18, layer 13 (high temperature) and in the Quest container from pallet 11, layer 12 (moderate temperature, minimum temperature not very low). Furthermore, pineapples from the coldest location (Quest container, pallet 11, layer 1) had an "average colour" at day 0. It can be concluded that the differences in colour can not be explained by the temperature.

Table 14 shows average temperatures, minimum temperatures and internal glassiness after 7.5 days of shelf life simulation.

Table 14 Locations, average temperature, minimum temperature and internal glassiness after 7.5 days of shelf life simulation, in both containers.

Pallet	Layer	Reference container			Quest container		
		Tmean	Tmin	Glassiness	Tmean	Tmin	Glassiness
		[°C]	[°C]	[0 – 6]	[°C]	[°C]	[0 – 6]
1	1	6.5	6.5	0.7			
1	2			0.1			
2	1	6.8	6.6	0.4	6.6	5.1	1.3
2	2			0.0			0.7
11	1	6.5	6.2	0.0	6.2	4.6	1.0
11	2			0.0			1.4
11	12	6.6	6.5	0.0	6.8	5.8	0.1
11	13			0.0			0.1
16	12				6.7	5.4	0.1
16	13						0.4
18	12	7.3	7.1	0.3	8.1	8.0	0.0
18	13			0.0			0.0
Mean glassiness in all boxes				**0.15**			**0.51**
Mean glassiness in boxes on same locations				**0.07**			**0.77**

Table 14 shows that pineapples from locations with the lowest minimum temperatures show most glassiness (Quest container pallets 2 and 11, layers 1 and 2). In the Reference container layer 1 from pallet 1 shows most glassiness. It can be concluded that there is a trend to more glassiness on spots with a lower minimum temperature. Glassiness can be a symptom of chilling injury, especially since it is found at the locations with the lowest minimum temperatures.

6 Conclusions

6.1 Power savings

The reference containers had a mean power usage of 5.2 kW, this was 2.4 kW for the Quest, a 54% saving.

6.2 Temperatures

The supply air of the Quest containers fluctuates in time, but with such a high frequency, that the fluctuations are hardly visible in the carton temperature data (measured with a 30 min period).

The carton temperatures in the Quest container were satisfactory and quite close to the setpoint and the temperatures in the reference container. The Quest container cartons were 0.1°C further from the setpoint, while the bandwidth was 0.7°C larger. The coolest cartons were 0.1°C further and the warmest cartons 0.5°C further from the setpoint.

6.3 Product quality

At arrival the average quality of the pineapples was good. Internal browning was not very serious and no effect of the container was found. After 7.5 days of shelf life crowns were dried in, and deviations were observed on the leaves of almost all pineapples.

After 7.5 days of shelf life pineapples from the Reference container were a bit more yellow than the fruits from the Quest container; the difference was very small and can not be explained as a temperature effect.

In the Quest container more internal glassiness was found than in the Reference container. There is a trend to more glassiness on spots with a lower minimum temperature. However, the level of glassiness was very low. The slight glassiness, which can be an indication of chilling injury, may have been caused by the (erroneous) low constant temperature setting during day 3. CCPC Mode was turned off on unit Quest test 1 and the unit was (mistakably) set to cool continuously on the low Quest setpoint of 4.5°C for 14 hours.

For the other quality indicators the Quest regime did not change quality output compared to normal regime.

References

[1] http://www.cdc.noaa.gov/cgi-bin/Composites/comp.pl

Appendix I: Ambient conditions between Brazil and Great Britain

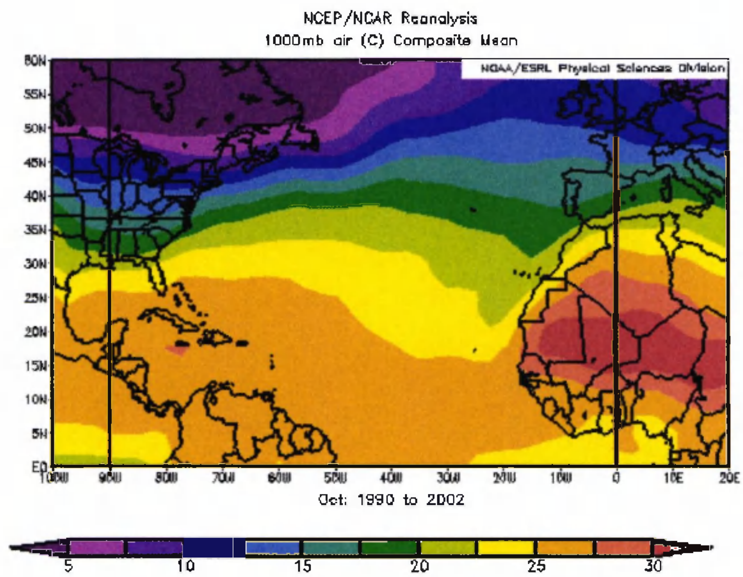


Figure 14 Mean October temperature between Panama and Great Britain [1]

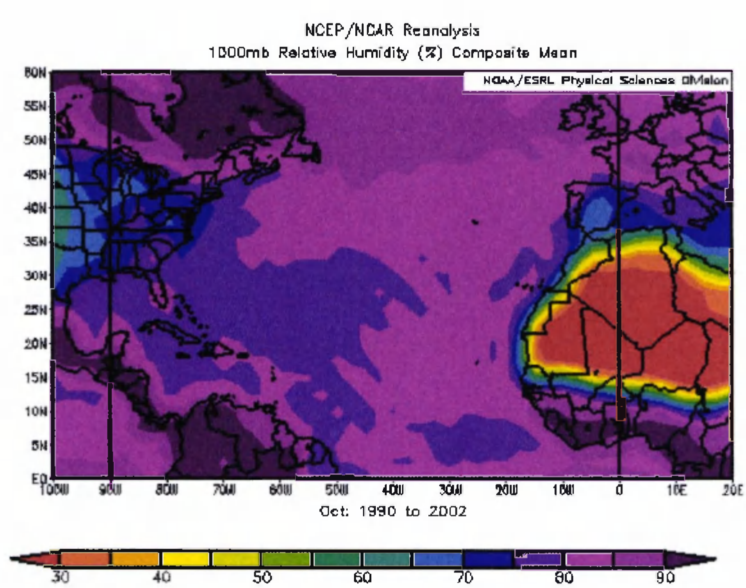


Figure 15 Mean October relative humidity between Panama and Great Britain [1]

Appendix II: Carton temperatures

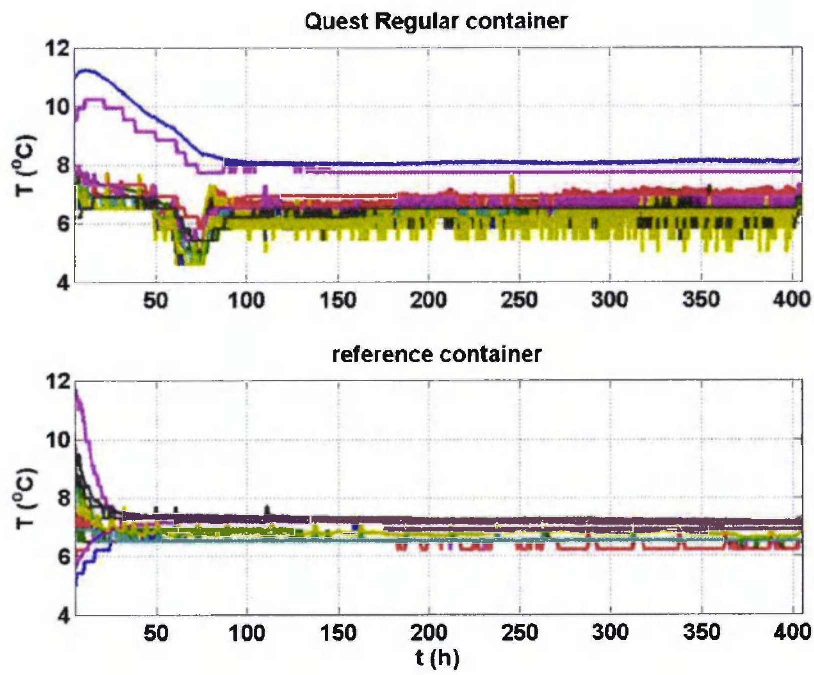


Figure 16 Temperature readings of Tiny Tags in cartons, all data, for both Pineapple 1 containers

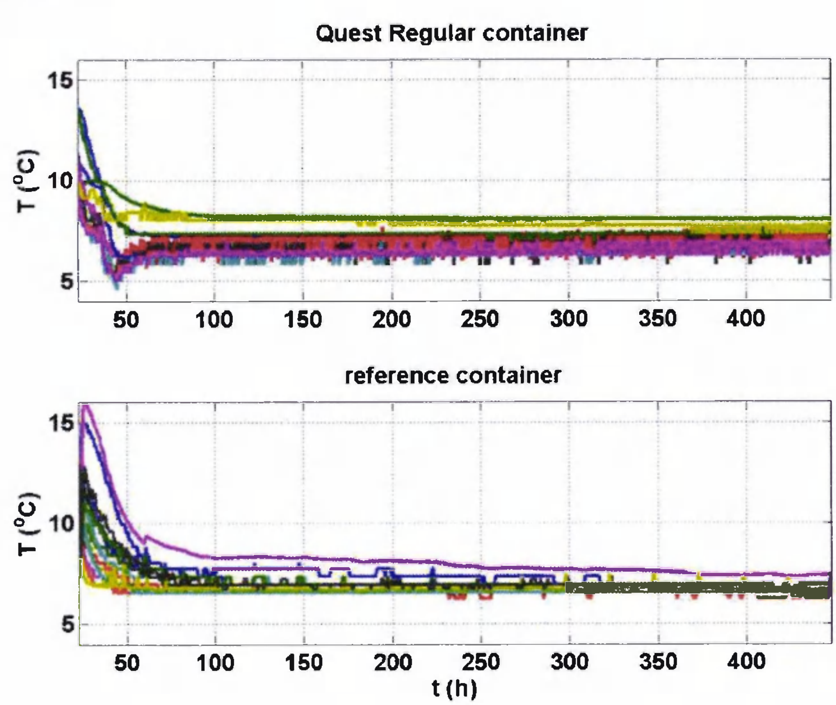


Figure 17 Temperature readings of Tiny Tags in cartons, all data, for both Pineapple 2 containers

Appendix III: Unit temperature readings as a function of time

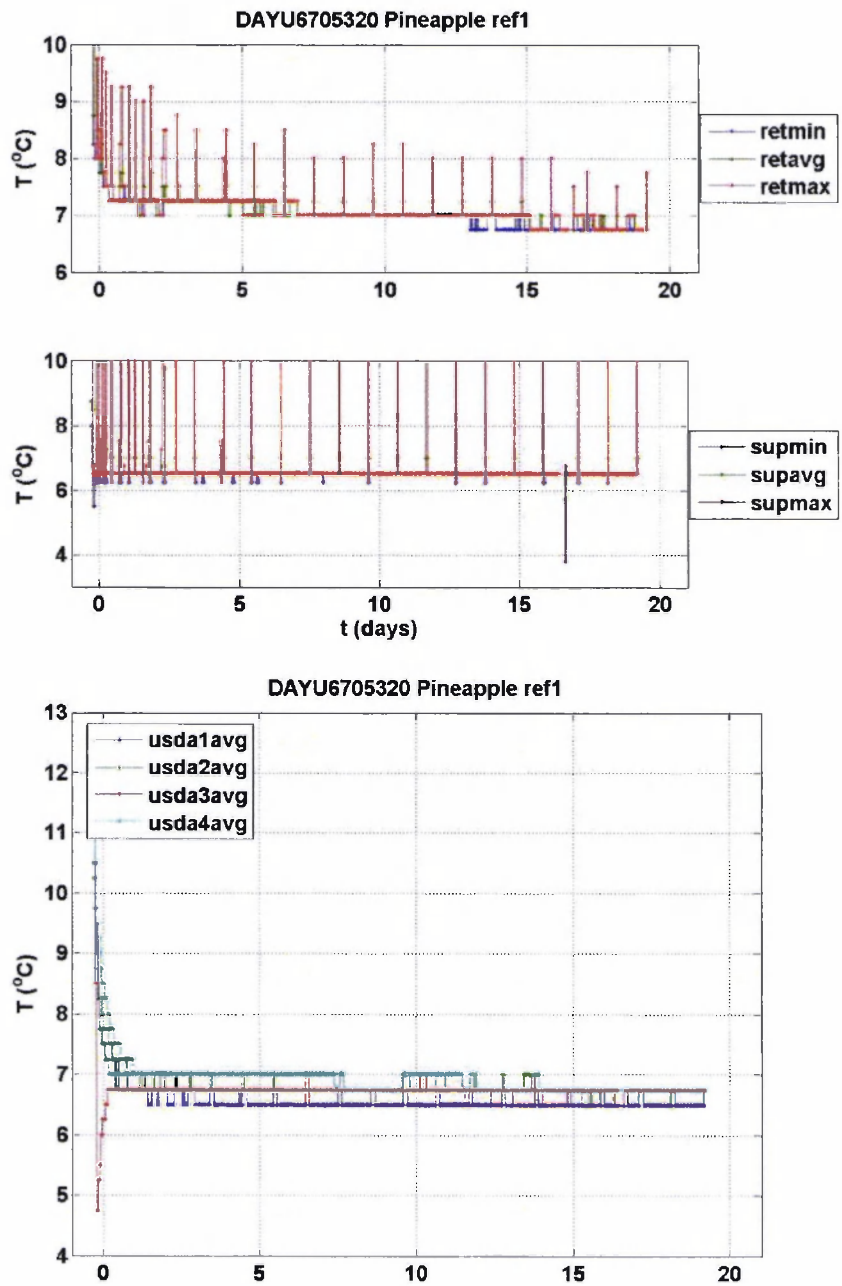


Figure 18 Temperature readings from the unit for the Pineapple ref 1container.

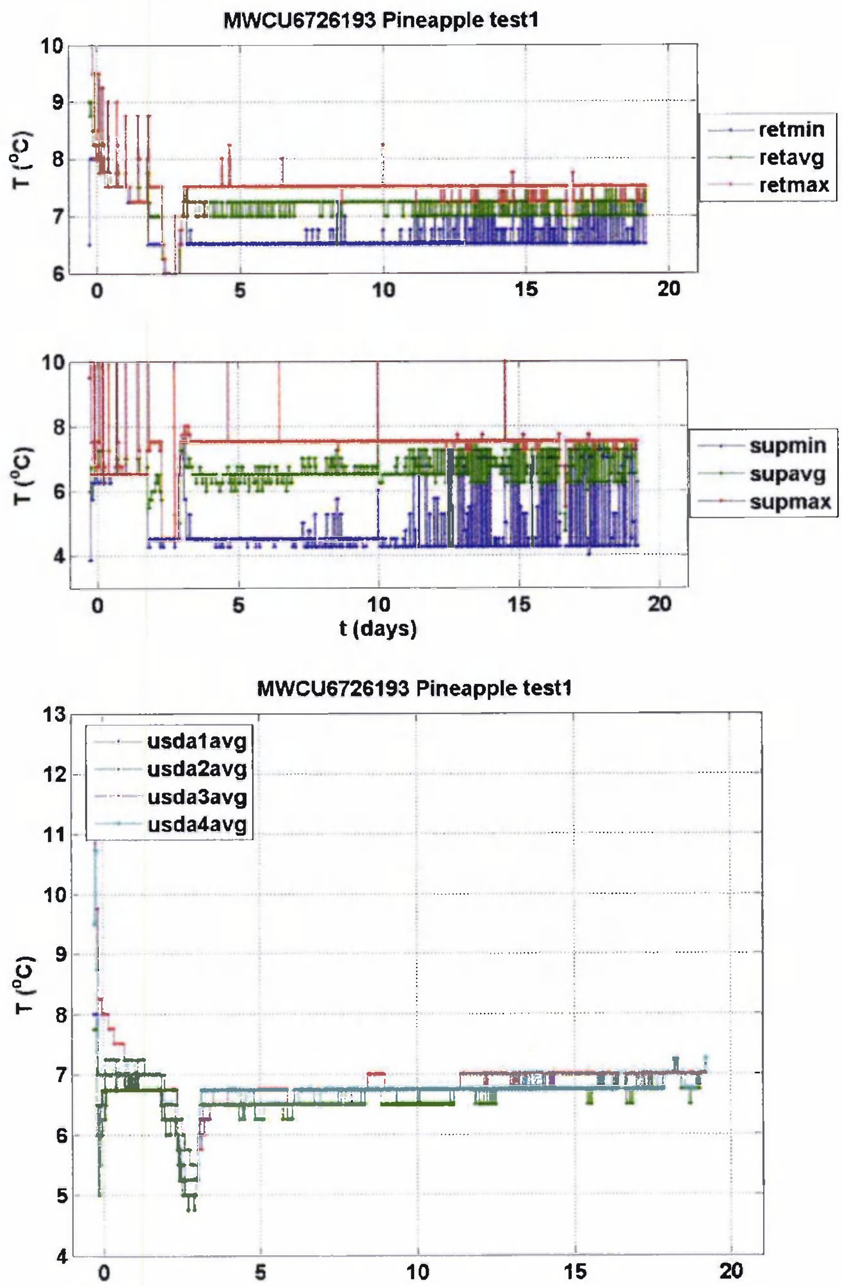


Figure 19 Temperature readings from the unit for the Pineapple test 1container.

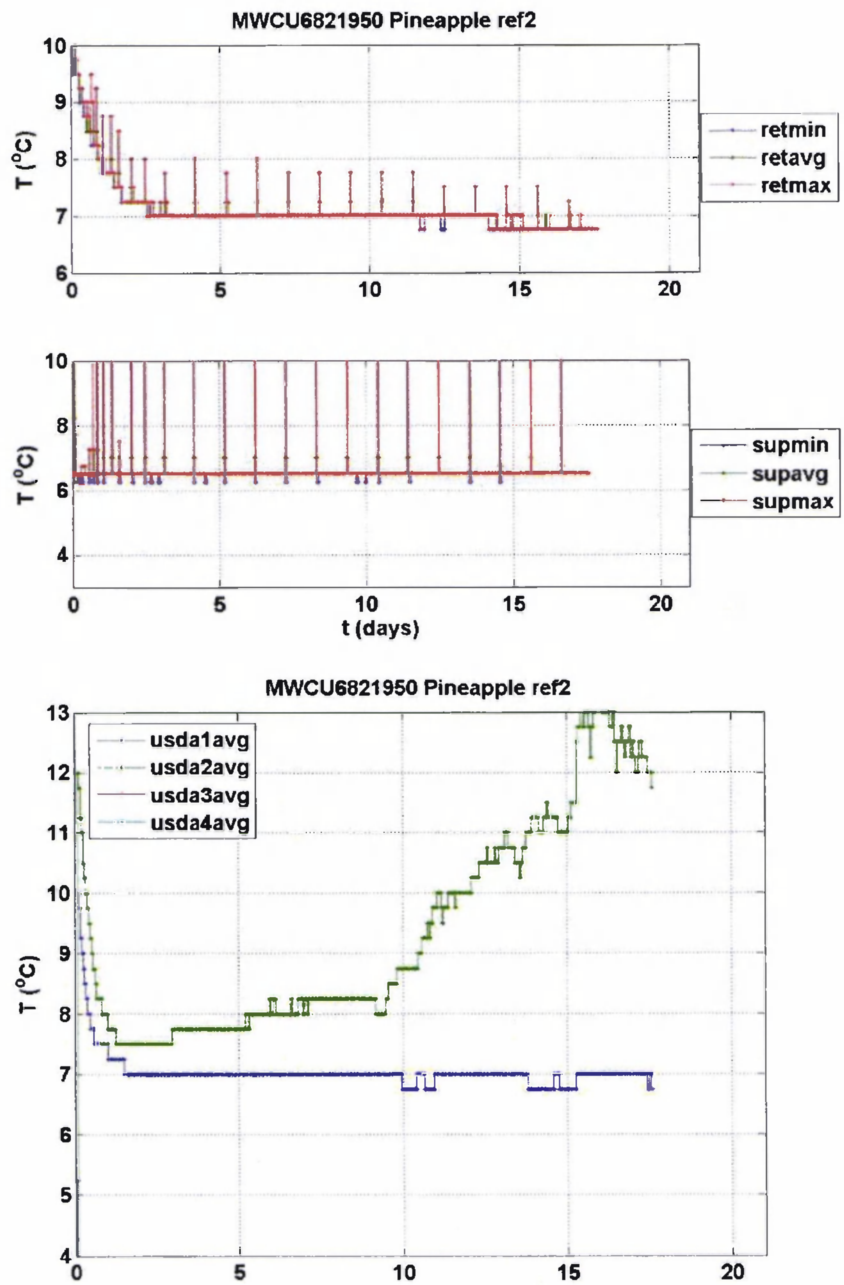


Figure 20 Temperature readings from the unit for the Pineapple ref 2 container.

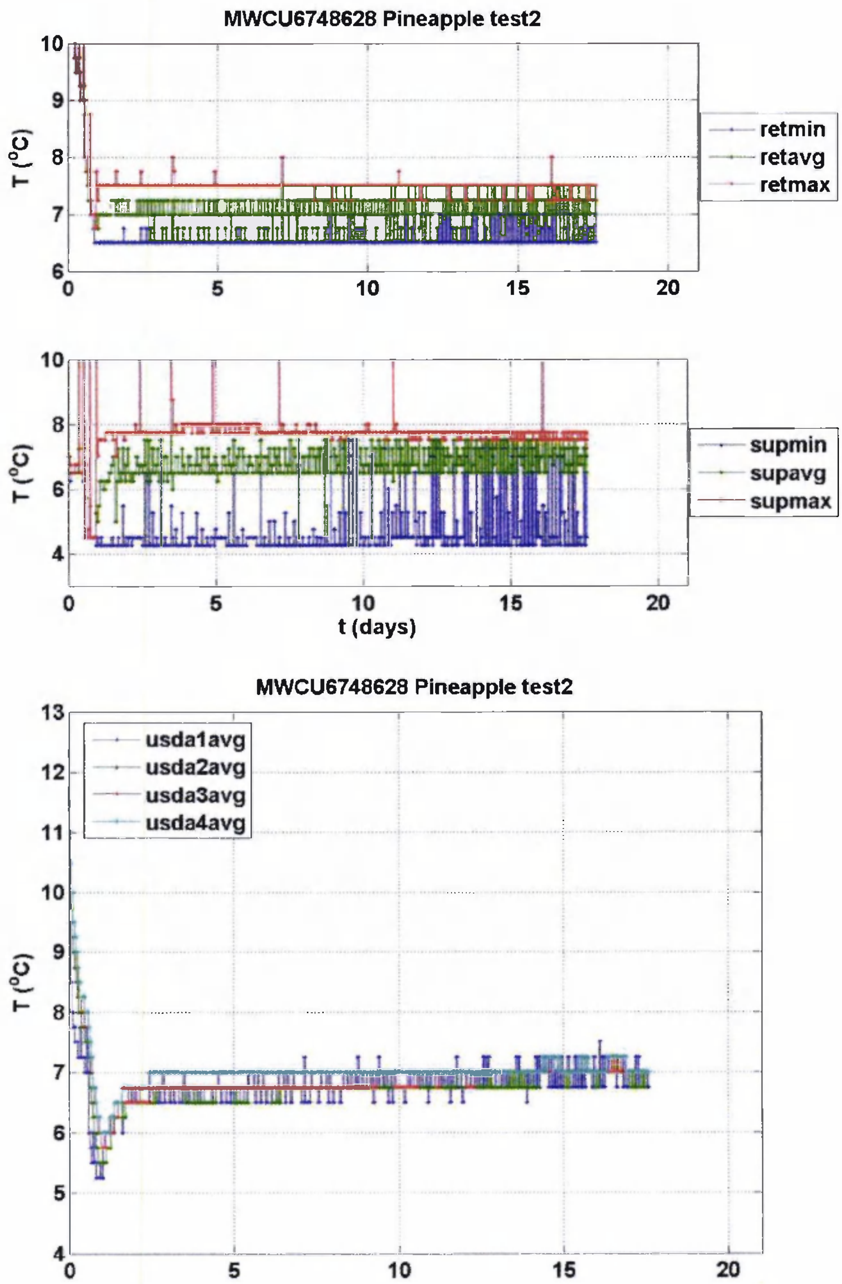


Figure 21 Temperature readings from the unit for the Pineapple test 2 container.

Appendix IV: Snapshot pictures of carton temperature readings

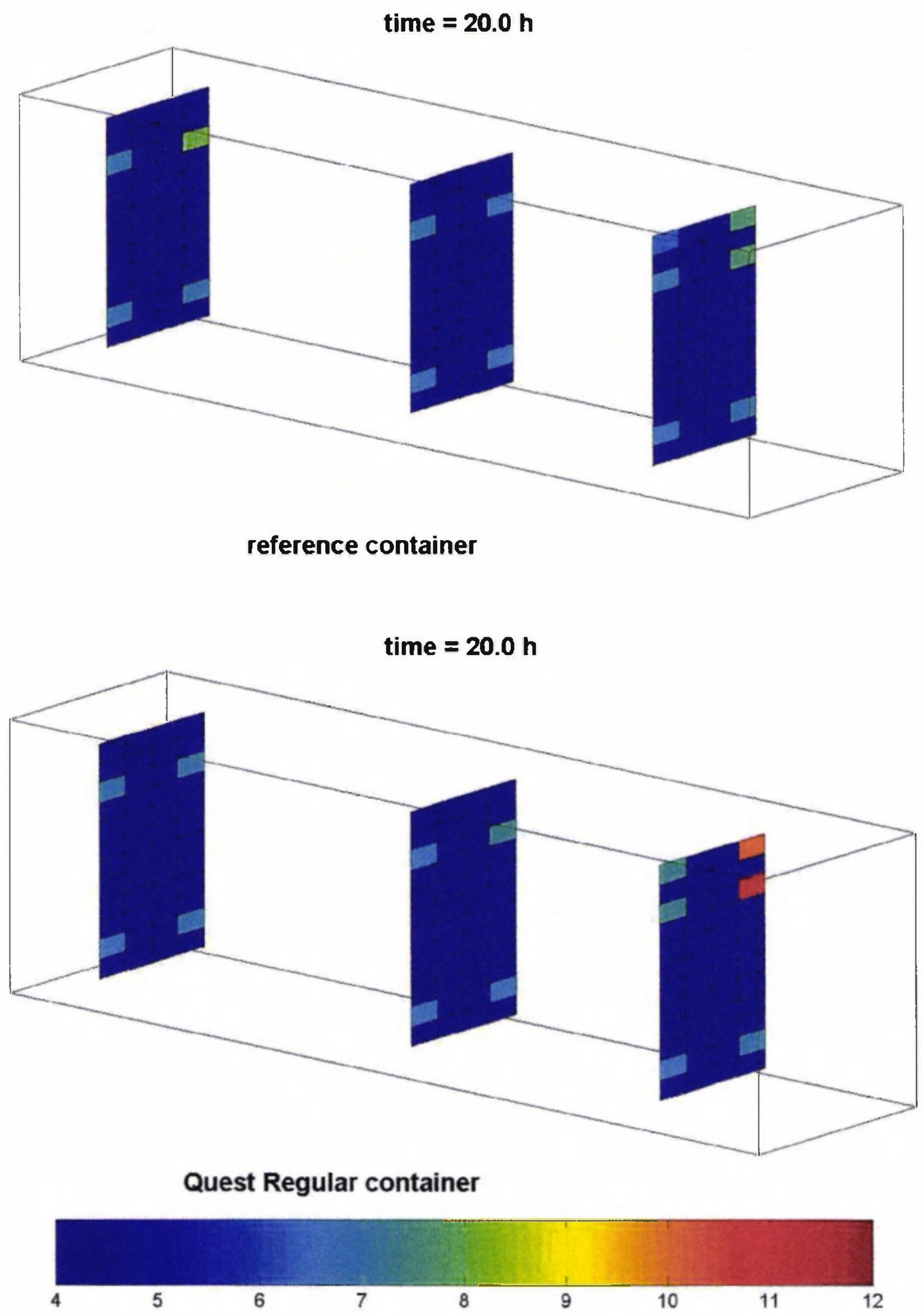


Figure 22 Tiny Tag readings of the carton temperatures after 20 hours, on September 20th, Pineapple 1

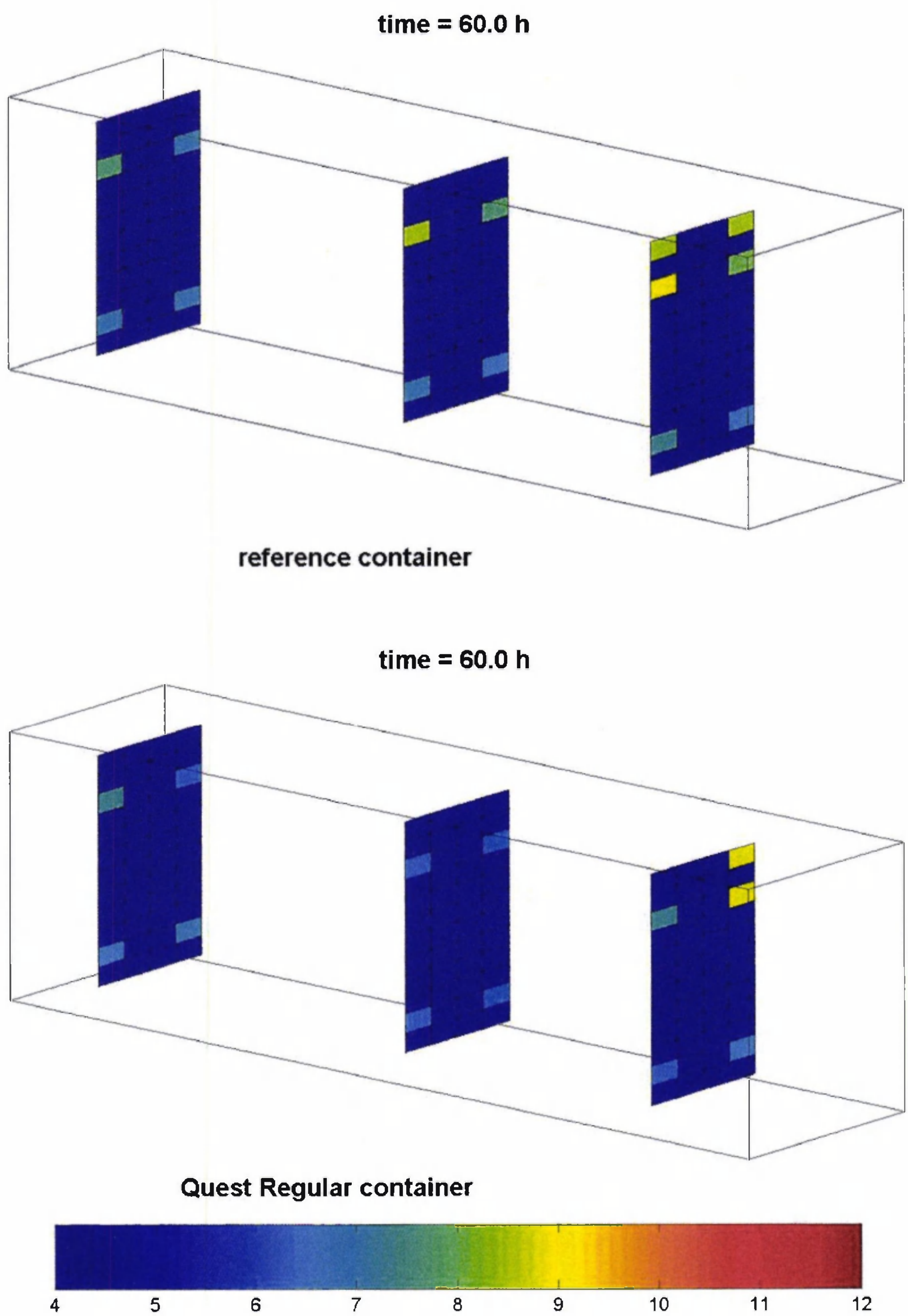


Figure 23 Tiny Tag readings of the carton temperatures 1,5 days after the start of the trip, on September 24th , Pineapple 2

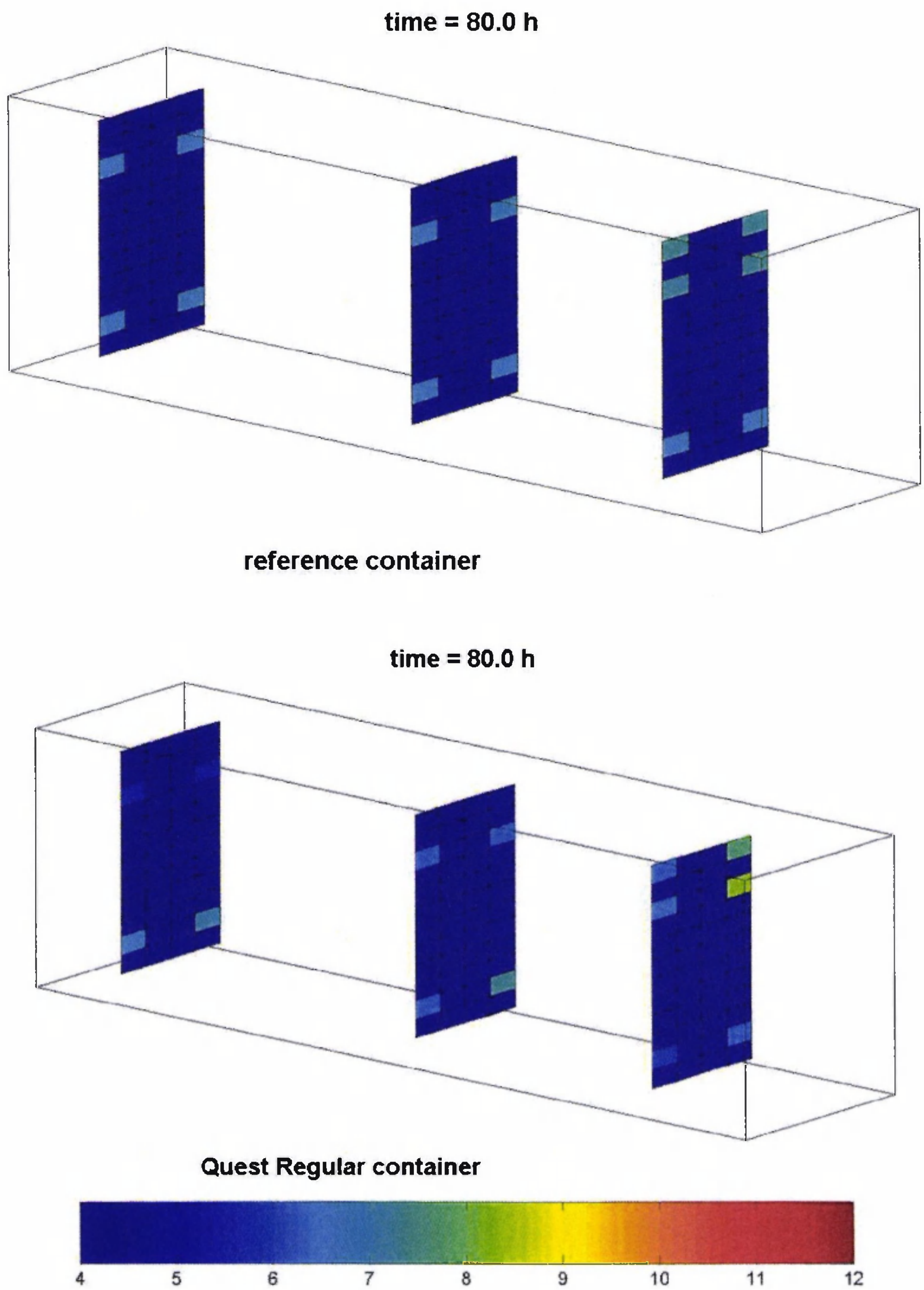


Figure 24 Tiny Tag readings of the carton temperatures 3,3 days after the start of the trip, on September 22nd , Pineapple 1

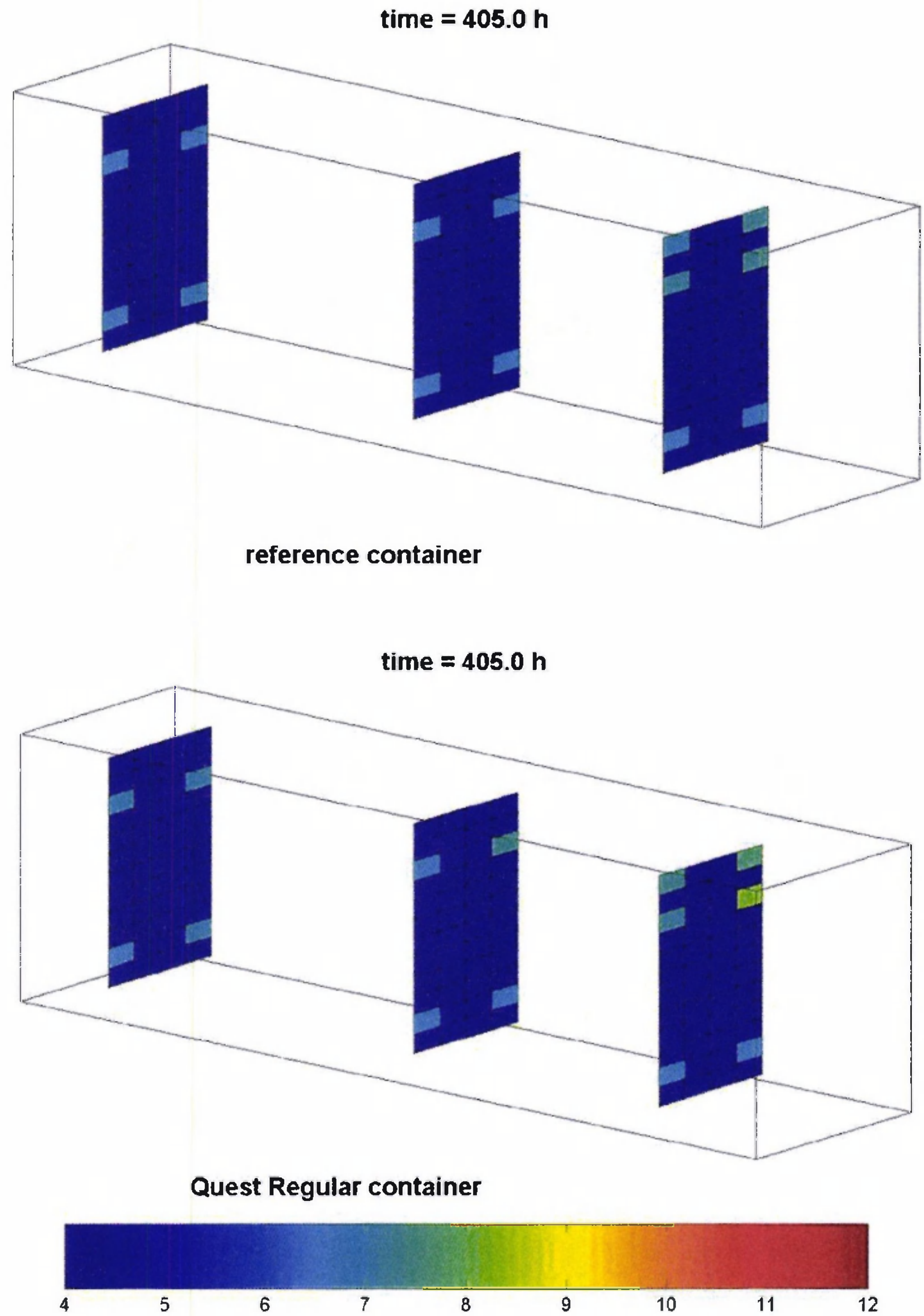


Figure 25 Tiny Tag readings of the carton temperatures near the end of the trip, on October 6th, Pineapple 1

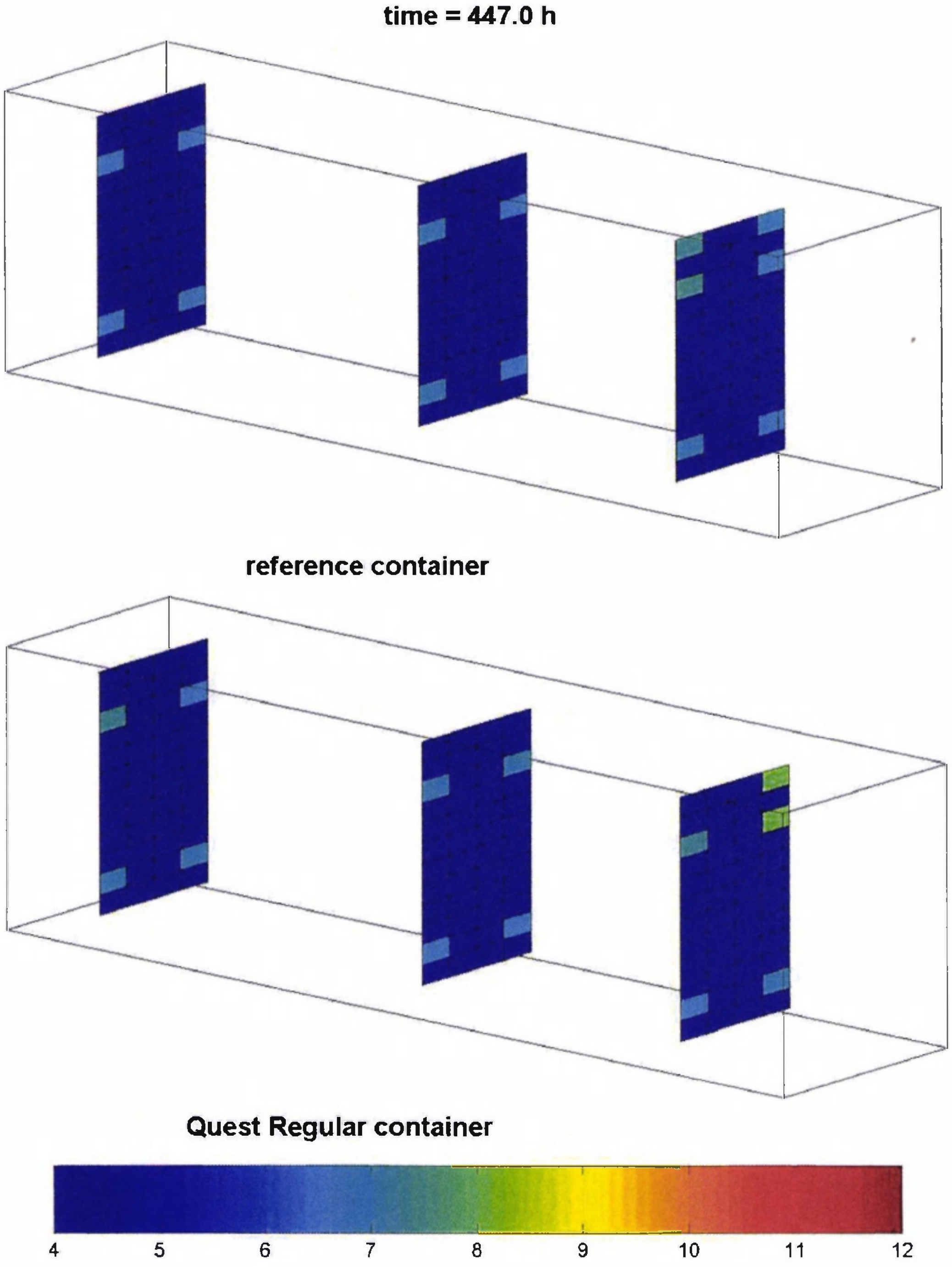


Figure 26 Tiny Tag readings of the carton temperatures near the end of the trip, on October 10^{th}, Pineapple 2

Appendix V: Ambient temperatures

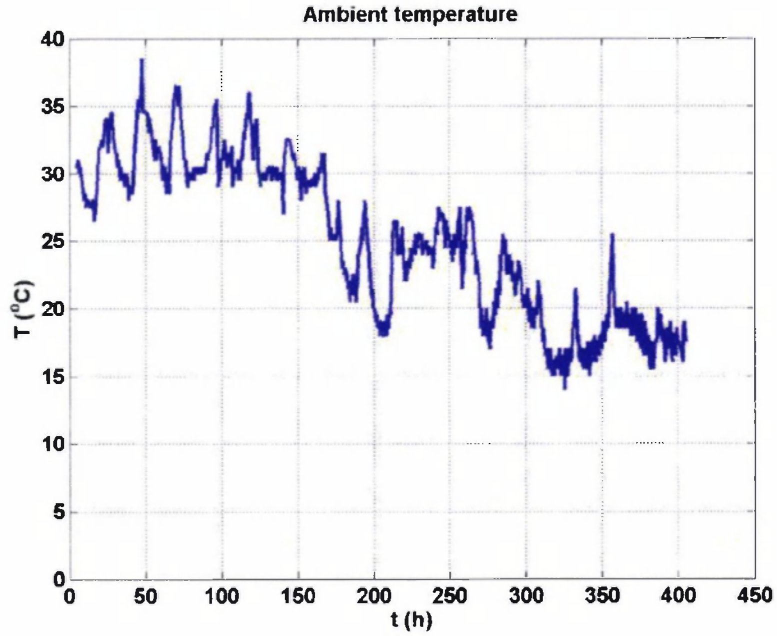


Figure 27 Ambient temperature readings form the Tiny Tag/Ibutton on the outside of the container, Pineapple test 1.

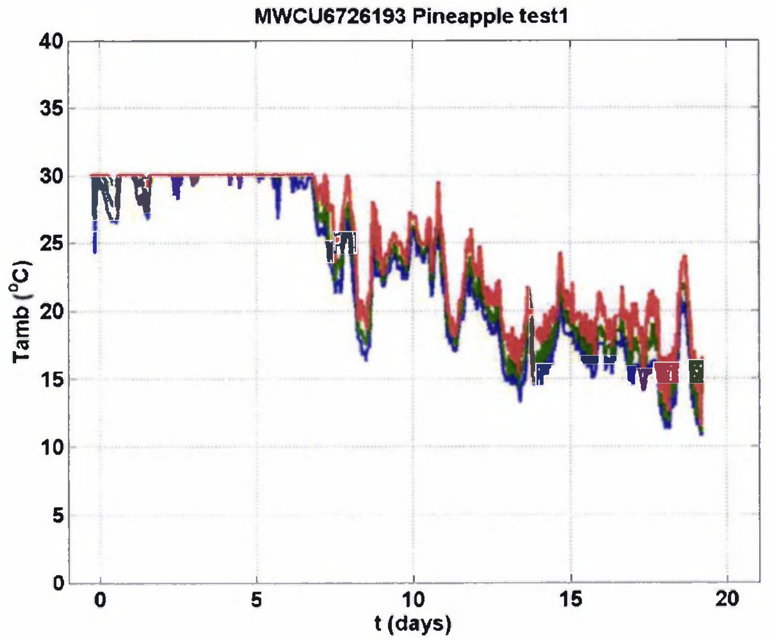


Figure 28 Ambient temperature readings form the unit, Pineapple test1.

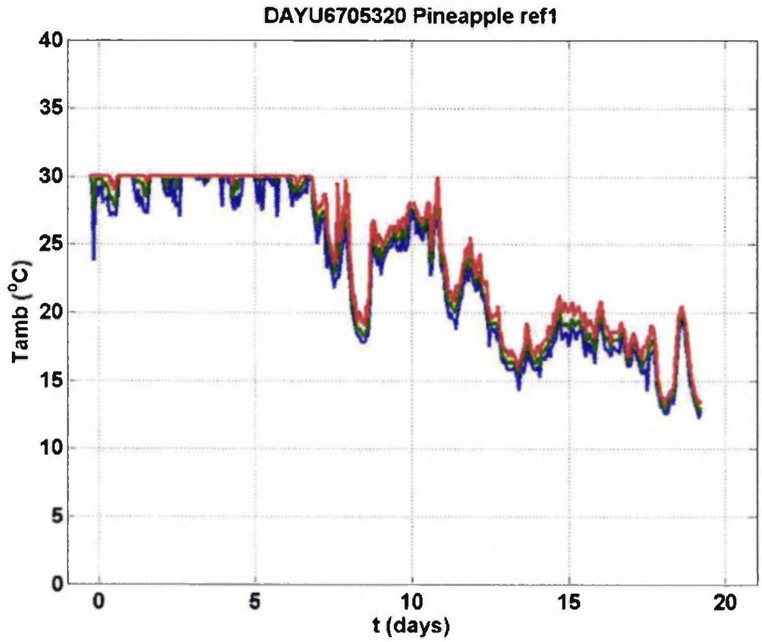


Figure 29 Ambient temperature readings form the unit, Pineapple ref1.

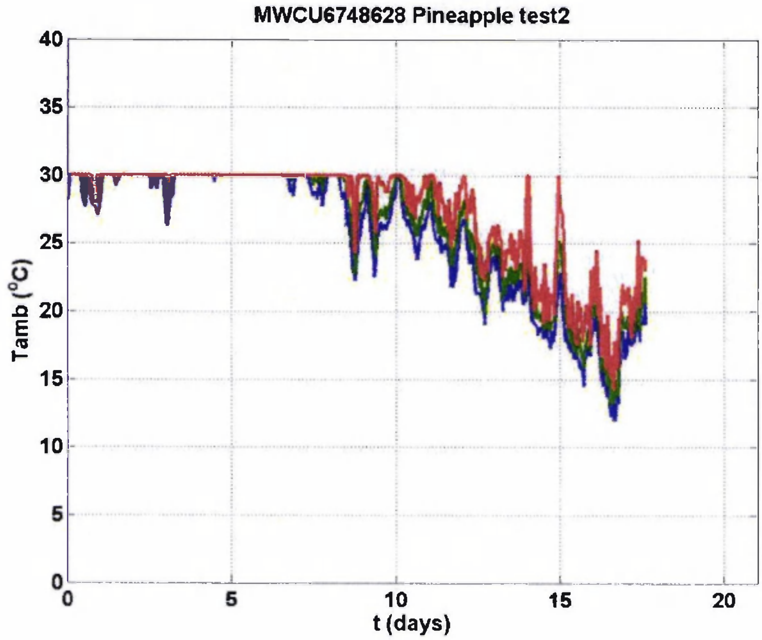


Figure 30 Ambient temperature readings form the unit, Pineapple test2.

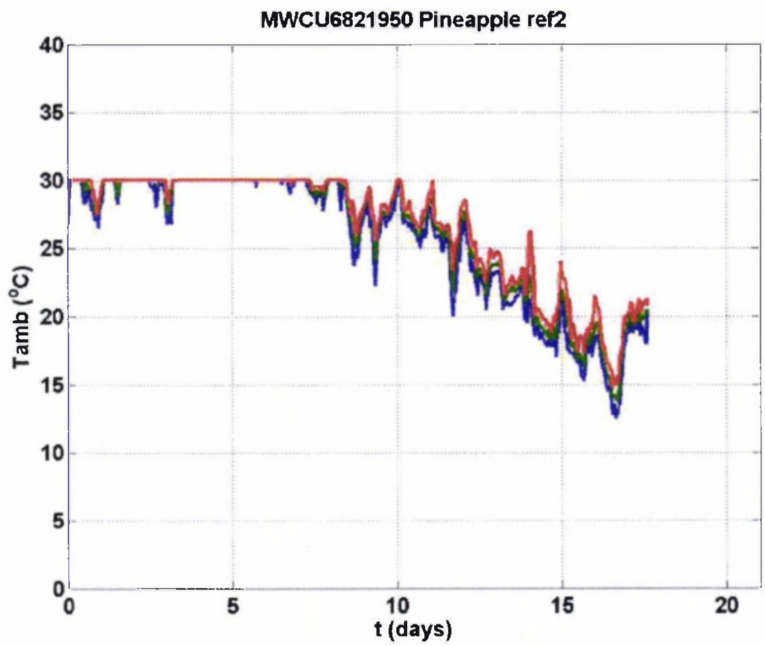
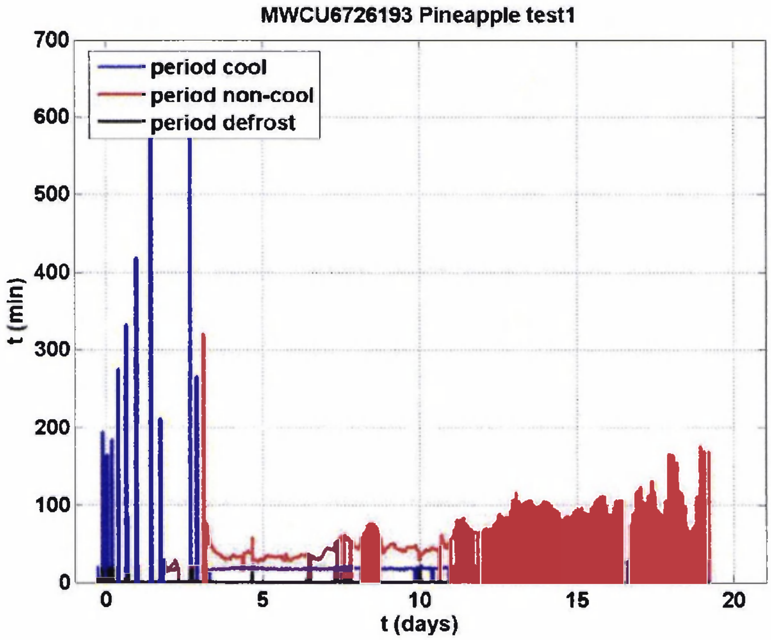


Figure 31 Ambient temperature readings form the unit, Pineapple ref2.

Appendix VI: Unit activity graphs



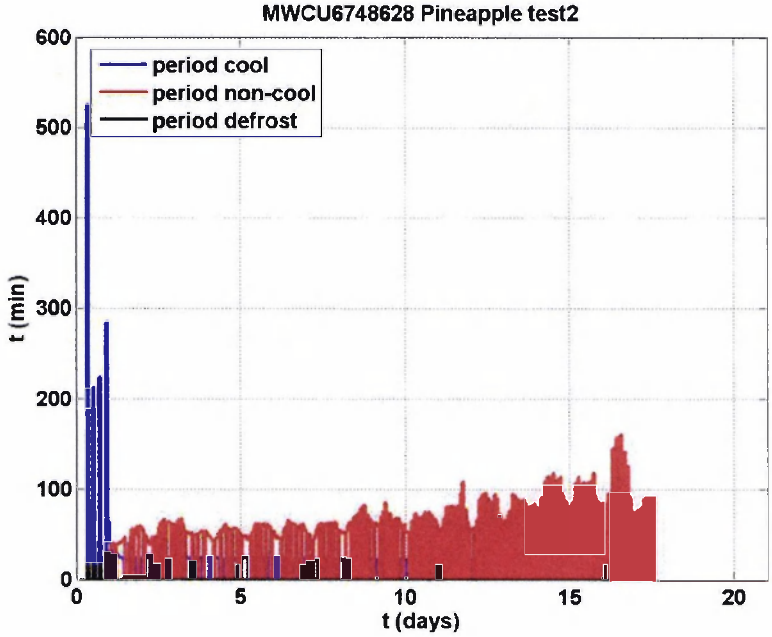


Figure 32 The number of minutes per cooling, non-cooling and defrost period as a function of time for the Quest Pineapple containers. At each time instant during the voyage when a period is finished a bar is drawn with the number of minutes that that period has lasted. If the period is smaller than an hour, the bars turn into a line.

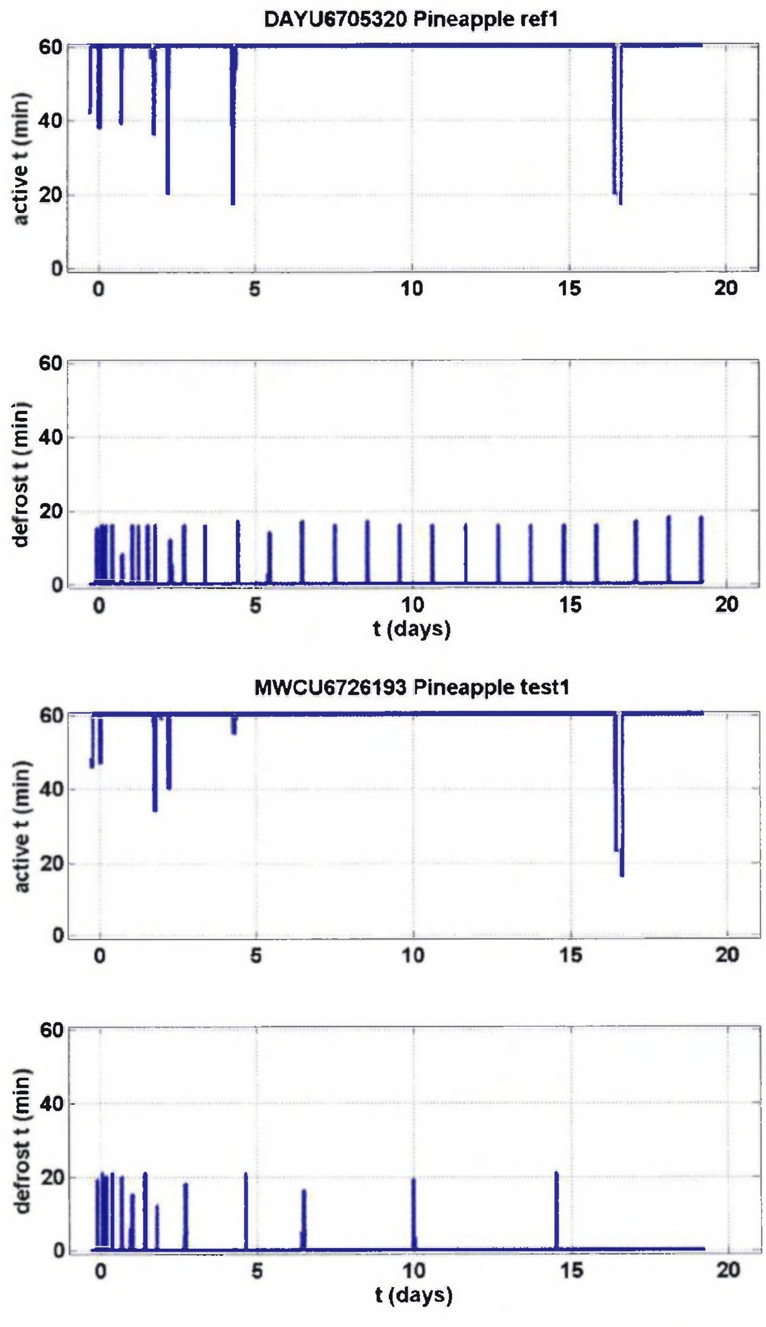


Figure 33 The number of minutes active, non-active and defrost period as a function of time for the Pineapple 1 containers. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less.

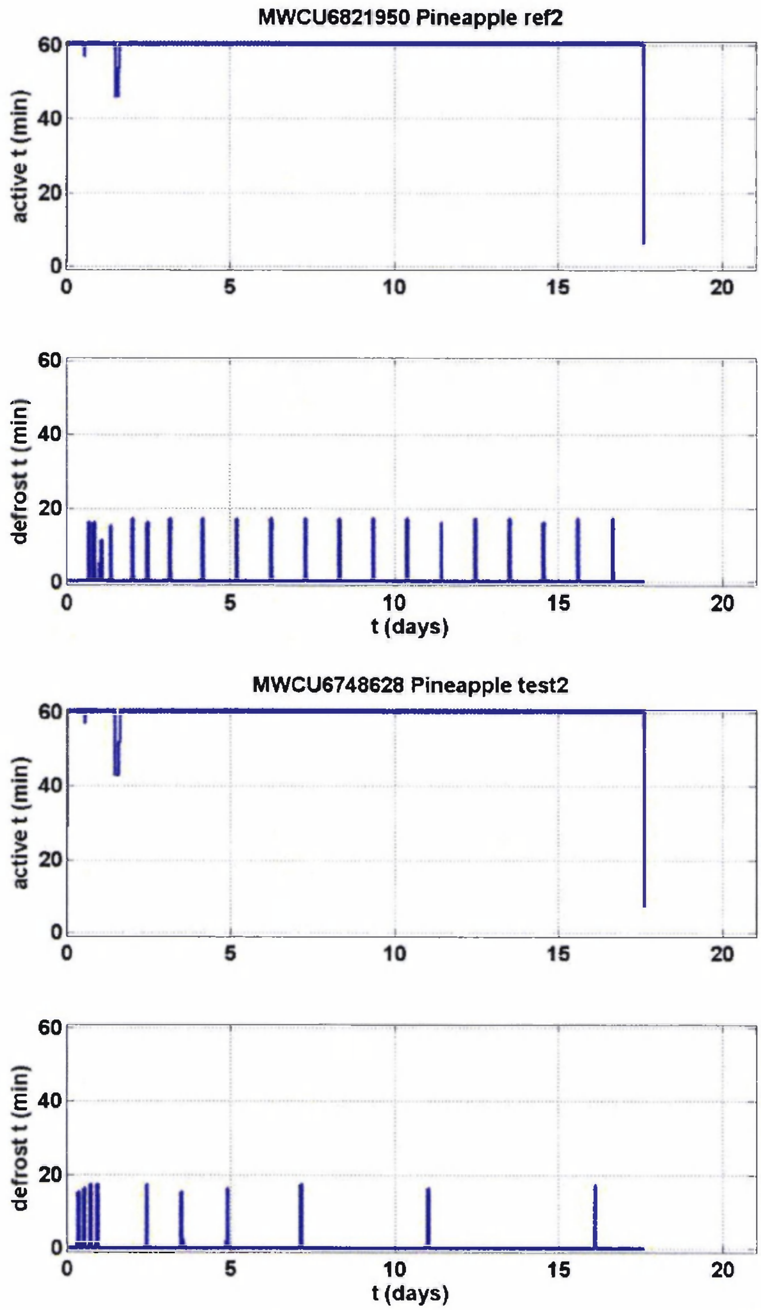


Figure 34 The number of minutes active, non-active and defrost period as a function of time for the Pineapple 2 containers. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less.