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Shipping and static trials of cauliflower containers using Modified Atmosphere Packaging (MAP)

VG148

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CAULIFLOWER SHIPPING TRIAL FROM FREMANTLE TO SINGAPORE USING 1ST GENERATION MODIFIED ATMOSPHERE PACKAGING (MAP)

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SEPTEMBER 1992

Organisations involved in conducting the trial:

* Sumich Group Limited, W.A. (Dennis Davis, Barry Buss)
* M-veg Vegetable Export Growers, W.A. (Steve O'Sullivan)
* Horticultural Research and Development Corporation
* Australian National Line (Brian Davis)
* ICI Films, Australia (Suzanne Baldwin, Chris King)
* Department of Agriculture, Victoria (Doris Blaesing, Christine Cooper, Peter Franz)
* Department of Agriculture, W.A. (S.C. Tan, Yvonne Haynes)
* CSIRO, Division of Food Processing (Alistar Sharp)

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EXECUTIVE SUMMARY

Modified atmosphere packaging (MAP) can extend the post-harvest life of cauliflower compared to traditional packaging methods. The extended lifespan can be utilised during storage or shipping.

In this trial, cauliflower was harvested 42, 28 and 14 days prior to arrival at the market. It was packed into 6 different types of packaging and stored prior to shipment under controlled temperature conditions for 28, 14, and 0 days.

In this trial paper wrapped cauliflower packed in MAP liners after 28 days from harvest to market had similar quality compared to 14 days in traditional paper wraps. It was found to be an additional benefit that the liners also prevented weight loss of cauliflower during storage and transport. In this trial 42 days old cauliflower turned out with a poor market quality independent from the packaging treatment. This was due to poor initial produce quality.

The results indicate that, if only good quality cauliflower was packed and an excellent temperature management was guaranteed between harvest and marketing, the cauliflower lifespan could be further extended using carton liners that provide a greater atmosphere modification.

In general the outturn quality could be improved by introducing single layer cartons. These would minimise mechanical impacts on the curds. Paper wraps would not be necessary, if some 'wrapper leafs' would be left on the cauliflower. A new carton format should also allow an improved container stowage pattern and should be designed to allow palletisation, column stacking and thus improve cooling.

The conservative Singapore market will very slowly adapt to new packaging concepts. However, new packaging will be more easily accepted, if importers and their customers can see an advantage, compared to the current system.

CONTENTS

1. INTRODUCTION

Australia is exporting more than 7000 tonnes of cauliflower annually. Western Australia is supplying more than 90% of the produce, mainly via seafreight. The major importing countries are Singapore, Malaysia and Hong Kong. Seafreight times from Fremantle to Singapore and Malaysia are about 7-10 days, to Hong Kong 10-14 days. The main export season is between February and October. Traditionally cauliflowers for Asian markets are individually wrapped in grease proof paper and packed in 18-20 kg cartons.

Earlier work on CA storage and modified atmosphere packaging of cauliflowers indicated that the use of MAP carton liners will allow an extended cool storage period of 14-25 days prior to shipment from W.A. This would enable growers and exporters to level out peaks and troughs in production, thus increasing market flexibility.

Victoria and New South Wales have been exporting small amounts of cauliflower during past years. Shipping times are 15-21 days to Malaysia and Singapore and 18-28 days to Hong Kong. Therefore the MAP technology is necessary to successfully seafreight cauliflowers from these states to Asian markets.

1.1. Trial objectives

The objectives of the trial shipment of cauliflower were to:

* Investigate whether up to 4 weeks cool storage is possible under commercial conditions with good outturn quality after subsequent shipment.
* Test the technical performance of MAP liners under commercial conditions.
* Test market acceptance of new packaging materials.
* Identify the optimum packaging for commercial use, as well as areas for further improvement in packaging design.
* Evaluate current temperature and quality management procedures in relation to the new packaging concepts.
* Evaluate whether extended post-harvest life could be used to export cauliflowers to more distant markets.
* Compare the performance of produce and packaging from the trial shipment with results from a static coolstore trial.

2. MATERIALS AND METHODS

2.1. Packaging treatments

The cauliflowers were packed into telescopic corrugated fibreboard cartons (540 X 360 X 250 mm) as currently used by M-VEG/SUMICH for export to Asia. The packaging treatments were as follows:

A - traditional paper wrap
B - high humidity carton liner
C - controlled permeability carton liner, MPCP 54C
D - controlled permeability carton liner, MPCP 72C
E - MPCP 72C plus paper wrap
F - individual polyethylene bags

Treatments C-E were MAP liners. All carton liners, (1000m x 1000 mm) were sealed using plastic ties. The individual bags (F, 310 x 350 mm) had 12 holes, 9 mm in diameter and were not sealed.

2.2. Harvest, packaging, storage, shipping and unloading

The cauliflower was harvested at three dates, at 14 day intervals and stored prior to shipment. Dates and times are listed in Table 1.

The produce was harvested, pre-cooled and packed on the commercial packing line by M-VEG in Manjimup, ca. 250 km South of Perth. Due to technical problems the trial cartons from harvest III had to be packed at M-VEG on the 10.7.92 using traditional packaging. They were re-packed into the trial treatments at SUMICH's on the 12.7.92. All trial cartons were stored in the SUMICH holding rooms in Perth. The shipping container (Mitsubishi, model CPE51-3BWP, ANNV 5020121) was stowed at the SUMICH premises on the 13.7.92. The container held 108 trial cartons plus 301 cartons of "normal" produce (harvested and packed at date III, paper wrapped).

At the first packing date a second lot of cauliflower, identical to the trial shipment lot, was packed to be monitored and assessed at the coolrooms of the W.A. Department of Agriculture (static trial).

Table 1: Dates and times for harvests, packing, storage, shipping and unloading (shipping trial)

	HARVEST I	HARVEST II	HARVEST III
HARVEST DATE VARIETY	12.6.92 Plana	26.6.92 Arfak	9.7.92 Plana
PACKING DATE	15.6.92	29.6.92	12.6.92
CONTAINER STOWAGE	13.7.92	13.7.92	13.7.92
SHIPPING	14.7.92	14.7.92	14.7.92
UNLOADING, ASSESSMENTS	24.7.92	24.7.92	24.7.92
DAYS FROM HARVEST TO ASSESSMENT	42	28	14
DAYS FROM HARVEST TO TRIAL PACKING	3	3	3
DAYS IN STORAGE	28	14	0
DAYS IN CONTAINER	11	11	11

After arrival in Singapore, the trial container (C1) was delivered to the CWT DISTRIPARK premises were it was kept on power overnight until the assessments took place. On the day of assessment the 301 cartons of "normal" produce from C1 were shifted straight to an identical container (C2), which was placed door to door to C1. The trial cartons were taken out of C1 in lots of 6 at a time. They were weighed, the produce was assessed and the cartons were then loaded into C2. During this process both containers were kept on power.

2.3. Measurements and assessments

2.3.1. Temperatures and humidities

Produce and air temperatures were recorded randomly before, during, and after packaging, during storage and prior to container stowage using a hand held digital thermometer (ANRITSU Anritherm). During shipment, produce temperatures, container supply and return air as well as ambient temperatures and return relative humidities were recorded using the CSIRO TransMonitor System. Thirty two thermocouples (Type T) and two Squirrel 1205 data loggers were used to record produce temperatures throughout the loadspace. Four thermistor probes and a Vasala humidity probe were used with a Squirrel 1201 to monitor air temperatures and humidity (Appendix 1). The container was set on 0°C supply air. (See separate report from CSIRO, Division of Food Processing.)

During unloading in Singapore, a hand held thermometer was used to measure produce and ambient temperatures. Produce temperatures were recorded for 2 heads of each experimental carton.

For the static trial the coolroom temperature was set at 1°C.

During the shipping and the static trial, produce temperatures were only monitored for the produce in paper wraps and individual bags because the sealed liners could not be punctured.

2.3.2. Atmospheres inside carton liners

Oxygen and carbon dioxide levels inside all sealed liners were monitored in the static trial only. It was technically impossible to measure carton liner atmospheres in the shipping trial cartons during storage,shipment or unloading. In the static trial atmospheres were measured 3 times per week using a SHIMADZU Gas Chromatograph.

2.3.3. Produce weights and quality assessments

Total weights (produce + packaging) for each experimental carton were recorded after packing, prior to loading the container, and at unloading in Singapore. The initial quality of the cauliflower as determined by production and harvest conditions was assumed to be the same within each harvest date. During packing, export quality produce was selected by the packers according to the usual packing shed procedures (trimmed heads of 1-1.5 kg, free of dirt, discolouration, mechanical damage, insects and diseases, head temperature < 3°C). Quality differences between harvests were described by ratings of average quality per harvest date (1= excellent, 2= good, 3= moderate, 4= poor, 5= very poor).

During unloading in Singapore, visual quality assessments were conducted on 5 randomly chosen heads per carton. Scores from 1-5 were used to describe the severity of rots and black/brown/yellow spots, the stem cut surface colour and quality, leaf quality and overall market quality (Table 2, Fig.1).

The assessments of the static trial were made at the W.A. Department of Agriculture using the same system. The first assessments ('ex store') were done the same day (24.07.92) as for the trial shipment. After the 'ex store' assessments the cauliflower was put into a 10°C coolstore to simulate a marketing period. It was assessed again on the 27.07.92 ('ex market').

Figure 1: Ratings for percent of total cauliflower surface area affected by spots or rots.

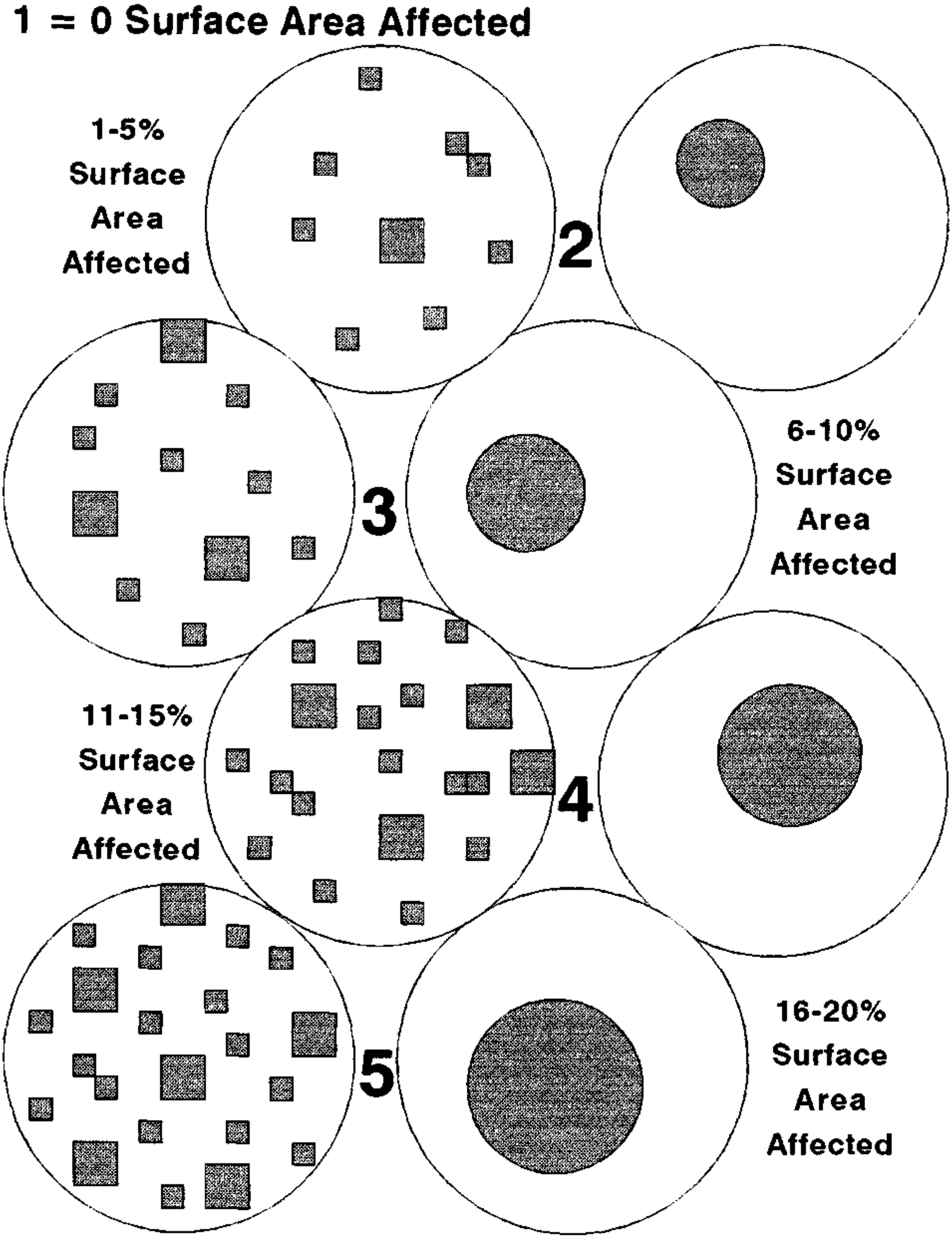

Table 2: Cauliflower assessment scores

SCORE	YELLOW, BROWN AND BLACK SPOTS	CUT SURFACE COLOUR	LEAF COLOUR AND QUALITY	ROTS	MARKET QUALITY
1	none	white	green	none	excellent
2	slight	light grey	yellow/ green	slight	good
3	moderate	grey	grey/ green	moderate	moderate
4	severe	dark grey	grey/ brown	severe	poor
5	very severe	black	black	very severe	very poor

2.4. Marketing

The morning after produce assessments, container 2 was brought to the Singapore wholesale centre 'Pasir Panjang'. The produce was treated as a normal consignment of SUMICH's to their importer Mr Lee Song Sia. On arrival at the market random inspections of the produce were made and the importer's comments regarding produce quality and packaging were noted. Part of the produce was sold that day and a part remained in Mr Lee's coolstores. It was inspected again on the 27.07.92 prior to sale.

2.5. Experimental design and statistical analysis

The experiment was designed with the support of The Biometrics Unit, Department of Agriculture. The positions of the TransMonitor probes were determined by CSIRO, Division of Food Processing.

2.5.1. Packaging and transport to holding rooms

Each of the 6 packaging treatments for the trial shipment were replicated 6 times at 3 packing dates (6 packaging treatments x 3 packing times = 18 treatments; 18 treatments x 6 replicates = 108 trial cartons). At each date the packing was done in 6 randomised complete blocks with 1 replicate of each treatment per block (6 packaging treatments x 6 replicates = 36 cartons). At packing dates I and II, two packers packed 3 complete blocks each whilst on packing date III three packers packed 2 complete blocks each. At packing date I two lots of 36 cartons were packed; one for the trial shipment and one for the static trial. For transport to the holding rooms, the 36 trial cartons of one harvest were stacked on pallets in layers of 6, 6 layers high, with each layer representing 1 randomised block (Figs. 2 - 4). The blocks from harvest date I were numbered 1-6, the blocks from harvest date II, 7-12 and the ones from

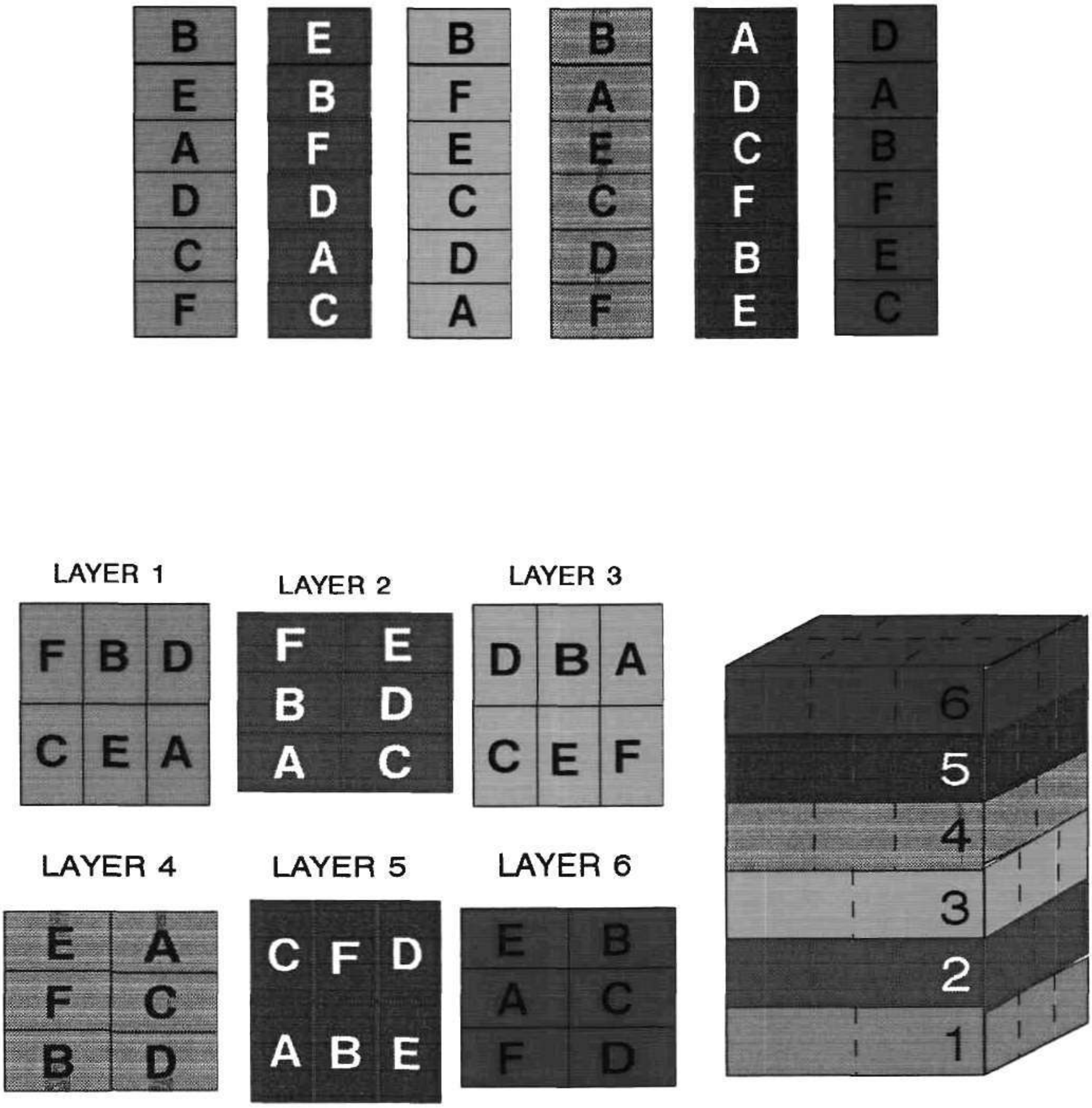

Figure 2: Packing order and pallet stacking design for harvest I.

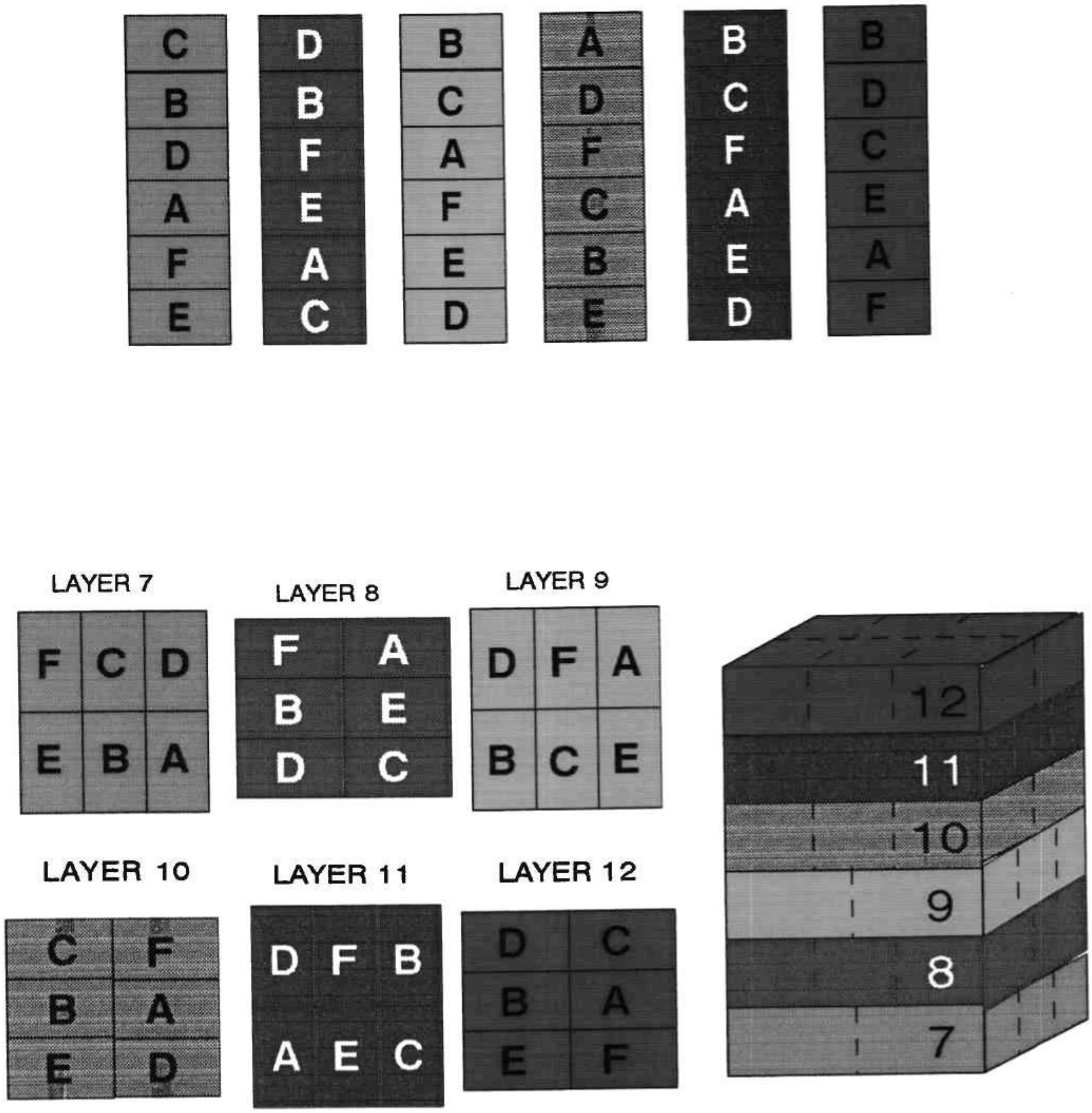

Figure 3: Packing order and pallet stacking design for harvest II.

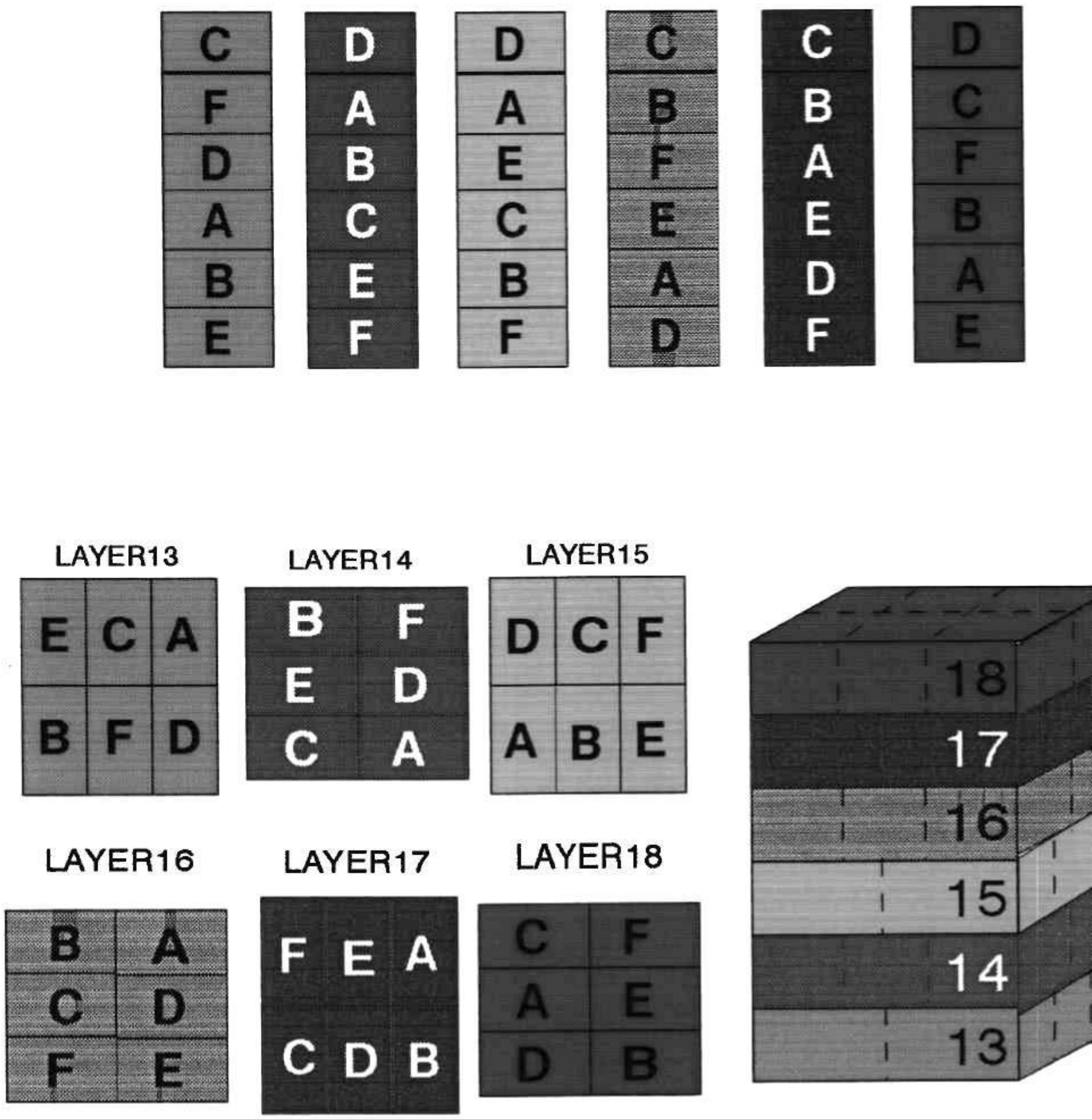

Figure 4: Packing order and pallet stacking design for harvest III.

the third harvest date 13-18. The packaging treatments were labelled A-F as described under 2.1.

2.5.2. Storage

The first trial pallet was stored in its transport configuration (Fig. 2) until the arrival of the second trial pallet 14 days later. The pallets from harvest I and II were then re-stacked for storage, forming 6 "superblocks" of 12 cartons on 2 pallets by combining 1 block from each harvest date (e.g. layer 1 from harvest I + layer 7 from harvest II = 12 cartons: 1 replicate per 6 packaging treatments and 2 harvest dates, Fig.5).

The third trial pallet (harvest III) was stored overnight in 6 layers, each layer comprising 1 randomised complete block with 1 replicate per treatment (Fig 4).

The static trial was set up on the coolroom floor in a randomised complete block design, according to the layers of the pallet storage design of packing date I (Fig.2).

2.5.3. Container stowage and unloading

The container was handstowed using Sumich's regular stowage pattern for cauliflower. The experimental cartons were stowed in the centre of the container, in 5 layers. The design included 6 superblocks, marked with coloured margins in Fig. 6, representing 1 carton of each packing treatment and packing date (6 packing treatments x 3 dates = 18 cartons per superblock). Superblocks 1-5 were located "lying flat" in the bottom 5 layers of the container. The entire load comprised 7 layers with the top 2 layers side stowed and thus not included in the trial. The right hand row was side stowed as well. Each layer of experimental cartons was divided into 3 sub-blocks of 6 cartons, marked with different colours within the superblock margins in figure 6. Due to the commercially used stowage pattern superblock 6 had to be located "upright" at the rear end of the container and divided into 4 sub-blocks of 4 and 1 sub-block of 2 cartons. The treatments within the sub-blocks were randomised. At unloading in Singapore 1 sub-block (= 6 cartons for superblock 1-5, 4 and 2 cartons for superblock 6) at a time was removed from the container for assessments.

At loading the thermistor and relative humidity (RH) probes were put into place and the thermocouples were installed throughout the loadspace. The Squirrels were placed in the headspace. Figure 7 shows the location of probes and thermocouples. The later were placed in the stem of a cauliflower in each of the marked boxes.

Figure 8 gives an overview of the trial from packaging to storage.

2.5.4. Statistical analysis

The statistical analysis was conducted by The Biometrics Unit, Department of Agriculture, Victoria. The seafreight trial, which was an unbalanced design, was analysed using the REML (Restricted Maximum Likelihood) technique, available in GENTSTAT 5. The static trial was analysed using analysis of variance (ANOVA, GENTSTAT 5).

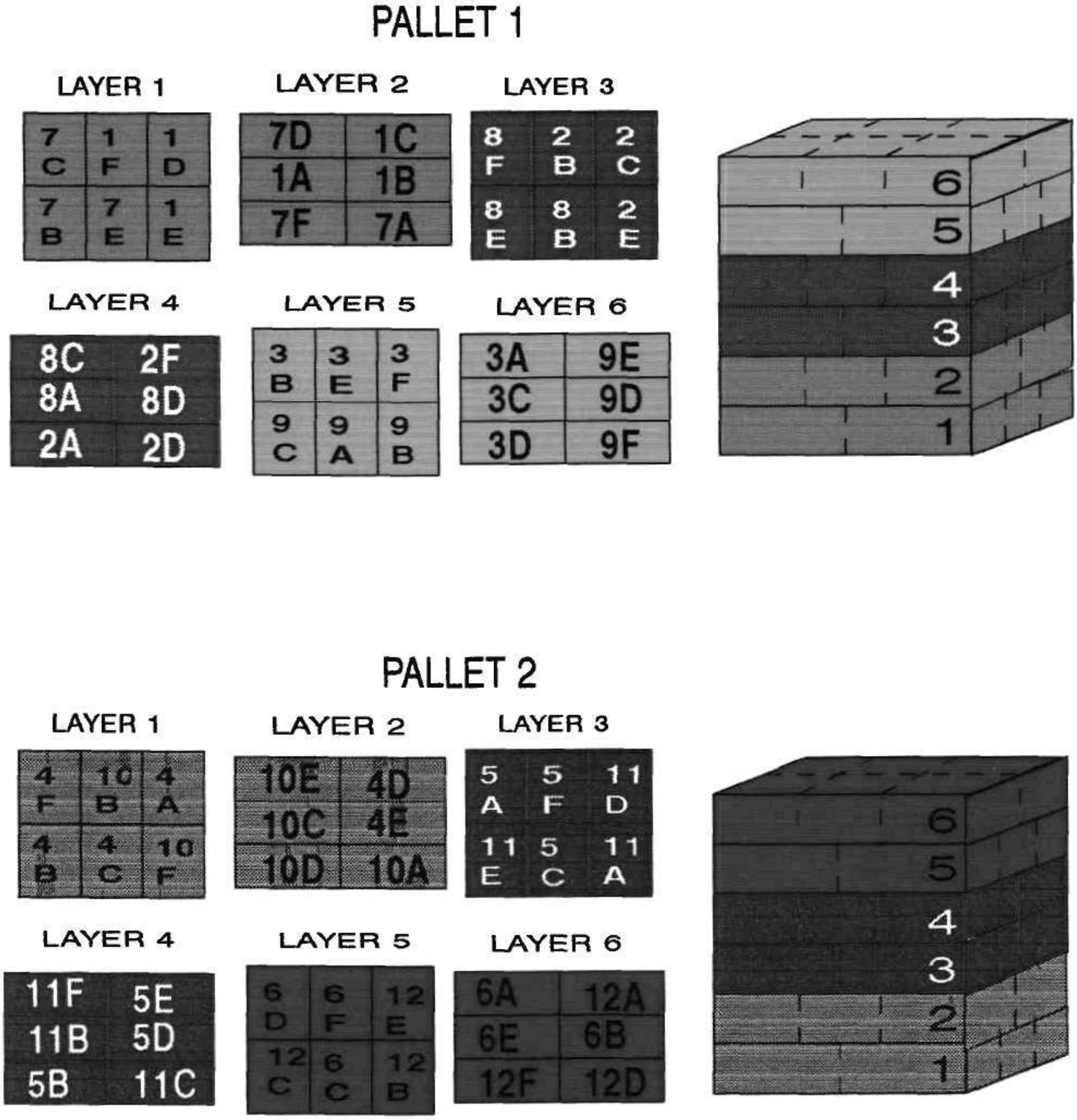

Figure 5: Pallet stacking design for storage of produce from harvest I and II. Two layers comprise 1 block with 6 cartons from 2 harvests.

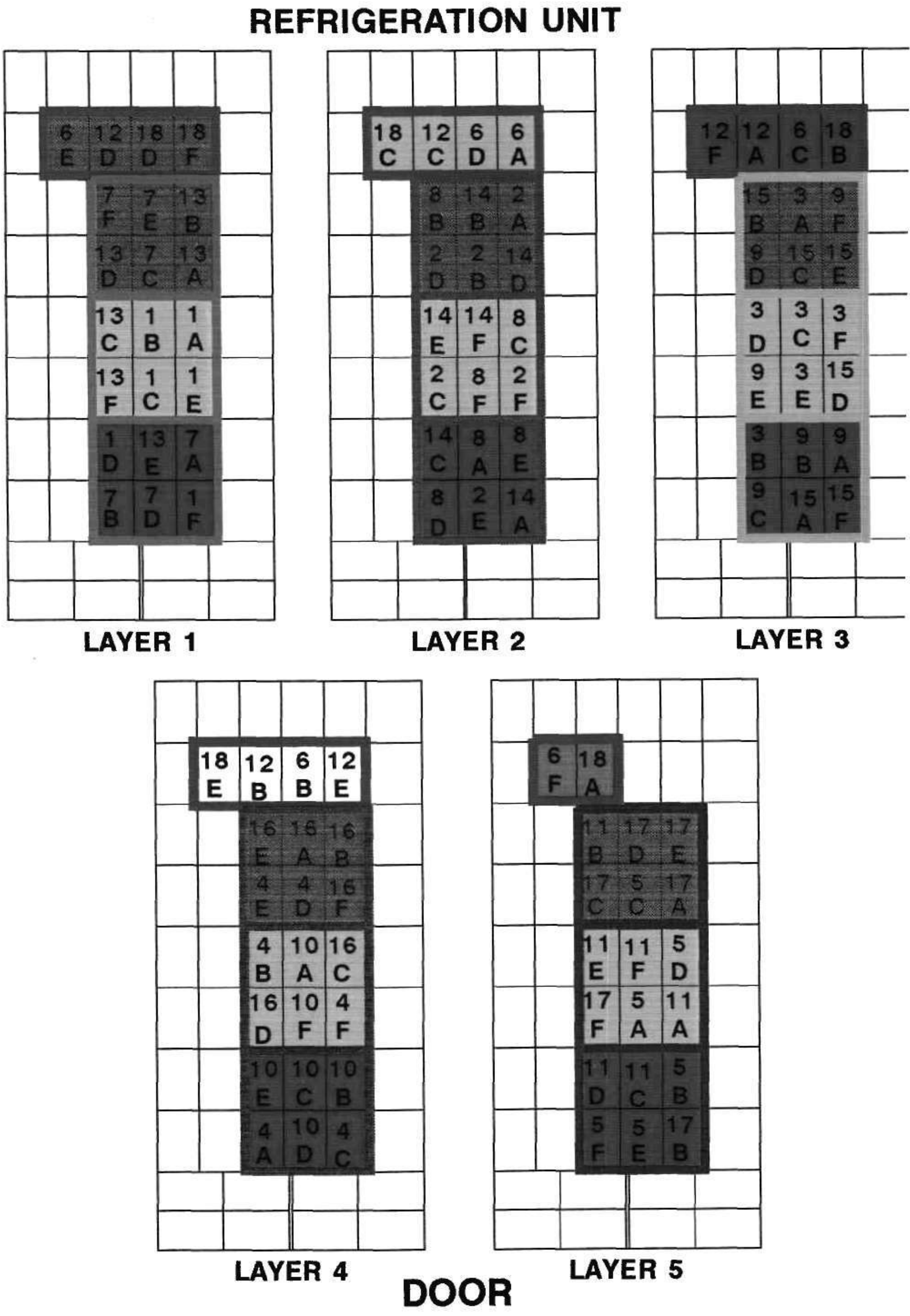

Figure 6: Container stowage design.

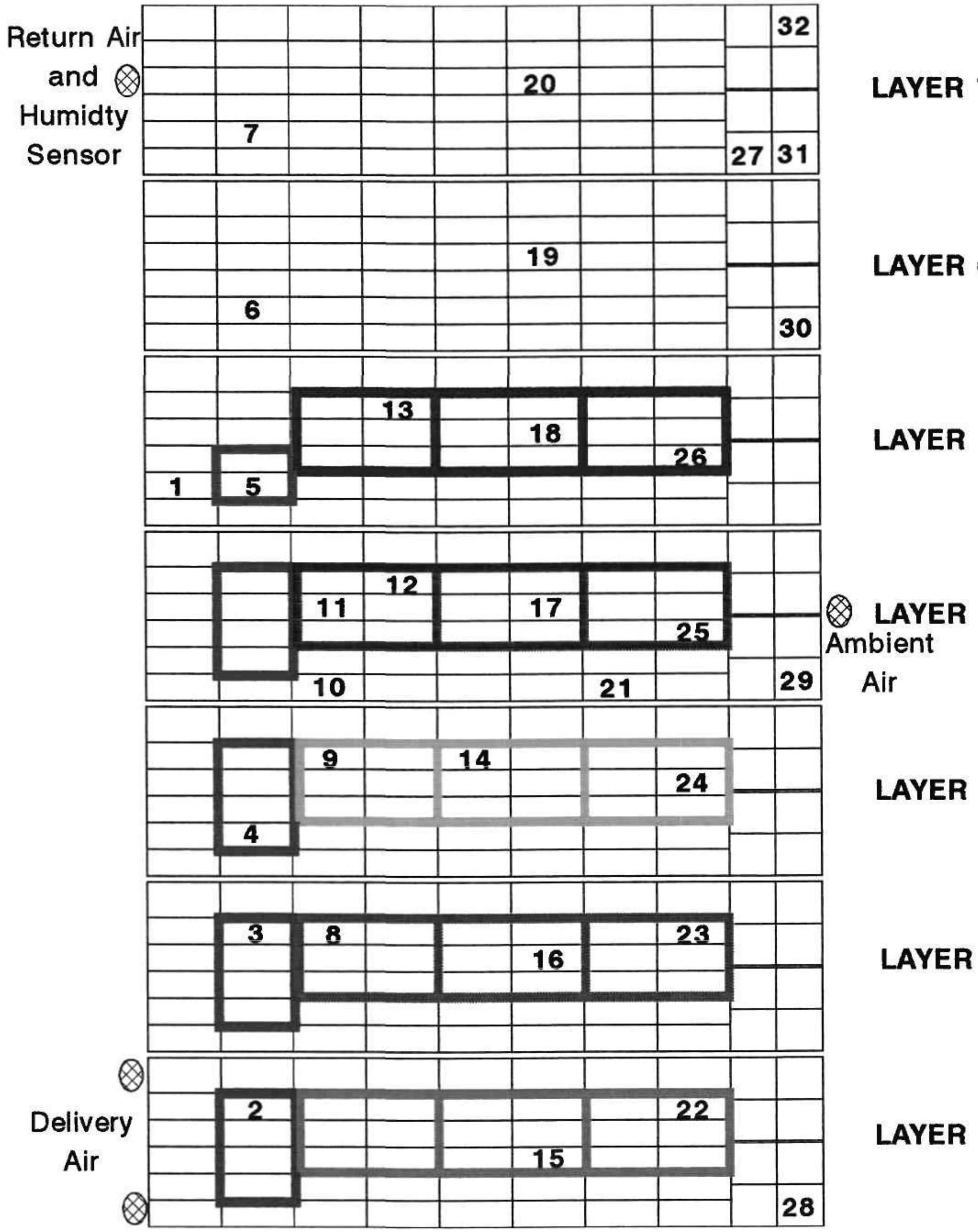

Figure 7: Location of thermocouples, thermistor probes and relative humidity probe in the container.

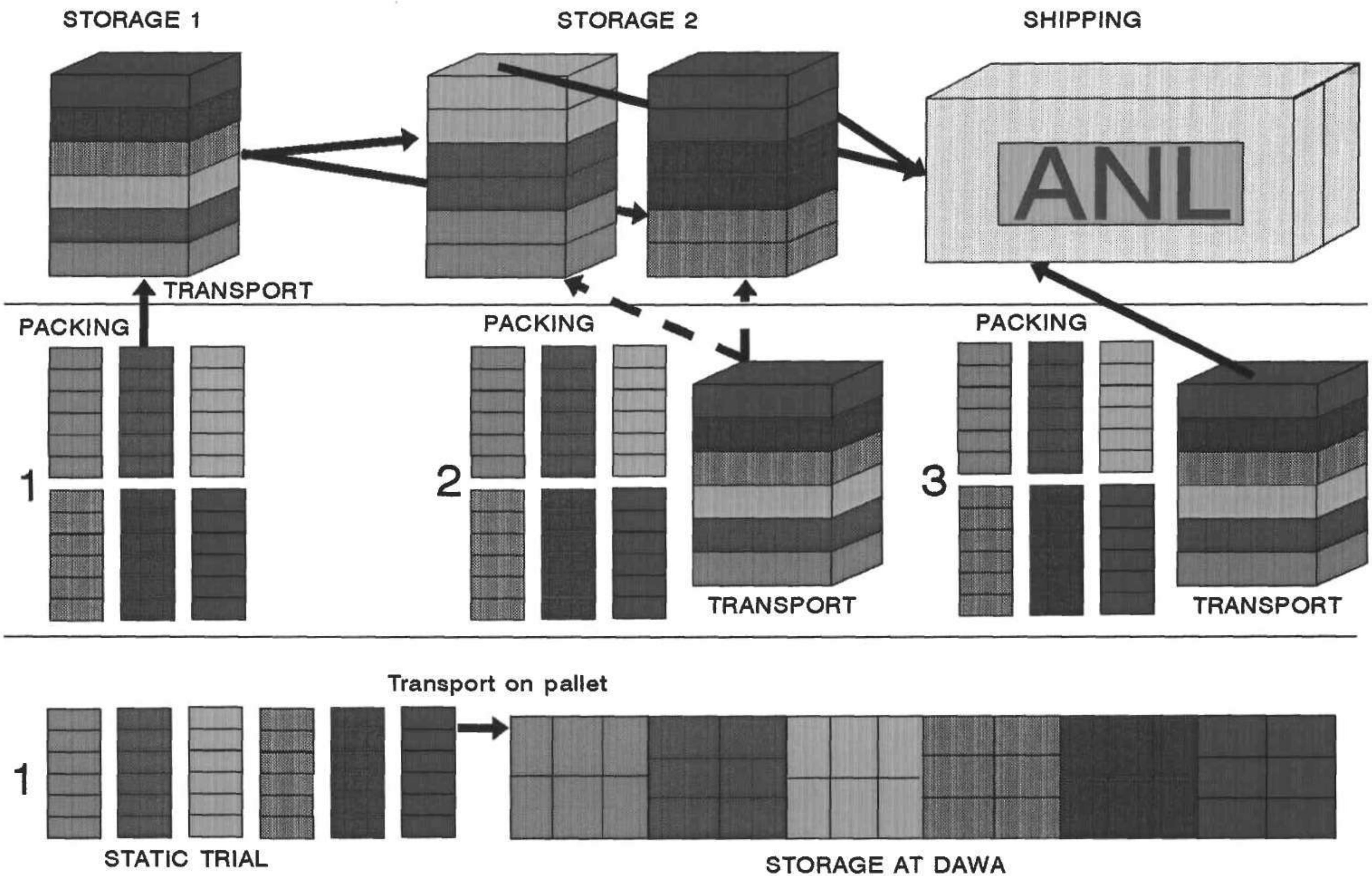

Figure 8: Overview of shipping and static trial.

3. RESULTS AND DISCUSSION

1. Temperatures and humidity

The produce was pressure-cooled at M-Veg's and held at temperatures of 0 - 2°C prior to packing. Table 3 shows that produce temperatures measured randomly before packing were 0 - 2.5°C. After packing, temperatures were between 0.6 and 2.7°C with most of them ≥ 2°C. Room temperatures during storage at Sumich's were -1.5 - 0°C, resulting in produce temperatures of 0.4 - 1.7°C.

In the static trial, room temperatures were between 0 and 2°C, resulting in produce temperatures of 0.7 - 2.1°C during the trial. In the static trial a higher cooling efficiency was to be expected as the trial cartons were set up on the coolroom floor and the room did not hold other produce.

Table 3: Produce and air temperatures (°C) at packing

DATE	AIR		PRODUCE		
	SHED	COOLROOM	COOLROOM	PREPACK	POSTPACK
15.6.	12.4-13.9	0.2-0.4	0.7-2.0	1.9-2.5	2.4-2.5
29.6.	8.5-8.7	1.0-1.5	0.8-0.9	1.4-2.4	2.3-2.5
12.7.	14.0	-1.5--1	-1.5-1.2	0.0-2.0	0.6-2.7

The shipping container was stowed at an ambient temperature of 8°C. During the 4 hours of weighing and loading the recorded warming of produce was < 1°C.

The data, for container and produce temperatures, and relative humidities during shipping, are shown and discussed in detail in a separate report (CSIRO, Division of Food Processing).

Prior to opening the container in Singapore, the supply air temperature was -0.1°C, the return air was 13.3°C with the vent set at an air circulation of 15 m^3/h and the container on a defrost cycle. The temperature inside the container was 2.4°C; the ambient temperature was 29°C. After closing the vent the return air temperature came down to 2.9°C within 20 minutes.

At unloading temperatures of individual heads measured with the hand held thermometer varied between 0.9 and 4.1°C. Table 4 shows the frequency of temperature ranges as measured during unloading.

Table 4: Frequency of temperature ranges as measured on 2 individual cauliflowers per experimental carton.

TEMPERATURE °C	FREQUENCY (TOTAL)	FREQUENCY (%)
≤ 1.4	3	1.4
1.5 - 2.0	40	18.8
2.1 - 2.5	83	39.0
2.6 - 3.0	58	27.2
3.1 - 3.5	21	9.9
≥ 3.6	8	3.7

The temperature difference between 2 individual heads out of the same carton was up to 1.5°C.

However, 60.4% of the differences within one carton were between 0 and 0.2°C, 84% were between 0 and 0.5°C.

Figure 9 shows mean produce temperatures as influenced by packaging treatments. The paper wrapped cauliflowers had significantly lower temperatures than in all other types of packaging, except for treatment F (individual bags) from harvest III. The temperatures of paper wrapped heads inside MAP liners (E) were always lower than those of unwrapped heads under MAP (C,D). Even the high humidity liners (B) kept the produce cooler than the MAP liners. It cannot be explained why the MAP liners C and D affected produce temperatures differently for all 3 harvests. The difference in produce temperatures cannot be due to differences in respiratory heat production by the cauliflower, because modified atmospheres have been shown to decrease respiration rates and thus heat production. It seems, however, that the type of packaging has an influence on heat transport away from the produce, e.g. evaporative cooling or convection and thus on cooling efficiency of the refrigeration system.

Figure 10 shows the distribution of mean produce temperatures per carton throughout the experimental load in the container. Even though temperatures varied due to precooling, storage and packaging order, higher temperatures occurred more often near the refrigeration unit and the left hand side of the container. These findings were confirmed by the thermocouple readings which are discussed in detail in a separate report (CSIRO, Division of Food Processing).

Given an optimum temperature control during holding and shipment, final produce temperatures will be determined by temperatures that are achieved through pre-cooling. One problem of the pre-cooling and packaging procedures is that the produce that arrives last in

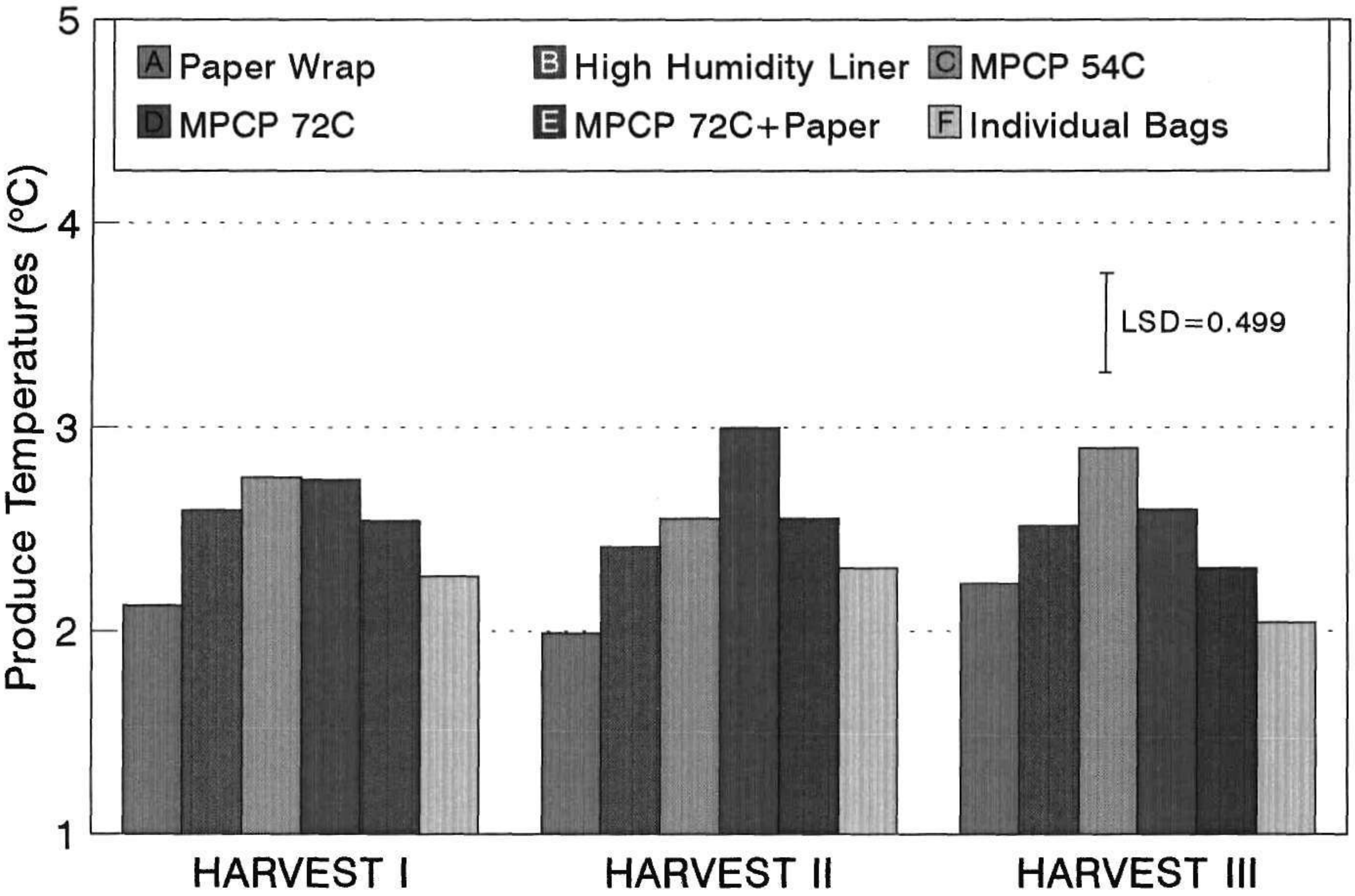

Figure 9: Mean produce temperatures as influenced by harvest and packaging treatment.

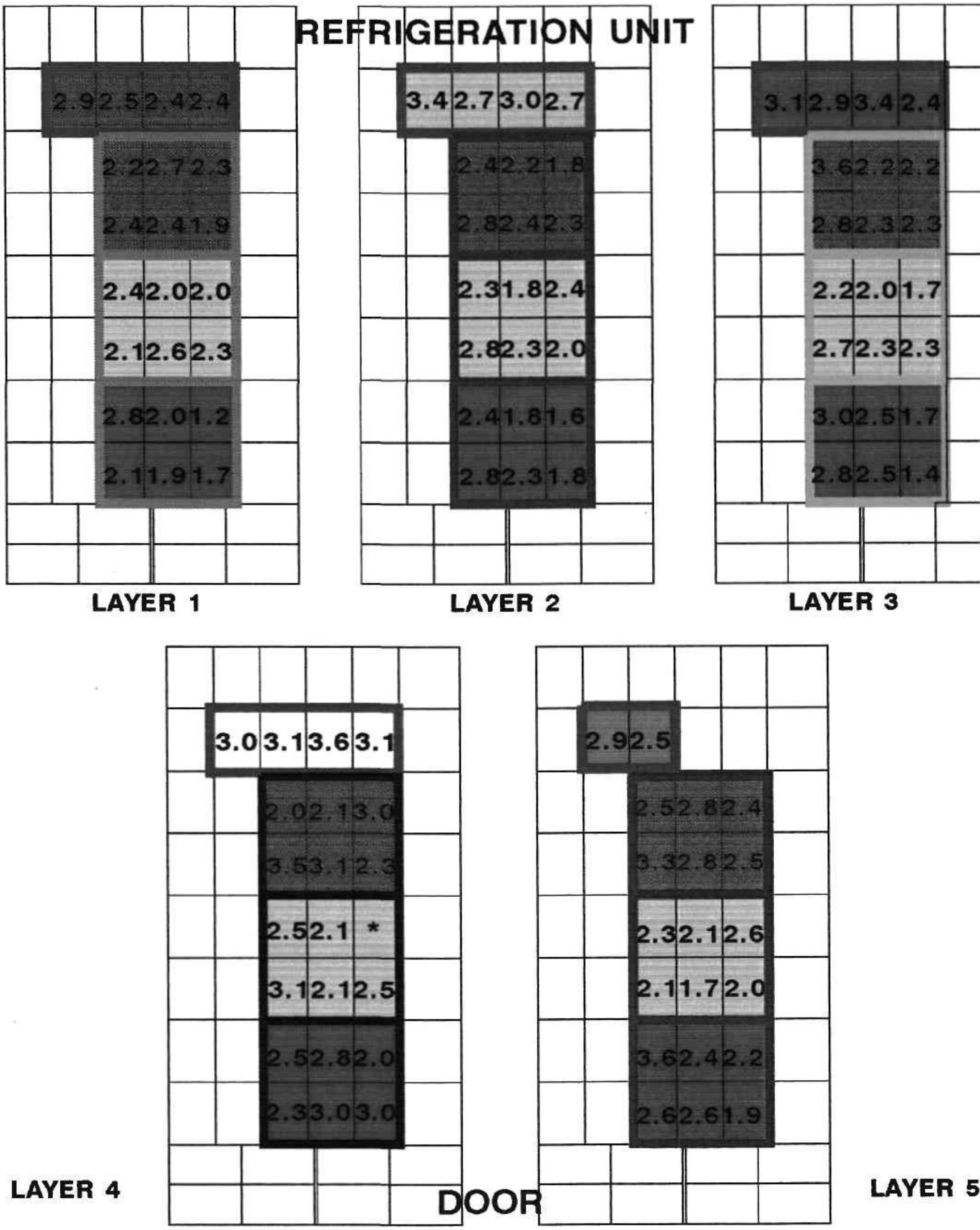

Figure 10: Temperature distribution throughout the stow of experimental cartons at unloading. Mean values for 2 heads per carton.

the pressure cooler is the furthest away from the fans and is removed first for packaging. This can cause a temperature spread in a container load. If produce is stored on pallets prior to shipment, the position of pallets in the coolstore in relation to the refrigeration unit and other stored produce can also affect produce temperatures. However, in this trial pre-cooling and storage effects were not monitored closely enough to assess the influence of these factors on outturn temperatures.

The uneven temperature distribution in the container would have made the interpretation of pre-cooling and storage effects difficult.

3.2. Atmospheres

The MAP carton liners were designed to achieve MAP benefits at air temperatures between 0 and 2°C and still allow for periods of elevated temperatures without causing high carbon dioxide or low oxygen damage to the cauliflower. The liners allowed for 7 days at 10°C including up to 8 hours at 29°C. They were, however, not designed to make up for the effect of elevated temperatures on produce quality.

In the static trial, atmosphere modification at a coolroom temperature of 1°C was:

B: 4-2% carbon dioxide - 18-19% oxygen in the high humidity liner

C: 8-7% carbon dioxide - 11-13% oxygen in the MAP liner MPCP 54C

D: 7-6% carbon dioxide - 14-15% oxygen in the MAP liner MPCP 72C

E: 8-6% carbon dioxide - 14% oxygen in liner MPCP 72C + paper wraps

Within the ranges of gas concentrations the first numbers give mean concentrations at the start, the last mean concentrations at the end of the trial.

The atmosphere data (fig.11) show that the technical performance of the liners was as expected from results of previous trials. The high humidity liner (B) modified the atmospheres slightly. None of the produce was in danger of going anaerobic, even during 8-10 hours at ambient temperatures (30°C). This can be concluded from the results of previous investigations (ICI confidential research) where oxygen levels in liners with an initial O_2 concentration of 9.5% did not drop below 2% during 8h at 28-30°C. The MPCP 72 carton liner produced slightly higher carbon dioxide levels when the produce was wrapped in paper. This confirms results from previous static trials where carbon dioxide levels were 1-2% higher and oxygen levels 1-2% lower for paper wrapped produce inside liners than for "naked" produce inside identical liners (ICI, confidential research). These results suggest that gas movement through the film might be slightly inhibited at contact areas between paper and film.

As the holding temperatures for the static trial were slightly higher than the holding room temperatures at Sumich's resulting in higher produce temperatures, the carbon dioxide levels would have been slightly lower and oxygen levels would have been slightly higher during storage of the shipping trial produce. During shipment, temperatures were similar or slightly higher than in the static trial.

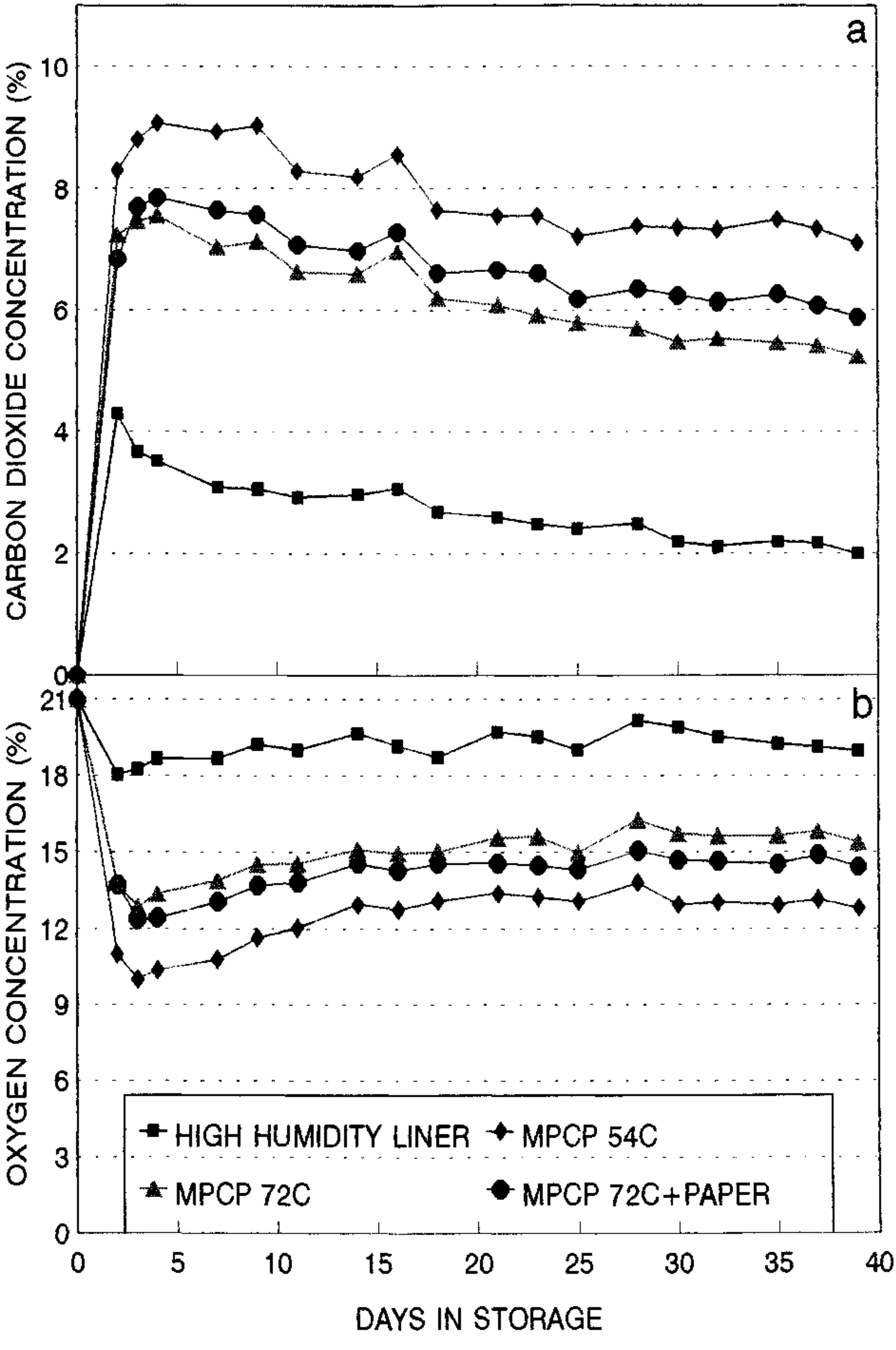

Figure 11: Development of carbon dioxide (a) and oxygen (b) concentrations inside sealed liners (static trial).

3. Produce weights and quality

3.1. Weights

The weight loss of produce plus cartons after shipment and after storage are shown in Figures 12 and 13. From the weight loss data it could be calculated that paper wrapped produce (treatment A) from harvest I lost 800-900g per carton, the loss was 600-700g from harvest II and 300-500g from harvest III cartons. For a shipping container of 400 cartons this would cause losses of around 120 -320 kg for produce 17-32 days old. Most of the weight loss occurs during shipment. The water loss of produce in high humidity and MAP carton liners with "naked" cauliflower (treatments B - D) was < 0.5%. The produce in the individual bags (treatment F) and in paper wraps inside a MAP liner (treatment E) lost up to 1.5% (ca 250 g per carton). These slightly higher losses were due to the rather big holes in the individual bags, and could be explained by paper acting like a wick when contact with the MAP film in the liners with paper wrapped produce.

The total weights of cartons from harvest I and II, treatments B - F, increased by 0.6 - 1.2% (150 - 400g) between packaging and unloading, because the fibreboard cartons absorb moisture, especially while they are in the shipping container. The weight data from harvest III show that the cauliflower in treatments B - F will have lost about 100 - 250g per carton, indicating that the total water uptake by the cartons can be between 250 and 650g.

The weight loss data from the static trial (Fig.14) has to be compared to the data from harvest I. In the static trial the cartons were spread on the coolroom floor. Therefore the paper wrapped cauliflower lost more weight than in the container, whereas the cartons did not gain much weight. Again all carton liners prevented excessive weight loss.

3.2. Quality

The initial produce quality was rated 'poor' for harvest I and 'good' for harvest II and III.

Rot ratings: Very small spots of bacterial soft rot were found at unloading on a few heads from treatments B-F from all harvest dates. The incidence was lowest in produce from harvest III. Paper wrapped produce never showed any rots (fig.15). The incidence of rots is related to initial produce quality, temperature management and produce age. Produce in plastic packaging is more conducive to microbial infections as the plastic wrap produces a high humidity environment around the produce. Microbial growth is positively correlated to relative humidities > 85%. Modified atmospheres with carbon dioxide levels >12% have been shown to control fungal and bacterial infections. However, in this trial, carbon dioxide levels have not exceeded 8% so that insufficient rot control was achieved in the MAP treatments. In the static trial, the incidence of rots was generally higher (Fig.16). The results indicate that all treatments that kept the cauliflower relatively drier than it was in plain plastic liners have a positive influence by reducing the incidence of rots. The higher incidence of rots in the static trial could have been caused by a combination of several factors: heavy condensation

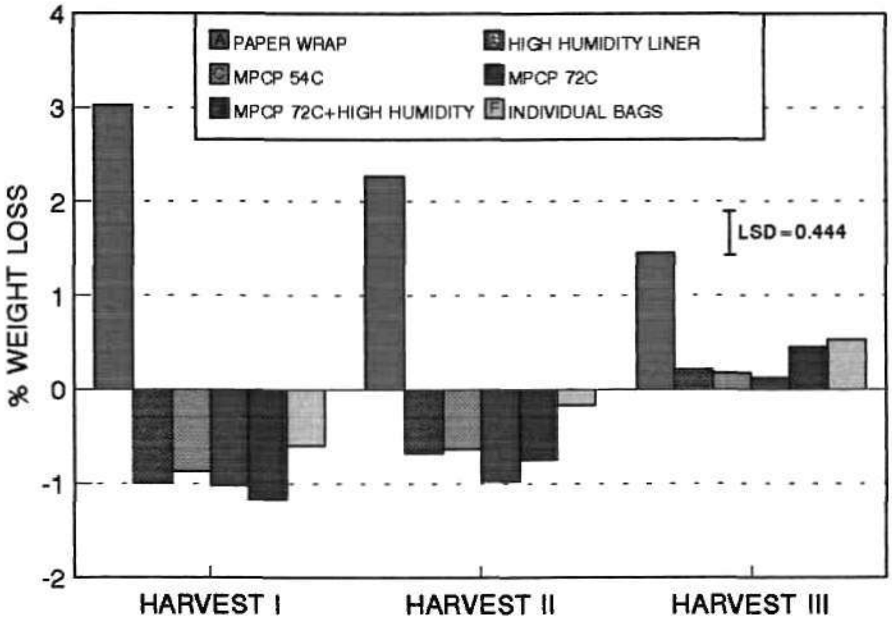

Figure 12: Weight loss of produce and cartons after shipment.

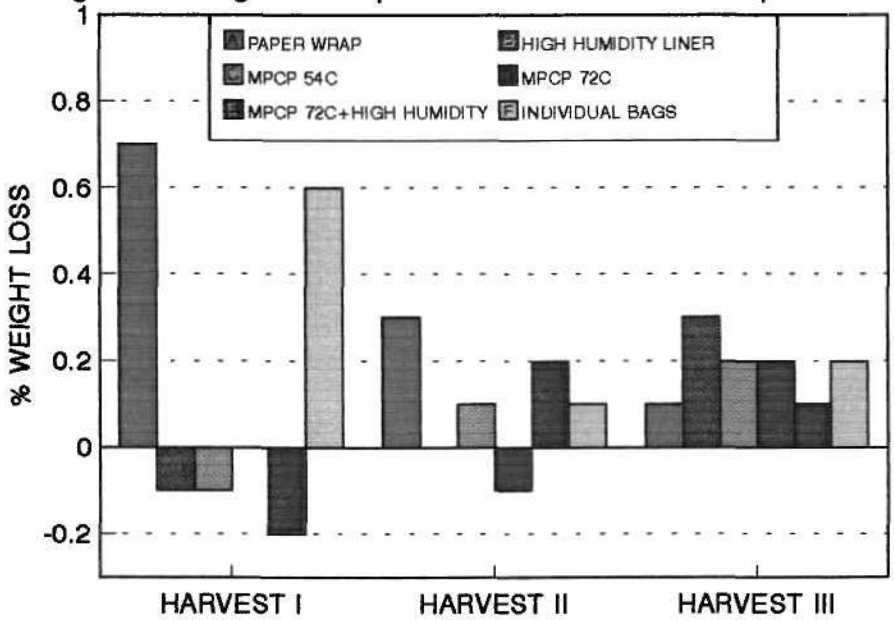

Figure 13: Weight loss of produce and cartons after storage before shipment.

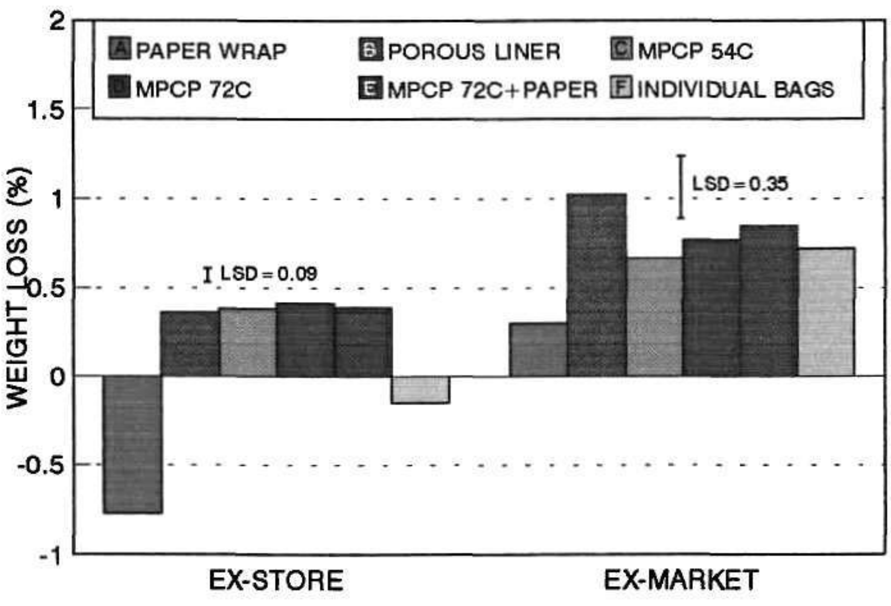

Figure 14: Weight loss of produce from harvest I after simulated storage (ex-store) and shipment and after simluated marketing (ex-market) - static trial.

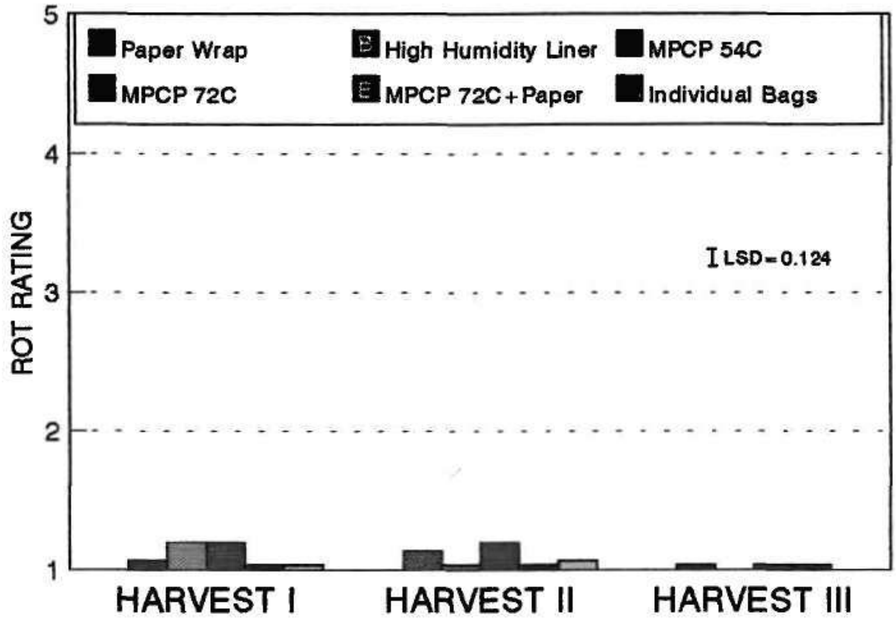

Figure 15: Rot ratings after shipment.

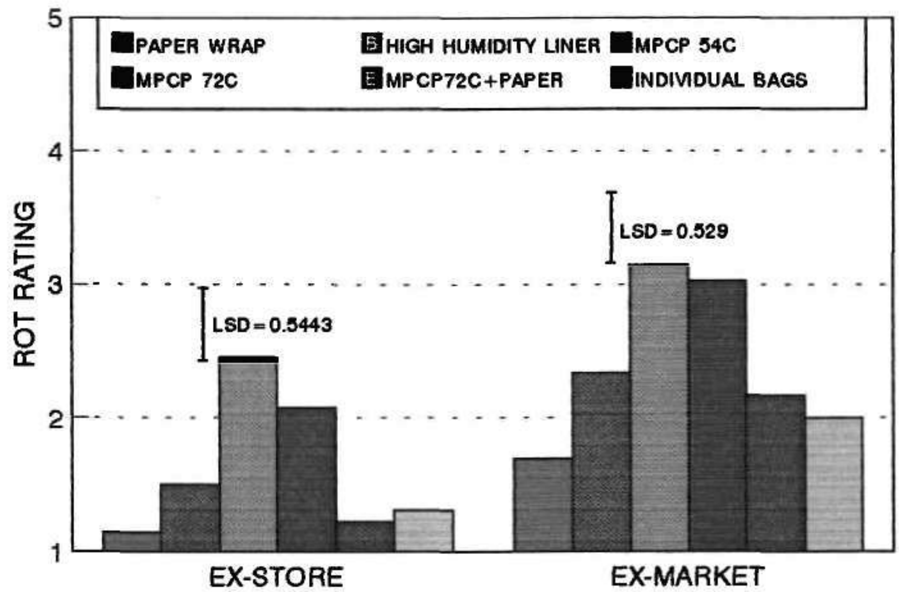

Figure 16: Rot ratings after storage (simulated shipment, ex-store) and simulated marketing (ex-market) - static trial.

due to temperature fluctuation as the produce was transported from the Sumich holding rooms to the W.A. Department, mechanical damage during unloading at the Department and higher holding temperatures than at Sumich's.

Yellow, brown and black spots: The cauliflower from harvest III showed some yellow discolourations of pressure points and minor bruises. Spots of this nature showed up slightly more severe on individually paper and plastic wrapped heads followed by high humidity liners (Fig.17).

On some produce from harvest II (treatments A, B, D and F), these discolourations appeared darker (brownish-yellow) than on the younger produce (harvest III), resulting in higher 'spot ratings' (Fig.17). Ratings for treatments C and E were the lowest within harvest II. This harvest had lower scores (less spots) than the younger cauliflower (harvest III) in treatments A, B and F and was not different from treatments C and E. This result indicates that the atmosphere modification slows down physiological processes (phenolic browning) that lead to the expression of yellow/brown spots at pressure points.

On produce from harvest I, most of the bruises and pressure points had turned dark brown to black. Some of this oldest cauliflower was also sprinkled with small black spots, 1-3 mm in diameter. Similar spots had been observed in earlier trials where no pathogens could be isolated from the spots. They seem to be the result of a senescent breakdown of cell groups. Treatment E (MCPC 72C+paper) had the lowest score, closely followed by A (paper), C (MPCP 54C) and D (MPCP 72C). The high humidity carton liner (B) had by far the highest rating, followed by the individual bag (F).

The results from harvest I, show that with prolonged storage time and/or poor initial produce quality the modified atmosphere treatments did not reduce the expression of black spots compared to the traditional paper wrap. However, if a high humidity environment is provided through the use of plastic liners (B, C, D and E) or individual bags (F), the modified atmosphere leads to less black spots than ambient gas concentrations (C,D and E vs B). In the oldest cauliflower, the high humidity liners B (sealed bags with small perforations), produced more black spots than the individual bags (non-sealed, 12 big holes per bag). There was no difference between treatments B (high humidity liner) and F (individual bags) from harvests I and II. This may be because that cauliflower was of better quality or was stored for less time.

Unfortunately, it cannot be judged from the data how much influence poor initial quality had on the development of black spots on the older cauliflower.

The spot ratings from the static trial (Fig.18), were generally higher. Here the individual bags had the lowest score, followed by the paper wrapped cauliflower in MAP liners. These scores were still higher than the comparable ones from the shipment. The spots got worse during simulated marketing. The higher ratings for the static trial are difficult to explain. The same factors that caused differences in rot ratings may have had an influence on spot development.

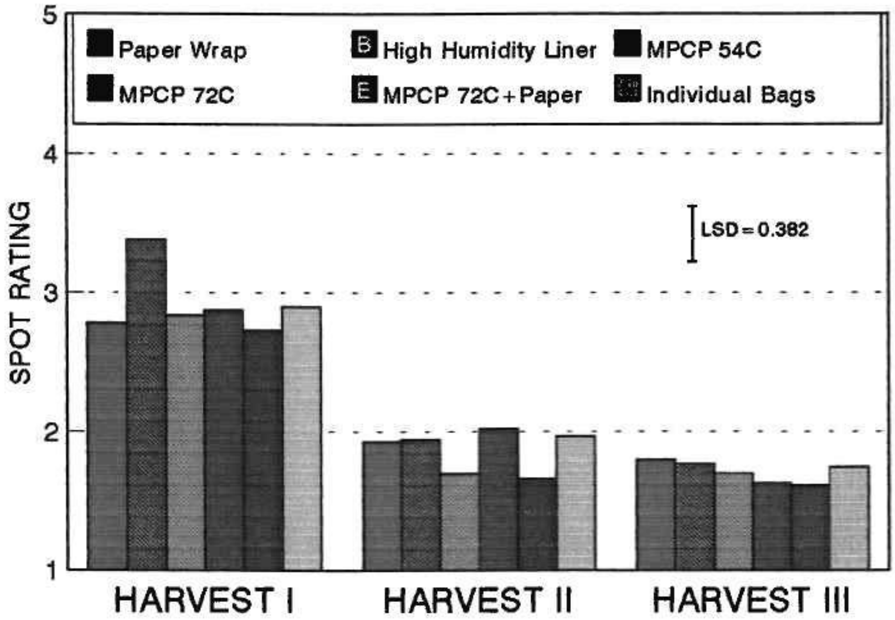

Figure 17: Spot ratings after shipment.

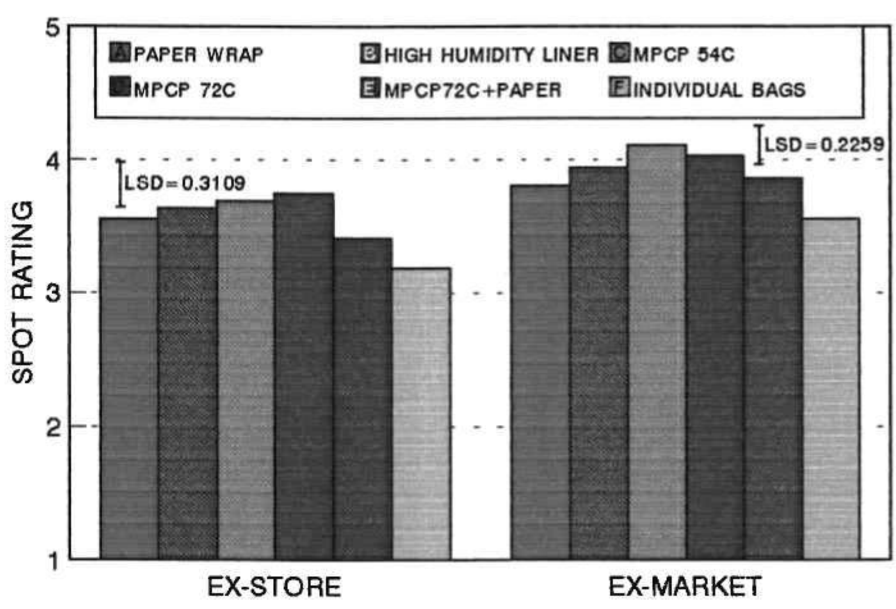

Figure 18: Spot ratings after storage (simulated shipment, ex-store) and simulated marketing (ex-market) - static trial.

Stem colour: Except from treatment C at harvest III, stem colour did not benefit from MAP treatments (Fig.19). Especially in harvest I, but also in harvest II and III the individual bags had a positive effect on stem colour. In the static trial the paper wrapped cauliflower with and without MAP liner had the best stem colour after storage (Fig.20). After simulated marketing, stem colour of treatment E was the worst. Ratings were generally lower than for the shipped produce.

Leaf colour: The results for leaf quality ratings are not consistent throughout the 3 harvests (Fig.21). This might be because the number and size of leaves left on the heads varied within and between harvests. Most of the cauliflowers had only 2-3 very small leaves left. Due to dehydration leaves from paper wrapped heads (A) of harvest I were the worst quality. Only for the youngest cauliflower (harvest III), did treatments F,C and D (individual bags, MAP liners) have a positive effect on leaf quality. To better assess the influence of packaging on leaf quality, cauliflowers with 4-5 wrapper leaves should be tested. It could not be done in this trial because the Singapore market demands trimmed cauliflower. Leaf colour was not assessed in the static trial.

Market quality: All produce from harvest III had overall market quality ratings of ≤ 2 (1 = excellent, 2 = good). From harvest II, treatment E (paper + MPCP 72C) was rated 2. All other treatments scored slightly higher (2.1 - 2.2; Fig.22). The 28 day old paper wrapped produce with MAP liner (E, harvest II) was rated the same as the 14 day old paper wrapped cauliflower without liner (A, harvest III).

The oldest cauliflower (all treatments, harvest I) scored above 3, which was mainly due to the expression of black spots, especially on the underside of the curds. Produce from treatment A was slightly dehydrated and thus less firm than cauliflower from the other treatments.

Even though the cauliflower was harvested at equal intervals, the quality difference between harvest II and I is much bigger than the difference between harvest III and II. Given a linear produce deterioration with time, most produce from harvest I should have been rated between 2.1 and 2.4. However, the actual ratings were between 3.1 and 3.6. These are still higher scores than could be expected even assuming that quality loss is non linear. Thus the high scores for harvest I are probably due to the poor initial produce quality. In general, treatment differences seem to become more pronounced with time as can be seen from the wider spread of scores within one harvest (score range for harvest III: 1.9 - 2.0, harvest II: 2 - 2.2, harvest I: 3.1 - 3.6).

The market quality ratings from the static trial (fig.23) were higher than from the shipping trial. This had to be expected as the overall quality is correlated to the incidence of spots and rots.

Treatments E (paper wraps + MPCP 72C) and F (individual bags) were the best ex-store. The high humidity and MAP liners were rated worse than the paper wrapped cauliflower, even though the later had lost considerably more water.

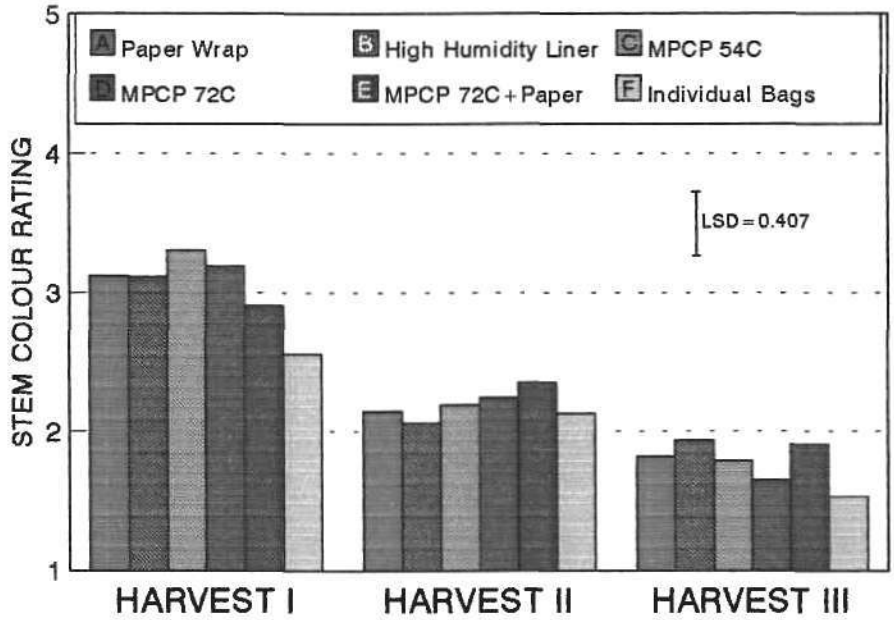

Figure 19: Stem surface colour ratings after shipment.

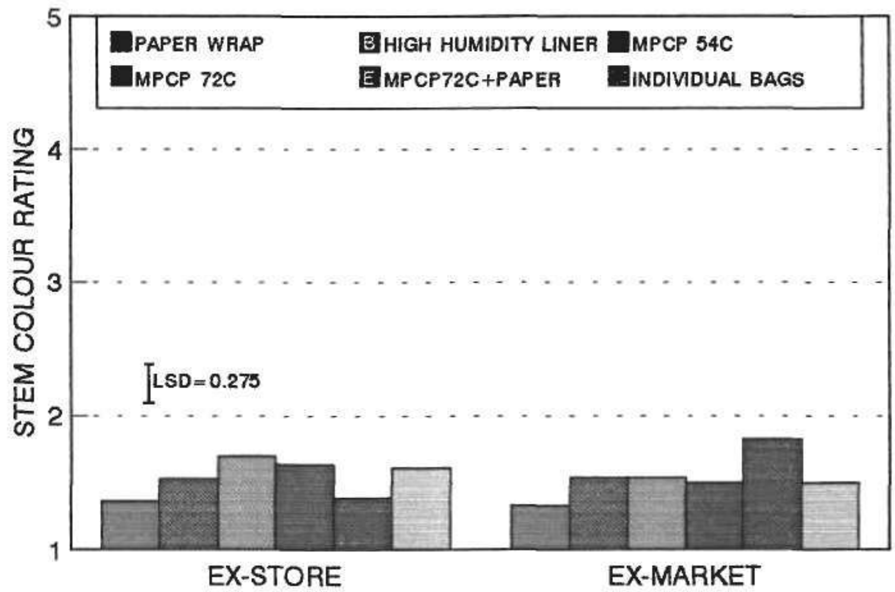

Figure 20: Stem surface coulour ratings after storage (simulated shipment, ex-store) and simulated marketing (ex-market) - static trial.

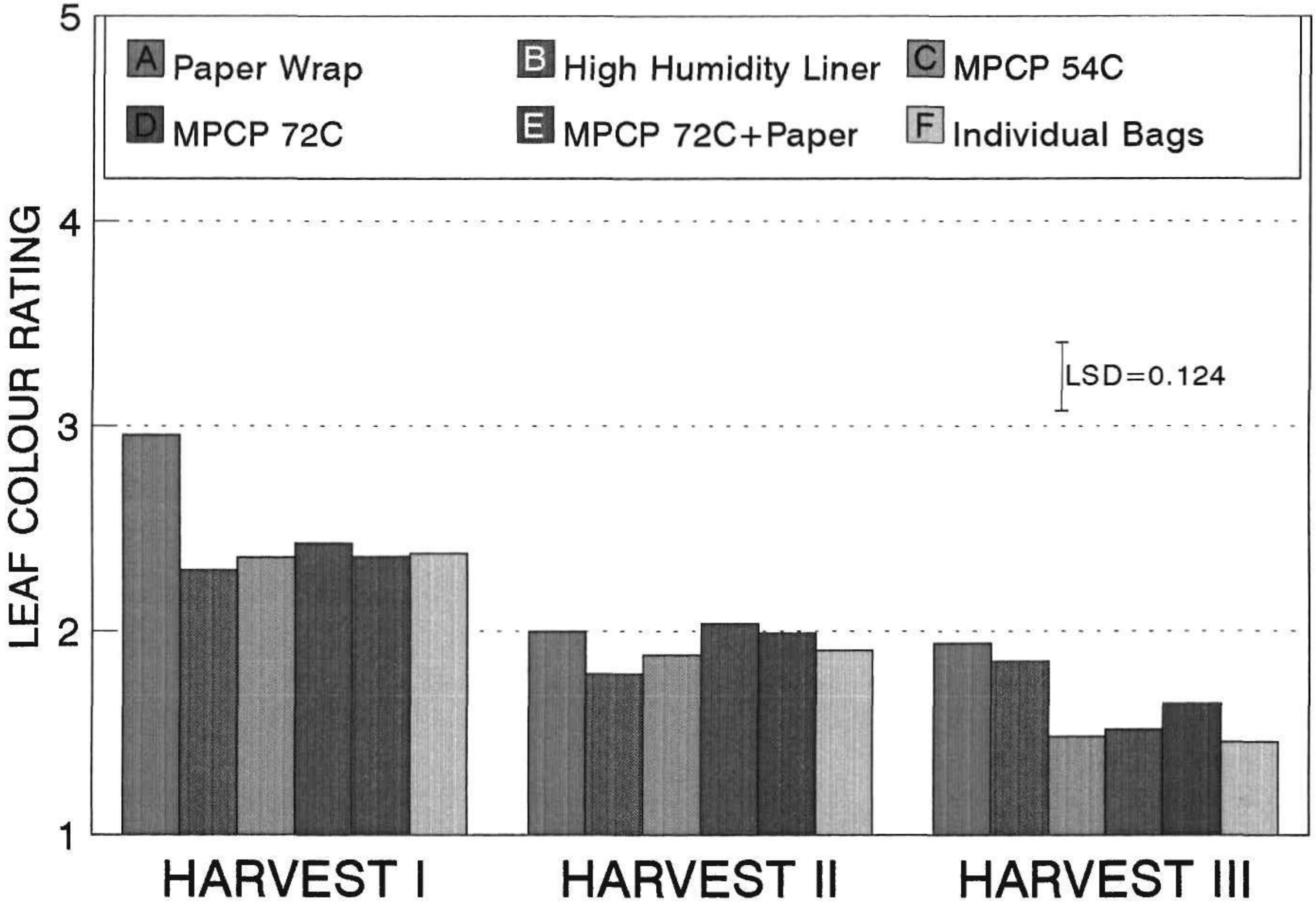

Figure 21: Leaf colour ratings after shipment.

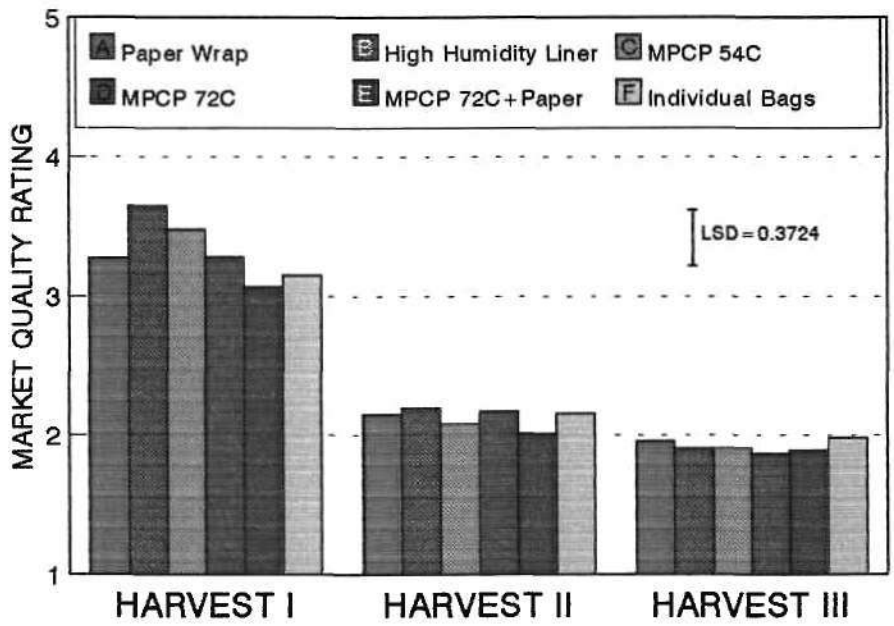

Figure 22: Market quality ratings after shipment.

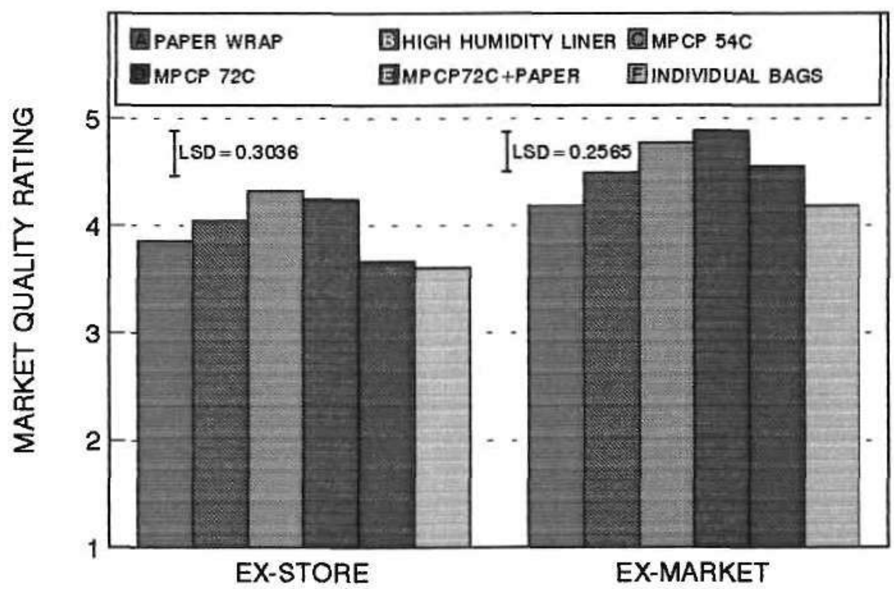

Figure 23: Market quality ratings after storage (simulated shipment, ex-store) and simulated marketing (ex-market) - static trial.

3.4. Performance of packing material

As shown under 3.1. some of the trial **cartons** in the container absorbed substantial amounts of water. However, this did not seem to have a detrimental effect on carton strength. Some of the well-filled cartons lost their shape but none of them collapsed. Most of the water in the cartons must have been lost by the paper wrapped produce in the container. Some moisture also will have entered the container through the vent. Carton liners and individual bags can prevent water movement from the produce into the carton.

The size of the trial under commercial conditions made it impractical to weigh packaging materials and produce separately at all stages of the trial. However, the weight data shown above indicate that water losses from produce and water uptake of cartons under commercial conditions should be further investigated.

The **paper wraps** were clean and intact but appeared to be moist. There was no difference in their appearance between treatment A and E (paper wraps inside MAP liners).

All **carton liners**, except one bag, were well sealed. The ties had to be cut to break the seal. None of the liners had holes or tears. There was no free water found on the bottom of any of the liners.

Some of the **individual bags** showed condensation water.

According to the packers, plain carton liners (treatments B-D) took the shortest time to pack, followed by; the paper wrapped cauliflower, the paper wrapped produce inside liners, and lastly the individual bags. The packaging time for individual bags could be reduced by increasing the size of the bags.

3.5. Market acceptance

All produce was sold by the 27.07.92. The cauliflower from harvest I was sold at a reduced price because of the black spots.

The importers comment concerning the packaging treatments was that he prefers to receive cauliflower in paper wraps as they cover the produce in a carton while 1 or 2 heads can be displayed to a customer. The criticism of the carton liner was that nearly all of the produce in a carton could be seen at the first sight and thus minor blemishes would be detected more easily. Carton liners would be acceptable if the produce was still wrapped in paper. Replacing the paper wraps with individual bags seemed to be another acceptable option to the importer. One of the requirements here was that the print on the bag shall not cover too much of the surface of the bag so that the produce could be seen.

It must be noted that these comments were made by one importer in one market place. The Singapore market is known to be fairly conservative.

As the trial produce from all 3 harvests went to the market and all produce from harvest I (1/3 of the trial) had some 'black spot', every third carton was of moderate to poor market quality. This had an influence on the importers general perception of the "new packaging" and supported his critical view.

To point out the lower quality 'spotty produce' to the exporter the importer actually inspected more of the older produce (harvest I) than that from other harvests. This led to the opinion that even the youngest trial cauliflower (harvest III) generally was of lower quality than the normal consignment (301 cartons of paper wrapped produce). However, the trial cauliflower from harvest III and the produce from the other 301 cartons was harvested, cooled, packed and shipped the same day. Therefore the quality of the 'normal consignment' was the same as that of the paper wrapped produce from harvest III. The assessment data show that this paper wrapped cauliflower was the same or worse than the produce from the other treatments of harvest III. It was noted that the produce from the 301 "normal" cartons was accepted with minimum inspection.

4. CONCLUSIONS AND RECOMMENDATIONS

1. Cool storage prior to shipment from W.A. to Singapore

The 42 days old produce did not have a satisfactory quality at unloading in Singapore. It was, however, of relatively poor initial quality. Conversely, the 28 day old produce in paper wraps plus MPCP 72C liners that had been stored for 14 days was of equal quality to the fresh cauliflower. Given only 1 day between harvest and packing and 8 days between container stowage and arrival at the market, a 20 day storage period in MPCP liners plus paper wrap is currently possible without quality loss compared with immediate shipment in traditional packaging. A further extension of the storage period may be achieved by using liners that provide a greater atmosphere modification (e.g. MPCP 36C). These liners would not allow for a loss of temperature control (temperatures increasing > 25°C) for more than 6 hours. After that period the produce would have to be cooled again or the liners would have to be opened to avoid anaerobic conditions (=lack of oxygen).

2. Market acceptance

At this stage the importer (= market ?) in Singapore would not accept non-paper wrapped cauliflower. A carton liner with paper wrapped cauliflower seems to be acceptable. The importer was also willing to try individual plastic bags. A new packaging design could certainly be introduced more easily to a market place, if the importer and his customers would see any advantages for themselves.

3. Optimum packaging for commercial use and further improvement of packaging design

Most of the yellow and brown spots on the cauliflowers were due to pressure on contact areas between individual heads and also contact of curds with packaging material. In most cases the underside of the curds was more severely affected, especially on older produce. With every care being taken during harvest and packaging the mechanical impact on individual heads can be reduced through: i) the use of single layer cartons, ii) assurance that the produce never has to take the weight of cartons stacked on top (sufficient carton height, column stacking on pallets and in the container, no side stow), iii) leaving 4-5 'wrapper leaves' on each head for protection. It would be of advantage if the paper wrap could be replaced by 'wrapper leaves'. However, the leaves would not act as a moisture buffer inside plastic liners.

4. Temperature and quality management procedures

Current quality management procedures at the packing shed and temperature management during storage were above average. An improved packaging concept (single layer cartons, MAP with greater atmosphere modification) has the potential to further improve outturn quality.

Besides reducing mechanical damage on the produce, column stacking and no side stow in the container will improve airflow and in-transit cooling. Pre-cooling times and temperatures as well as rewarming during packaging and transport will have a major influence on outturn quality. MAP with greater atmosphere modification can only be used with strict temperature control.

5. Export to more distant markets

A very good initial produce quality, an improved packaging design (greater atmosphere modification, less mechanical impact) and an excellent temperature management at all stages (e.g. improved container stowage) will be essential to successfully ship cauliflower to more distant markets.

6. Comparison of seafreight and static trial

In this investigation the results from the static and seafreight trial were not directly comparable. The static trial generally had a worse quality. To be able to draw conclusions from static trials the handling, stowage and temperature management has to be simulated as closely as possible to a commercial situation. In these trials the commercial situation provided a better temperature regime than the simulation. In lots of cases the reverse can be expected.

5. ACKNOWLEDGMENTS

This project greatly benefited from the results of a previous HRDC project on MAP of cauliflower, initiated by Mr Bruce Tomkins, M-Veg and Sumich. It could not have been successful without the research and technical inputs from ICI Films, Australia. ANL's commitment to the project and its organisation of shipping and unloading in Singapore was a major contribution to the success of the trial.

I want to thank Ms Christine Cooper, Mr Peter Franz, Dr SC Tan, Ms Yvonne Haynes, Mr Denis Davis and all of the M-veg staff for their efforts and hands on work.