Development of an avocado rapid library tray system for Hass

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Department of Employment, Economic Development & Innovation

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Development of an avocado rapid library tray system for Hass and Shepard

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Purpose:

The *Avocado library tray project* was an initiative of Agri-Science Queensland, Simpsons Farms Ltd, CostaExchange and Horticulture Australia Ltd. The aim of this eighteen month project was to develop a library tray system for 'Hass' and 'Shepard' avocados that accurately reflected commercial reality.

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MEDIA SUMMARY

The Australian avocado industry currently produces 49,500 tonnes of fruit annually worth AU$180M at farm gate and AU$420M at retail level. The industry is growing by 8% per year. In order to accommodate the escalating fruit production, consumption of avocado in Australia will have to increase and/or alternative markets will have to be sought. Consumer surveys have shown that avocado fruit sales continues to be seriously hindered by variable and poor fruit quality. Consumers have indicated that they would be more inclined to purchase avocados if the quality was guarantied.

Library tray systems are used in many fruit industries throughout the world to monitor fruit quality through the cold chain. These systems are most commonly used for export lines and involve long cold storage periods mimicking commercial reality. Since the Australian avocado industry is domestic market based and the cold chain is highly variable, a simple rapid ripening regime was developed which accurately reflects commercial out-turn fruit quality.

The system, developed for both Hass and Shepard fruit, produces fruit quality results within seven days of fruit sampling. Fruit marketability is based on internal fruit quality since consumers have identified this as the most important repeat sales criteria. Fruit rots and vascular browning are the main parameters used.

The library tray system developed is unique in that not only can it serve as an insurance policy against poor out-turn quality and provide growers with much needed fruit quality feedback, it can also be used to feed information forward to marketers and retailers. If marketers act upon the information received, the library tray system has the potential to significantly improve retail fruit quality almost immediately. As adoption of the system increases an corresponding increase in fruit quality should be observable on the retail shelf. This will boost consumer confidence and increase product sales. Growers acting upon feedback generated by the library tray system will result in improved fruit quality entering the cold chian which will further contribute towards improve the overall quality of fruit reaching the consumer.

Commercialization of the system will require further research in order to develop the logistics necessary for its incorporation into existing commercial packing and cold chain operations. Standardization of the program will be essential. If wide scale adoption is successful it would need to be managed on an industry wide bases similar to the existing AAL infocado system.

Over time, information gained from the library tray system can be used to identify the main causes of fruit deterioration in the industry and to direct future research and development investments. Utilization of the library tray system would be of great benefit to all stakeholders in the industry and would be a powerful tool not only for expansion of existing markets but also to penetrate new domestic and export markets.

TECHNICAL SUMMARY

The Australian avocado industry currently produces 49,500 tonnes of fruit annually worth AU$180M at farm gate and AU$420M at retail level. The industry is growing by 8% per year. In order to accommodate the escalating fruit production, consumption of avocado in Australia will have to increase and/or alternative markets will have to be sought. Consumer surveys have shown that avocado fruit sales continues to be seriously hindered by variable and poor fruit quality. Consumers have indicated that they would be more inclined to purchase avocados if the quality was guaranteed.

Library tray systems are used in many fruit industries throughout the world to monitor fruit quality through the cold chain. The systems are usually implemented as a form of insurance to counteract poor out-turn quality claims and to provide suppliers (growers) with much needed fruit quality feedback. These systems are most commonly used for export lines and the library tray storage regime usually mimic commercial reality.

The Australian avocado industry is domestic market based and its cold chain is highly variable. Simulating commercial cold chain conditions for a library tray storage system involves too many temperature fluctuations to be viable. Therefore, a simple single regime storage system, 22°C with 10 parts per million of ethylene, was developed that produced fruit quality which reflected commercial reality with reasonable accuracy.

The system was developed for both Hass and Shepard fruit and produced fruit quality results within seven days of fruit sampling. Emphasis was placed on internal fruit quality since consumers have identified this as the most important repeat sales criteria. Fruit marketability was based on the severity of fruit rots and vascular browning. Market tolerance to fruit quality problems varies depending on price and market supply.

Therefore, three categories of fruit quality was used; clean fruit (0% defects), fruit with up to 5% defects and those with up to 10% defects. Fruit with more than 10% defect were regarded as unmarketable. Although significant correlations were found between the quality of the fruit in the library tray and commercial simulation in all three fruit quality categories, on average the strongest correlations existed at the 0% defect level (r^2=0.3-0.9 for Hass and r^2=0.3-0.8 for Shepard). Furthermore 0% defect is the simplest and easiest category to utilize and will hopefully encourage industry adoption.

The library tray system developed is unique in that not only can it serve as an insurance policy against poor out-turn quality and provide growers with fruit quality feedback, it can also be used to feed information forward to marketers and retailers. If marketers utilize the information obtained and act upon it, the library tray system has the potential to significantly improve retail fruit quality almost immediately. As adoption of the system increases an corresponding increase in fruit quality should be observable on the retail shelf. This will boost consumer confidence and increase product sales. Growers acting upon feedback generated by the library tray system will result in improved fruit quality entering the cold chian. This too will greatly improve the overall quality of fruit reaching the consumer.

The library tray system was developed as a privately funded project for two of the avocado industry market leaders. It is hoped that their adoption of the system will give them a significant marketing advantage and encourage others to adopt the library tray system also.

Commercialization of the system will require further research in order to develop the logistics necessary for its incorporation into existing commercial packing and cold chain operations. Systems may need to be tailor made to suit individual stakeholders. Standardization of the program will be essential. If wide scale adoption is successful it would need to be managed on an industry wide basis similar to the existing AAL infocado system.

Recommendations made for the commercial implementation of the system includes:

- One tray of fruit should be sampled from the end of the pack line per block/orchard per harvest.
- Fruit should be stored immediately after sampling, on site, at 22^{o}C with a constant supply of Ripegas, 10ppm of ethylene.
- The International Avocado Quality Manual (White et al. 2009) is to be used as the assessment standard.
- Internal fruit assessment should be done at eat ripe i.e. firmness stage 4 which is approximately seven days after fruit sampling.
- Digital photos should be taken of external fruit quality for each tray of fruit, and of the internal quality for the first five fruit cut.
- Although all fruit defects are noted in order to provide feedback to growers, parameters used to rate marketability are stem end rot, body rots and vascular browning.
- Use the category of 0% defect tolerance (i.e. no rots or vascular browning). This will simplify the process and eliminate human error.
- The acceptable percentage of fruit in a sample (5.5kg tray) with 0% defects (clean fruit) must be determined by the pack shed manager and marketers. For the purpose of this study a minimum of 60% clean fruit per sample is recommended but this may be altered depending on market tolerances.
- The fruit quality information should be captured on a data sheet, processed, and the information fed back to the growers and forward to marketers.

Over time, information gained from the library tray system can be used to identify the main causes of fruit deterioration in the industry and to direct future research and development investments. Utilization of the library tray system would be of great benefit to all stakeholders in the industry and would be a powerful tool not only for expansion of existing markets but also to penetrate new domestic and export markets.

INTRODUCTION

The Australian avocado industry currently produces 49,500 tonnes of fruit annually worth AU$180M at farm gate and AU$420M at retail level (Avocados Australia Limited 2011). The industry is growing by 8% per year (Avocados Australia Limited 2011) and is focused mainly on domestic consumption. Less than 2% of the total crop is exported. In order to accommodate the escalating fruit production, consumption of avocado in Australia will have to increase and/or alternative markets will have to be sought.

Due largely to the efforts of Avocado Australia Limited, local consumption of avocado has increased 106% over the past decade to 2.7 kg of avocado per capita (Avocados Australia Limited 2011). Despite this, consumer surveys have shown that avocado fruit sales continues to be seriously hindered by variable and poor fruit quality (Avocados Australia Limited 2011; Harker, F, Hofman & Stubbings 2007). Industry performance has to improve in three key areas, internal fruit quality, fruit maturity and ripeness (Avocados Australia Limited 2011).

Over the past decade the supply chain has been identified as a major source of fruit quality problems and considerable effort has been made to improve supply chain management and educating the stakeholders (Embry, J 2009a; Embry, J 2009b; Hofman, P & Ledger 2001; Hofman, P et al. 2001; Petty 2011). Despite ongoing efforts fruit quality has not improved significantly over the past decade (Embry, J 2007, 2009a; Hofman, P & Ledger 2001). A possible reason for this lack of quality improvement is that suppliers / growers receive virtually no feedback from the marketers and retailers regarding their out-turn fruit quality. Feedback is only given if quality is extremely poor and supply abundant. This is a common problem in many fruit industries around the world (Woolf et al. 2009).

Growers are often unaware of their fruit quality problems and therefore cannot act upon it. Fruit quality can never be improved through the cold chain and only deteriorate as the fruit ages (Cutting, J 2004; Dixon & Pak 2002). The fruit quality is at its peak at harvest and if growers were made aware of the intrinsic fruit quality, they would have an invaluable tool to either make informed marketing decisions and/or to ameliorate quality problems for future seasons. Over the past four years Avocado Australia Limited has been conducting monthly surveys of fruit quality at the major retailers in the Perth, Brisbane, Melbourne and Sydney (Petty 2011). The project aims not only to collect fruit quality information but also to educating retailers and marketers on improving fruit handling systems.

Library tray systems are used in many fruit industries throughout the world as a means of monitoring quality through the cold chain (Woolf et al. 2009). They are regarded in some industries as the corner stone to improving quality (Pak, Dixon & Cutting 2005). Originally purpose of the library tray systems was as a form of insurance to counteract poor out-turn quality claims (Wolstenholme 2003; Woolf et al. 2009). However, modern progressive industries have recognized the value of the system in its potential to provide growers and pack shed operators with much needed fruit quality feedback. The system can aid in tracing the cause of quality issues either to the cold chain, the pack shed or back to the orchard (Pak, Dixon & Cutting 2005). The New Zealand avocado industry places great value on the information feedback from their library tray system (Pak, Dixon & Cutting 2005). The information generated from such systems can be used to compare out-turn fruit quality between orchards, growers, seasons, etc. and also to gauge the efficiency and cost benefit of orchard management changes (Pak, Dixon & Cutting 2005). The system has the potential to become a valuable management tool for many industry stakeholders, suppliers, pack shed operators and marketers.

Several of the larger export focused fruit industries throughout the world utilize library tray systems, such as the avocado, kiwi fruit and cherry industries in New Zealand (Pak, Dixon & Cutting 2005; Woolf et al. 2009), the avocado, mango and citrus industries in South Africa (author's personal experience), the mango and avocado industries in Peru (Woolf et al. 2009), the Californian citrus and avocado industries (Woolf et al. 2009), etc. New Zealand regards its out-turn fruit quality monitoring and library tray system as significant industry strength (Cutting, J 2004). It serves to provide the New Zealand avocado industry with an overview of its out-turn fruit quality within and between seasons, and orchards (Pak, Dixon & Cutting 2005).

Most library tray systems have been developed for export lines where fruit are consigned under single cold storage regime for an extended period, often up to 30 days. The library tray storage regime usually mimic commercial reality and the fruit are removed from storage either after a fixed period or at the time corresponding with the arrival of the commercial shipment at its destination (Dixon & Pak 2002; Woolf et al. 2009). Since the Australian industry is domestic market focused with relatively short consignment times and highly variable storage conditions, mimicking commercial reality in a library tray system would be impractical. A single storage regime would be more appropriate. The Australian avocado industry has yet to develop such a system.

A rapid ripening fruit quality test, referred to as 'Avotest' was recently developed as part of the Avocado Robustness Project, AV07005 (Le Lagadec 2010). Avotest was able to predict out-turn fruit quality eight weeks prior to the commercial harvest with reasonable accuracy. However, the Avotest had its limitations. Since the fruit used in the test were not commercially harvested and packed the test could not reflect handling injuries caused during these processes. Also, the eight week laps between fruit sampling and the commercial harvest resulted in significant differences in fruit maturity and potential changes in orchard disease pressure, limiting the reliability of the test. Despite its limitations, the simplicity of Avotest renders it an attractive option for use in a library tray system.

The aim of the current project is to develop a simple fruit storage regime that can be used for avocado library trays and which results in fruit quality which accurately reflects commercial reality. The library tray storage regime must be:

- An accurate reflection of commercial reality (fruit quality)
- A constant temperature and ethylene (Ripegas) regime, to facilitate the process without having to alter the storage temperature and ethylene status, and to allow easy movement of fruit in and out of the system
- Easy to manage by partially skilled workers, to maximize commercial adoption
- Cost effective

- Offer the user a significant marketing advantage.

MATERIALS AND METHODS

The library tray system was developed for Hass fruit during the 2010 season and for Shepard fruit during the 2011 season. A suitable storage regime for the library trays was identified early in the 2010 season through experimentation and was then confirmed over the next two seasons. Development of the library tray system took place at the Bundaberg Research Facility (DEEDI) using fruit from various pack sheds in Bundaberg and Childers, Central Queensland. All fruit used were locally grown.

Fruit sampled

For both Hass and Shepard, fruit were sampled from the end of the packing line which is where many existing library tray systems draw their samples (Dixon & Pak 2002; Woolf et al. 2009). On each sampling occasion fruit were taken from as many blocks (orchards) as possible. Four 5.5kg trays of fruit of the same count were taken from each block sampled on the day of packing. The sampling dates and number of blocks sampled are shown in Table 1.

Table 1. Sampling dates, number of blocks / orchards sampled and number of pack sheds involved

Cultivar	Date sampled	Number of orchards	Number of pack sheds
Hass	20 May 2010	14	6
	21 June 2010	10	5
	7 July 2010	11	5
	27 Aug 2010	9	4
	28 Sept 2010	7	1
Shepard	9 March 2011	5	1
	18 March 2011	8	3
	5 April 2011	7	3
	12 April 2011	10	3

Developing the library tray storage regime

Early season Hass fruit were used for the development of the library tray storage regime (fruit sampled on 20th May 2010). Eight trays of fruit were taken from the end of the pack line per block. All eight trays were of the same fruit count but varied from block to block depending on the count that typified the block and harvest. Two trays per block were stored under each of the following regimes:

- 22°C with 10ppm ethylene (Ripegas) till ready to assess,
- 22°C without ethylene till ready to assess,
- 24°C without ethylene till ready to assess,
- Simulation of a typical commercial cold chain (see below), to verify the resulting fruit quality.

Simulation of a typical commercial cold chain

In order to verify that the fruit quality observed in the library trays was a accurate reflection of market reality, two trays of fruit per block were subjected to simulation of a typical cold chain. The cold chain simulation conditions are not 'Best practices' but a true reflection of fruit storage regimes as found in the industry (Campbell, 2011, Project: AV08018 Development of best practice guidelines for avocado ripening, unpublished data) and (Hofman, P & Ledger 2001).

The simulated cold chain involved:

- five days at 10°C (to simulate the pack shed cold storage and transport to the markets),
- three days at 18°C with 10ppm ethylene (ripening at market / dispatch),
- two to three days at 5°C for Hass and at 7°C for Shepard (cold storage at market / dispatch),
- 20°C till assessment.

Fruit assessment

One tray of fruit per block was assessed at eat ripe, firmness 4, and the remaining tray was assessed two days later at soft ripe, firmness 5-6, using the International Avocado Quality Manual scale (White et al. 2009). The second assessment, at soft ripe, represented a simplistic shelf life test. Fruit firmness was determined using gentle hand pressure and confirmed using a fruit densimeter. Fruit quality was assessed in accordance with the International Avocado Quality Manual (White et al. 2009). All defects were expressed in terms of severity (percentage of fruit flesh affected) and incidence (percentage of the fruit in the sample affected). Photographic records were kept of both external and internal fruit quality.

External fruit quality

The following fruit characteristic were assessed:

- Skin spotting,
- Discrete patches (only in the simulated cold chain fruit),
- External colour development (for Hass only).

Since Hass fruit darken as it ripens, skin spotting was assessed while in storage two days after fruit sampling. Shepard fruit retain their green skin colour during ripening and thus external fruit quality was assessed at eat ripe.

Internal fruit quality

The fruit were cut longitudinally, the seeds removed, the flesh scooped out and the following flesh disorder assessed:

- stem end rot (Fig. 1, left),
- body rots (Fig. 1, middle),
- vascular browning (Fig. 1, right),
- seed cavity browning,
- flesh bruising,
- diffuse flesh discolouration,

- stones in the flesh,
- other, e.g. seed germination, pink staining, etc.

Figure 1. Left: stem end rot; middle: body rot; right: vascular browning

Rots and vascular browning were the most common defects observed and were used as parameters to determine the fruit marketability. Other defects were noted and used for grower feedback. Based on the severity (percentage of fruit flesh affected) of rots and vascular browning fruit were categorised as:

- Fruit with 0% defects (with no rots or vascular browning, Fig. 2, fruit 1, 3 and 5). This category was included for its accuracy and ease of assessment.
- Fruit with up to 5% flesh defects (rots and/or vascular browning, Fig. 2, fruit 2). This category is used by the New Zealand avocado industry in their out-turn fruit quality studies (Dixon 2001; Mandemaker 2004).
- Fruit with up to 10% flesh defects (Fig. 2, fruit 4). This is the recommended Australian avocado industries defect tolerance for marketable fruit (Avocados Australia Limited 2011).

Fruit with more than 10% internal flesh defects was regarded as unmarketable in accordance with consumer tolerance studies (Harker, F, Hofman & Stubbings 2007).

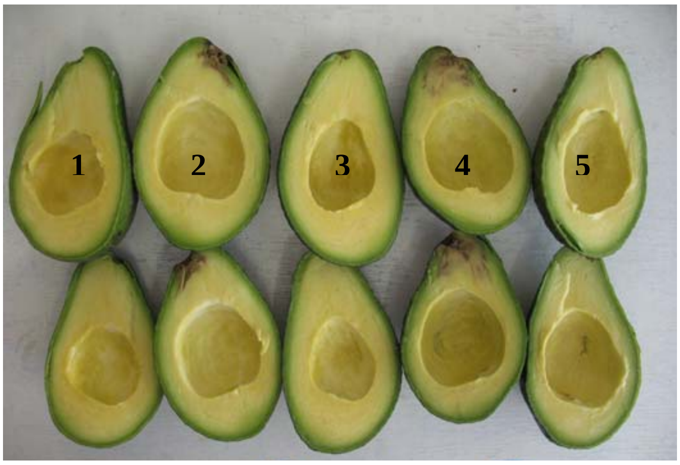


Figure 2. Fruit quality categories: fruit 1,3 and 5: clean fruit (0% defect), fruit 2: ≥ 5% internal defects, fruit 4: ≥ 10% internal defects

The fruit quality was expressed as the percentage of the fruit in each of those categories in a tray. For example, Block A produced:

- 85% clean fruit (0% defects),
- 10% fruit with up to 5% defects,
- 4% fruit with up to 10% defects and

- 1% unmarketable fruit (more than 10% defects).

The quality of the library tray fruit was compared with fruit from the same sample subjected to the simulated cold chain.

Statistical analysis

The results were analysed using GenStat 11th edition using the analysis of variance at 95% confidence level. Simple statistical correlations and linear regression analyses were used to verify the relationship between the library tray and cold chain simulation data.

RESULTS AND DISCUSSION

Developing a library tray fruit storage regime using Hass fruit

The number of days for fruit to reach eat ripe under the various storage regimes were:

- 11.04 days at 22^{o}C;
- 7 days at 22^{o}C with Ripegas;
- 10.4 days at 24^{o}C;
- 18 days under cold chain simulation, which includes three days with Ripegas.

In the absence of Ripegas the fruit ripened unevenly which necessitated several assessments episodes. This may not be a viable option for a commercial library tray system. In terms of rapidity and evenness of fruit ripening 22^{o}C with Ripegas was found to be the most appropriate storage regime. However, evenness and time to ripen was not the principal criteria for choosing the storage regime. The storage regime used had to produce fruit quality which reflects commercial reality.

In developing a library tray storage regime emphasis was placed on internal fruit quality since this has been shown to be the major cause of consumer dissatisfaction (Harker, F, Hofman & Stubbings 2007; Harker, FR et al. 2011). The resulting percentage of Hass fruit in each fruit quality category is shown in Table 2. The correlations (r^2) between the internal quality of fruit subjected to the simulated cold chain and those stored at various temperatures are shown in Table 3. Clearly, both at the eat ripe and at soft ripe assessments 22^{o}C with Ripegas produced fruit quality that most closely correlated with the cold chain simulation fruit.

Table 2. Average percentage of Hass fruit in each quality category. Fruit stored at 22^{o}C, 22^{o}C with Ripegas, 24^{o}C and cold chain simulation.

	% Fruit							
	Eat ripe assessment				Soft ripe assessment			
Quality category	22^{o}C	22^{o}C+E	24^{o}C	CS	22^{o}C	22^{o}C+E	24^{o}C	CS
0% rots	32.1	71.1	35.2	73.3	9.0	13	9.2	27.4
≤ 5% rots	58.1	91.1	58.8	94.6	32.5	36.9	29.3	74.5
≤ 10% rots	72.6	95.4	67.7	97.6	49.6	51	43.7	86.6

22^{o}C+E: 22^{o}C with ethylene (Ripegas)
CS: Cold chain simulation

Table 3. Correlation (r^2) and statistical significance of the correlation (P) between the quality of Hass fruit stored under simulated cold chain conditions and at 22°C, 22°C with Ripegas and 24°C, n=14, P<0.05 is statistically significant, the larger the r^2 value the stronger the correlation.

Assessed at eat ripe

	22°C		22°C + Ripegas		24°C	
Fruit grading categories	R^2	P	R^2	P	R^2	P
0% rots	0.09	0.3	0.6	0.0012	0.3	0.04
≤ 5% rots	0.01	0.735	0.5	0.005	0.08	0.765
≤ 10% rots	0.1	0.258	0.18	0.134	0.02	0.62

Assessed at soft ripe

	22°C		22°C + Ripegas		24°C	
Fruit grading categories	R^2	P	R^2	P	R^2	P
0% rots	0.3	0.26	0.73	<0.001	0.22	0.09
≤ 5% rots	0.3	0.29	0.7	<0.001	0.19	0.124
≤ 10% rots	0.18	0.13	0.7	<0.001	0.12	0.225

Figure 3 is a graphic representation of the correlation in fruit quality (0% defect category) between fruit stored at 22°C with Ripegas and those in the simulated cold chain.

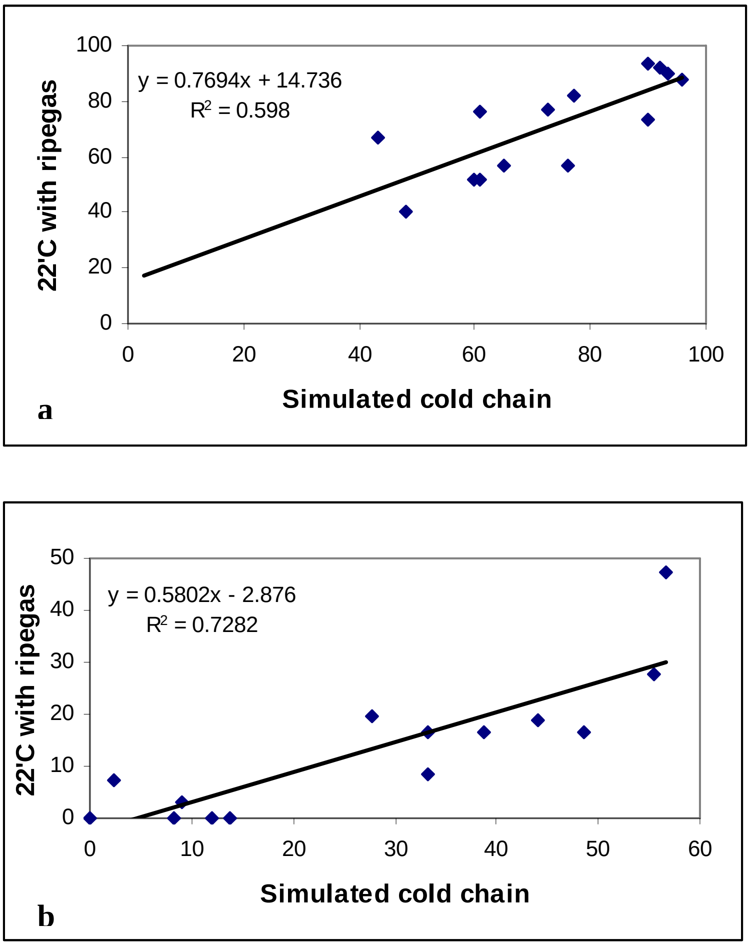


Fig. 3. Correlation between percentage of clean Hass fruit stored under simulated cold chain conditions and at 22°C with Ripegas, (a) fruit assessed at eat ripe; (b) fruit assessed at soft ripe, n=14, x- and y-axis are the % of fruit in the sample with 0% defects.

At all the storage regimes tested, it was noted that as the tolerance to defects increased from 0% defect to 10%, the correlation between the quality for fruit in the library trays and those under simulated cold storage weakened. It is speculated that this may be due to the introduction of human error. It is difficult to confidently ascertain the percentage of fruit flesh affected by rots on a curved fruit surface. By using the category 'clean fruit' (0% defects) human error is eliminated and a stronger correlation ensured. However, since consumer tolerance to internal fruit quality varies depending on the selling price (Harker, F, Hofman & Stubbings 2007) and on the quantity of product available, for the purpose of developing the library tray system, the three fruit grading categories were maintained.

Based on the results presented in Tables 2 and 3, 22^{o}C with Ripegas appears to be the best regime for storing library trays fruit. The resulting fruit quality (rots and vascular browning) under this regime correlated strongly with that of fruit subjected to the simulated cold chain. Thus, 22^{o}C with Ripegas (10ppm ethylene) was implemented as the storage regime for the library tray fruit.

Testing the library tray system across the season for Hass fruit

As the harvesting season progresses and fruit mature, intrinsic and extrinsic condition alter. Since disease pressure often increases with time and the fruit susceptibility to pathogens change (Lallu et al. 2005; Pak 2001; Prusky, D. et al. 1990; Prusky, D, Plumbley & Kobiler 1991), it was necessary to ascertain the accuracy of the library tray system across the season. The trial was conducted at monthly intervals for the duration of the 2010 Hass season.

External fruit quality

Based on fruit firmness and external colour assessed at eat ripe, the fruit ripened more evenly in the library trays than under the simulated cold chain condition. According to the International Avocado Quality Manual (White et al. 2009) the library tray fruit were approximately one colour rating point higher than the cold chain simulation fruit. The correlation between the external fruit colour at eat ripe in the library trays and the cold chain simulation fruit was weak (r^2= 0.03-0.32, P>0.05). The library tray storage regime was not found to accurately reflect fruit ripening under simulated commercial conditions. This however is not surprising given the vastly different conditions under which the fruit were stored and ripened.

Skin spotting or nodule damage is one of the major external defects of avocados on the retail shelf (Figure 4). Although skin spotting has received considerable attention over the past two decades (Arpaia et al. 1987; Boshoff, Slabbert & Korsten 1995; Duvenhage 1993; Everett, Kerry R. et al. 2008; Everett, K.R. et al. 2001; Hofman, P. et al. 2003; Van Rooyen 2009), it remains a serious down grade factor on the wholesale markets and has been associated with external and internal fruit rots (Everett, K & Pak 2002; Le Lagadec 2010; Pak et al. 2003). It is however, not usually a reject factor at retail level since the Hass fruit darken as they ripen masking the skin spotting. Skin spotting is thought to be a handling injury caused by vibrations and impacts as the fruit travels along the fruit handling chain (Arpaia et al. 1987; Boshoff, Slabbert & Korsten 1995).

Figure 4. Skin spotting damage on Hass fruit

The Hass skin spotting was assessed two days after fruit sampling, before the fruit in the library trays started to darken. The correlation between skin spotting in the library trays and the cold chain simulation ranged between r^2=0.49 – 0.77 (Fig. 5). Although this is a good correlation its practical value is questionable since it is probably that skin spotting damage increases due to rough handling as the fruit move through the cold chain. The cold chain simulation used in this trial mimics only the fruit storage regime and cannot anticipate handling injuries after packing. In commercial reality the skin spotting damage would probably be more severe in the fruit at the markets than seen in the corresponding library tray samples. The library tray samples can be used as an effective indication for rough fruit handling on farm and at the packing shed but cannot reflect damage incurred further along the cold chain. This is nonetheless good feedback information for growers regarding their fruit handling procedures.

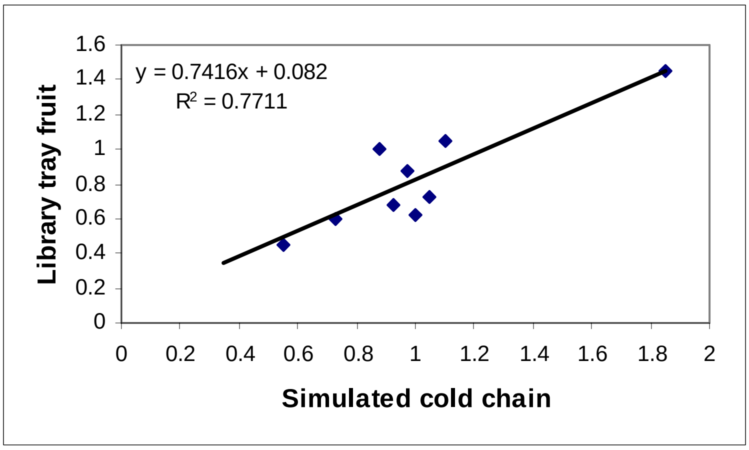


Figure 5. Skin spotting damage on Hass fruit. Correlation between library tray storage and simulation of the cold chain, x- and y-axis use a rating scale of 0-3 (0 = no spotting and 3 = more than 50% of fruit surface affected).

Since fruit used in the trial were of premium grade, few other external skin defects were encountered. Discrete patches, a symptom of cold damage (Arpaia, M 2005), was occasional observed in a few fruit stored under the simulated cold chain conditions. Since fruit were not subjected to cold temperatures in the library trays, no correlations were drawn.

Internal fruit quality

Avocado consumers have a low tolerance for fruit with more than 10% of the flesh affected by internal defect (Avocados Australia Limited 2011; Harker, F, Hofman & Stubbings 2007). A recent survey of internal fruit quality problems on the Australian retail shelf has shown that bruising is the major cause of fruit rejection affecting approximately 12% of fruit, followed by body rots (7.5%), vascular browning (6%), diffuse discolouration (5%), stem end rots (3%) and other defects (0.5%) (Embry, J 2009a). In the present project although all defects were noted, emphasis was placed on rots and vascular browning because collectively, they are the major cause of customer dissatisfaction (representing 16.5% of marketed avocado fruit). Flesh bruising is a major defect on the retail shelf but is associated with rough handling of sprung fruit (Arpaia, ML 2005; Lee & Burkner 1971). This implies that flesh bruising occurs mainly in the market place after fruit ripening has been initiated. Bruising could therefore not accurately be simulated in the library trays and was rarely seen in the fruit assessments.

The incidence and severity of all internal defects was recoded in order to provide growers with feedback regarding their out-turn fruit quality. Stones in the flesh were common in certain orchards/blocks and may be an indication of preharvest insect damage (Joubert & Claasens 1994). Growers may be able to use this information to gauge the efficiency of their pest control measures. Physiological fruit quality problems such as seed cavity browning and diffuse discolouration were occasionally encountered. These defects may indicate a tree health issue or a nutritional deficiency and could signify that orchard management practises may need to be altered (Arpaia, M 2005; Smith & Kohne 1992).

As with the New Zealand library tray system (Dixon 2001; Dixon & Pak 2002), fruit rots and vascular browning were the most common defect observed in the fruit assessments. Providing growers with information regarding the level of rots in their ripe fruit may serve to gauge the success of their preharvest disease control programs. Disease control efficiency is almost impossible to estimate in unripe fruit. It only becomes evident once fruit ripen (Pak, Dixon & Cutting 2005). Providing growers with this information may serve as an excellent tool in planning future disease control strategies. As an example of this, in the Avocado Robustness Project, AV07005 (Le Lagadec 2010) a grower was identified as having high levels of post harvest fruit rots resulting in very poor fruit quality. The grower used this information, altered his fungicide and fertilizer application programs and produced one of the best quality fruit in the following season.

In the current trial the average incidence and severity of rots and vascular browning in the library trays and the cold chain simulation fruit were similar (averaged for all blocks / orchards over the season, Table 4). This indicates that the library tray system is a good reflection of commercial reality. The incidence of stem end rot tended to be higher in the library tray fruit than in the cold chain simulation fruit while body rots were usually higher in the cold chain simulation fruit.

The same trends were observed over two seasons in the Avocado Robustness Project, AV07005 (Le Lagadec 2010). A possible explanation is that the two rot types, stem end rot and body rots, have different causal pathogen complexes, each with their own optimum development temperatures and development times (Elmsly & Dixon 2008; Hopkirk et al. 1994). The incidence of vascular browning tended to be higher in the library tray fruit and almost twice as many fruit were affected as compared to fruit in the cold chain simulation.

Table 4. The average incidence (% affected fruit) and severity (% of fruit flesh affected) of rots and vascular browning in Hass fruit in the library trays and under cold chain simulation. Fruit assessed at eat ripe and at soft ripe over five months.

	Eat ripe				Soft ripe			
	Incidence		Severity		Incidence		Severity	
	Lib	CS	Lib	CS	Lib	CS	Lib	CS
Stem end rot	23	19.9	1.1	0.9	51.8	48.3	5	3.8
Body rots	19.1	23.8	1.3	1.7	51.6	57.2	5.5	5.7
Vascular browning	15	7.5	0.7	0.3	39	20.4	2.1	1

Lib: library tray fruit
CS: cold chain simulation fruit

In conventional library tray systems that mimic commercial consignment conditions better fruit quality is usually observed in the library trays than in commercial reality. This is because library tray fruit are not subjected to multiple handling processes and temperature fluctuations (Woolf et al. 2009). Therefore it is possible to achieve good quality in the library trays only to have the fruit rejected at the market. In the current project the average percentage of fruit in each defect category (0%, ≤5% and ≤10%) was similar for the library tray and cold chain simulation regime (Table 5) with fruit in the library trays usually being of slightly poorer quality than those in the cold chain simulation. This is because of the high storage temperatures used library trays. The higher the storage temperature the higher the incidence of rots (Elmsly & Dixon 2008; Hopkirk et al. 1994). The elevated temperatures used in the library trays seem to compensate for adverse temperature fluctuations encountered in commercial cold chains and results in similar if not slightly poorer quality fruit.

Table 5. Average percentage of fruit in each fruit quality category for library tray and cold chain simulation fruit.

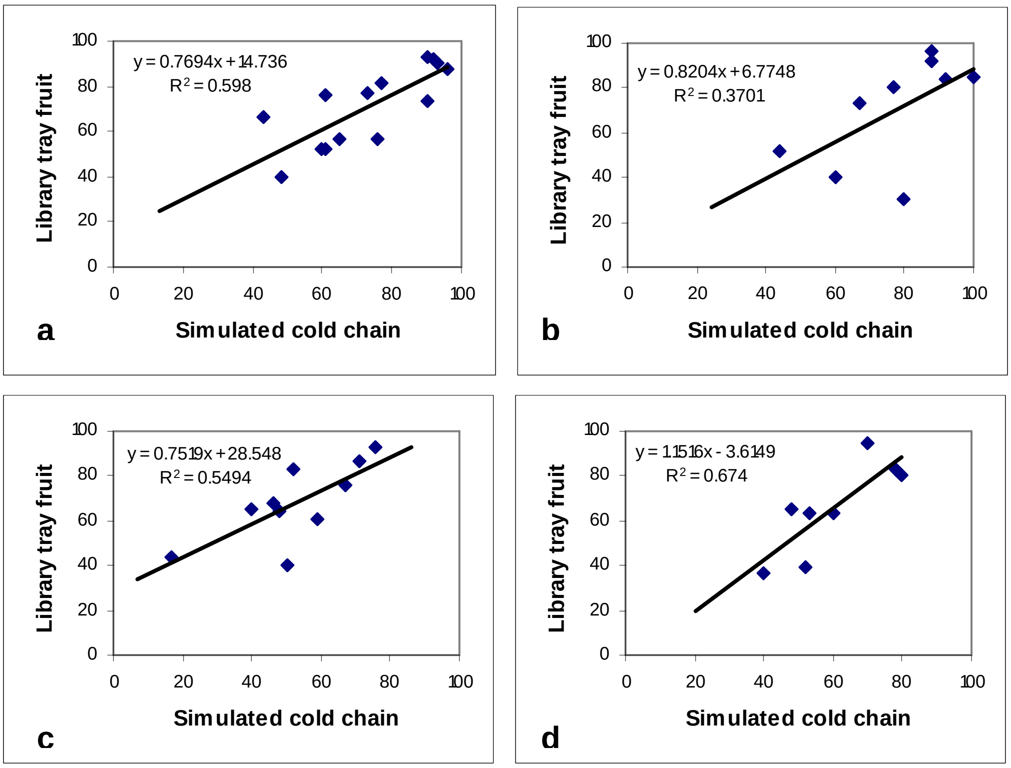
	% Fruit			
	Eat ripe assessment		Soft ripe assessment	
Quality category	Library tray	Cold chain sim	Library tray	Cold chain sim
0% rots	59.5	63.1	20.1	25.6
≤ 5% rots	84.6	85.3	48.6	49.9
≤ 10% rots	91.5	89.8	64.3	65.5

The correlations drawn between the percentage of the fruit in each of the defect categories in the two storage regimes is shown in Table 6.

Table 6. Correlation (r^2) and statistical significance (P) in Hass fruit quality between the library tray and cold chain simulation fruit sampled at monthly intervals. Fruit were assessed at eat ripe. R^2 closes to 1 is highly significant, P<0.05 is statistically significant at 95% confidence level.

	Fruit sampling date									
	May		June		July		Aug		Sep	
Fruit quality categories	R^2	P	R^2	P	R^2	P	R^2	P	R^2	P
0% rots	0.6	0.001	0.4	0.08	0.6	0.01	0.7	0.01	0.9	0.005
≤ 5% rots	0.3	0.03	0.3	0.15	0.6	0.004	0.45	0.05	0.7	0.04
≤ 10% rots	0.4	0.01	0.1	0.41	0.3	0.14	0.5	0.03	0.15	0.45

In general, the correlations were strongest for the '0% defect' category and weakened as defect tolerance increased. Zero defect tolerance is a simple almost full-proof category which does not allow for human error. The introduction of defect tolerance mandates a defect rating which is subject to human error. In developing the library tray system all Hass fruit assessments were carried out by partially skilled casual workers in order to test the robustness of the system. Despite this, the correlations were good especially at the 0% defect level which indicates the ease with which the system could be adopted by commercial stakeholders. A graphic representation of the correlations for 0% defect tolerance assessed at eat ripe is shown in Figure 6.



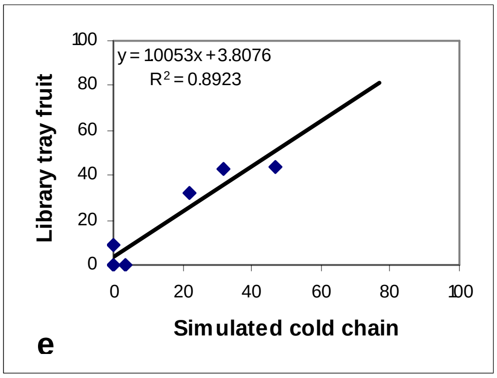


Figure 6. Correlation between the percentage of Hass fruit with no defects (0% rots and vascular browning) in the library trays and the simulated cold chain fruit. Fruit assessed at eat ripe and sampled in (a) May, (b) June, (c) July, (d) August, and (e) September. X- and y-axis are the % of fruit in the sample with no defects.

Fruit firmness at the time of assessment was found to be of critical importance. The quality of fruit in the two storage regimes only correlates if the fruit were assessed at the correct firmness. Fruit softens and quality deteriorates rapidly in the library tray regime and if fruit were assessed too soft (a day late) the quality did not correlate well with fruit in the simulated cold chain. In the International Avocado Quality Manual White et al. (2009) also stressed the importance of assessing fruit at the correct firmness. Training fruit assessors to correctly judge fruit firmness is essential.

At soft ripe, 48 hours after eat ripe, the fruit quality was poor especially in the library trays. It is well documented that the higher the ripening/storage temperature the more rapid the deterioration (Elmsly & Dixon 2008; Hopkirk et al. 1994). In most samples the fruit quality deterioration more rapidly in the library trays than in the cold chain simulation fruit. None-the-less, the correlation between fruit quality in the two storage regimes remained strong even at the soft ripe stage.

Testing the library tray system across the season for Shepard fruit

In central Queensland the Shepard season extends over approximately two months, March to end April. Despite the short season it was important to verify the accuracy of the library tray system as the fruit matured.

External fruit quality

Unlike Hass, Shepard fruit do not darken as they ripen. External skin defects such as skin spotting and scuff marks are visible on fruit on the retail shelf and can potentially be a significant reject factor. A system that can forewarn marketer and retailers of potential skin blemishes would be greatly advantageous.

In the current trial the correlation between skin spots in the library tray fruit and those in the cold chain simulation was not strong, ranging from r^2=0.4 - 0.56 (Figure 7). The severity of skin spotting was low to moderate in most of the fruit assessed and rating the severity of the defect with accuracy proved difficult. This may account for the inconsistent results. However, the odd trays of fruit with high levels of skin spots or those with extreme low levels produced similar results under both storage conditions. Theoretically, library trays may be reliable indicators of skin damage which occurs during picking and on the pack line but cannot account for injuries incurred after the pack shed gate. Since the severity of the defect probably increases as fruit moves through the cold chain (Arpaia et al. 1987) the library tray system may not adequately predict the severity of skin spotting in commercial consignments. Therefore, the library tray system may not be the ideal predictive tool for this defect.

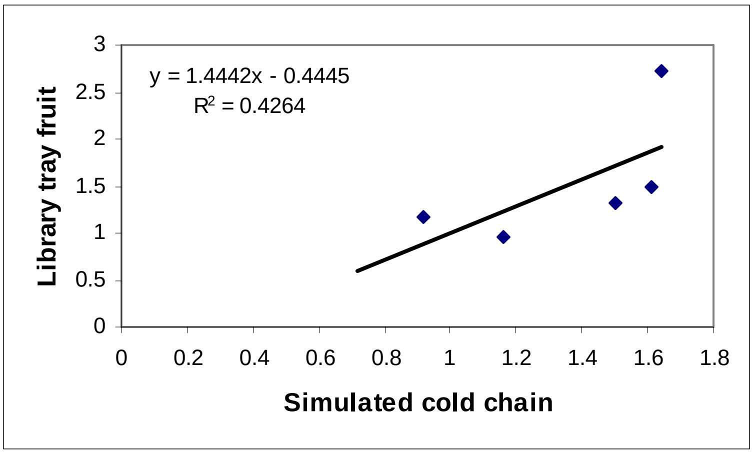


Figure 7. Skin spotting damage on Shepard fruit. Correlation between library tray storage and simulation of the cold chain, x- and y-axis use a rating scale of 0-3 (0 = no spotting and 3= more than 50% of fruit surface affected).

Internal fruit quality

A recent consumer survey has shown that internal fruit quality had a far greater impact on repeat purchasing decisions than the external appearance of Shepard fruit (Harker, FR et al. 2011). Hence, emphasises was placed on internal fruit quality issues in developing the library tray system.

As with the Hass fruit, the incidence and severity of all internal defects were recoded in order to provide suppliers (growers) with out-turn quality feedback. However, only internal rots, i.e. stem end rot and body rots, and vascular browning was used to determine fruit marketability. The incidence and severity of rots and vascular browning in the library tray and cold chain simulation fruit is shown in Table 7. As with the Hass fruit in this study and in the previous Avocado Robustness Project, AV07005 (Le Lagadec 2010), body rots tended to be higher in the cold chain simulation fruit whereas stem end rot was more prominent in the library try fruit. These trends remained consistent throughout the Shepard season.

Table 7. The average incidence (% affected fruit) and severity (% of fruit area affected) of rots and vascular browning in Shepard fruit in the library tray and under cold chain simulation. Fruit assessed at eat ripe and at soft ripe over two months.

	Eat ripe				Soft ripe			
	Incidence		Severity		Incidence		Severity	
	Lib	CS	Lib	CS	Lib	CS	Lib	CS
Stem end rot	22	20.9	1.6	1.3	59	50	7	4.7
Body rots	11.8	19.9	0.8	1.4	40.7	47.7	3.7	5.3
Vascular browning	22.8	8.8	0.5	0.4	51.8	27.7	1.9	1.3

Lib: library tray fruit
CS: cold chain simulation fruit

The resulting fruit quality categorized as: 0% defect, ≤5% defect and ≤10% defect, is shown in Table 8. As with the Hass fruit, the two storage regimes produced very similar fruit quality in Shepard. In general, the library tray system produced slightly poorer quality fruit than the cold chain simulation regime but the differences were not statically significant ($P>0.05$). Obviously as the tolerance for rots increased so to did the percentage of fruit in the respective defect categories.

Table 8. Average percentage of Shepard fruit in each quality category for library tray and cold chain simulation fruit.

	% Fruit			
	Eat ripe assessment		Soft ripe assessment	
Quality category	Library tray	Cold chain sim	Library tray	Cold chain sim
0% rots	57.1	61.9	12.9	18.2
≤ 5% rots	86.4	84.9	45.6	51.4
≤ 10% rots	91.8	91.9	63.3	66.6

Correlations were drawn between the percentage of the fruit in each of the defect categories in the library trays and cold chain simulation, Table 9. The correlations were strongest in 0% and 5% categories and weakened in the 10% category. This may, once again be due to human error. Rating the severity of rot proved difficult especially for inexperienced workers. Surprisingly although the percentage fruit with ≤10% defects in the eat ripe stage was very similar for both storage regimes (Table 8), the correlation between individual blocks sampled was poor (Table 9). Should the library tray system find adoption, it is recommended that the 0% defect tolerance category be utilized since it is clearly the easiest and most accurate to access. Figure 8 is a graphic representation of the fruit quality correlations for 0% defect category.

Table 9. Correlation (r^2) and statistical significance (P) for Shepard fruit quality between the library tray and cold chain simulation fruit. Fruit were assessed at eat ripe. R^2 closes to 1 is highly significant, P<0.05 is statistically significant.

	Fruit sampling date							
	9 March		18 March		5 April		12 April	
Fruit quality categories	R^2	P	R^2	P	R^2	P	R^2	P
0% rots	0.6	0.01	0.76	0.004	0.77	0.05	0.33	0.08
≤ 5% rots	0.66	0.09	0.8	0.002	0.73	0.06	0.6	0.009
≤ 10% rots	0.3	0.33	0.66	0.015	0.47	0.2	0.37	0.06

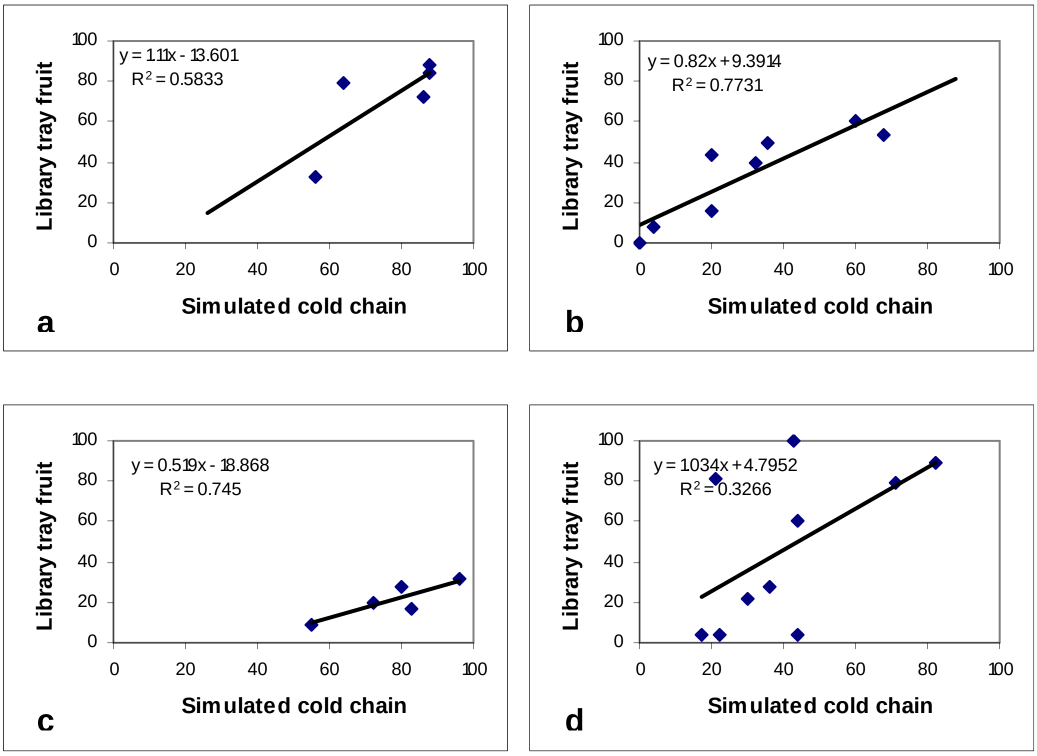


Figure 8. Correlation between the percentage of fruit with no defects (0% rots) in the library trays and the simulated cold chain fruit. Fruit assessed at eat ripe and sampled in (a) 9 March, (b)18 March, (c) 5 April, (d) 12 April.

As with the Hass fruit, fruit firmness at the time of assessment was found to be of critical importance. If the library tray fruit were assessed soft ripe or too firm, the resulting quality did not correlate well with that of the cold chain simulation fruit.

General discussion

The library tray system developed in this project is unique in that it employs a rapid ripening fruit storage regime rather than the traditional extended low temperature regime mimicking commercial reality. Two seasons of testing has shown that this rapid ripe library tray system is a good indicator of commercial out-turn quality.

The main defects encountered in the rapid ripe system and the cold chain simulation fruit were rots and vascular browning which cumulatively represent the greatest rejected factor on the retail shelf (Embry, J 2009b). Similar results have been reported from New Zealand's library tray system that using a storage regime mimicking commercial export conditions (Dixon 2001; Dixon & Pak 2002). Fruit rots are thought to originate in the orchard and possibly the packing shed. By providing growers and pack shed operators with feedback regarding the level of rots in their fruit, corrective action can be taken, and in time, the problem can be minimized.

Unfortunately flesh bruising, which is the single largest Australian retail reject factor (Embry, J 2009b) can not be simulated or predicted in any library tray system. This, therefore, is not seen as a failing of the present rapid ripe system but a shortcoming of all library try systems. Another shortcoming of the rapid ripening library try system is its inability to predict internal cold injury. Cold injury accounts for approximately 5% retail fruit rejection (Embry, J 2009a) especially in late season fruit (Cutting, JGM & Wolstenholme 1991). However, it has been observed that fruit that are susceptible to cold damage are often also susceptible to rots (Le Lagadec 2010). It may therefore be possible to guesstimate the probability of developing internal cold injury based on the samples' susceptivity to rots.

The rapid ripe library tray system can successfully fulfil three main functions; (1) it can serve as an insurance policy against poor out-turn quality, (2) provide growers with fruit quality feedback, and (3) feed information forward to marketers and retailers. The first two functions are shares with most other existing library tray systems. The third function is unique to the rapid ripe system. Because the fruit quality results are available within seven days of sampling, out-turn quality data would be available before the fruit reach the retailers and often before the fruit reach the markets.

This rapid information turnover provides a unique opportunity to feed information forward to the fruit handlers in the cold chain. Marketers would be better informed on how to handle individual consignments to produce the best fruit quality. If marketers are able to act on the information provided, a significant improvement in avocado fruit quality should be noticeable on the retail shelf within a season. This would be a first for avocado industries world wide and would have a marked impact on consumer confidence and consequent fruit sales. Stakeholders who adopt this library tray system and act on the information generated would have a powerful marketing tool distinguishing them from their competitors.

Over time, information gained from the library tray system can be used to identify the main causes of fruit deterioration in the industry. Use of the library tray system in New Zealand has indentified three major causes of fruit quality problems; delay time between harvest and fruit packing, the duration of cold storage of fruit, and rainfall prior to harvest (Mandemaker 2004; Pak, Dixon & Cutting 2005). At present there is considerable evidence and hearsay in the Australian industry regarding the major causes of fruit quality loss but no coordinated effort exists to verify these speculations. The implementation of a library tray system by the industry would help clarify the situation and direct future research and development investments.

The variability of internal avocado fruit quality has been identified as one of the major factors limiting sales of the product. Consumer surveys have shown that consumers would be willing to purchase more avocado fruit and at a higher price if the quality was guaranteed (Harker, FR et al. 2011). However there is an obvious risks; the industry would need to ensure that it can deliver on this guarantee (Harker, FR et al. 2011). The rapid ripe library tray system would greatly contribute towards the industry achieving this goal and thus boost consumer confidence and future sales.

TECHNOLOGY TRANSFER

An important part of the project was to work with the collaborators to integrate the library tray system into the existing quality assurance systems used across the business.

A procedure was written for sampling, handling assessment of fruit performance (Appendix 1), recording results (Appendix 2) and determination of appropriate actions was developed. This has been rewritten by the quality manger to integrate it into the quality system.

A spreadsheet was developed so that the library tray results could be recorded and the quality manager can visually see the blocks which need sampling and re-sampling and determine the appropriate actions.

A training workshop was developed and delivered on the correct procedures for sampling and assessment of samples and importantly the critical stage of ripeness for assessment. This training was held at the collaborators' business and was attended by key pack shed and quality assurance staff. Key quality staff from the handling and ripening component of the supply chain also attended the training.

RECOMMENDATION

The rapid ripe library tray system effectively predicts out-turn quality for both Hass and Shepard fruit. The following recommendations have been made to the funding parties regarding the commercial implementation of the system:

- Fruit are to be sampled from the end of the pack line using the typical fruit count for that orchard / block / harvest round. One tray of fruit sampled per block / orchard per harvest is generally regarded as sufficient (Woolf et al. 2009).
- Fruit should be stored immediately after sampling, on site, at 22^{o}C with a constant supply of Ripegas, 10ppm of ethylene.
- The International Avocado Quality Manual (White et al. 2009) is to be used as the assessment standard.
- For Hass, external fruit quality defects should be assessed before the exocarp (skin) darkens, i.e. within 2 to 3 days of storage. For Shepard, external fruit quality can be assessed at eat ripe.
- Internal fruit assessment should be done at eat ripe i.e. firmness stage 4 (White et al. 2009) which is approximately seven days after fruit sampling. The correct fruit firmness is essential. However, if fruit firmness variation is encountered across the tray, all fruit should be assessed when the majority are

at the correct firmness. It is not cost effective to do multiple assessments on a tray of fruit.

- Digital photos should be taken of external fruit quality for each tray of fruit, and of the internal quality for the first 5 fruit cut. Any severe internal defects or unusual defects should also be photographed.
- Although external fruit quality should be noted, emphasis is placed on internal fruit quality.
- Parameters used to rate marketability are stem end rot, body rots and vascular browning.
- Use the category of 0% defect tolerance (i.e. no rots or vascular browning). This will simplify the process and eliminate human error.
- The acceptable percentage of fruit in a sample (5.5kg tray) with 0% defects (clean fruit) must be determined by the pack shed manager and marketers. For the purpose of this study a minimum of 60% clean fruit (0% rots & vascular browning) per sample is recommended but this may be altered depending on market tolerances.
- If less than 60% of the fruit in a sample is found to be clean, i.e. more than 40% of the fruit have rots, it is recommended that fruit sampling is repeated and that commercial consignments be handled with caution.
- The fruit quality information should be captured on a data sheet. An example of such a sheet is give in Appendix 2. The data is to be processed, analyzed and the information fed back to the growers. The method of reporting (standardized reporting format) needs to be developed with the commercial partners.
- It is essential that a method be developed to feed information forward to marketers. Without this, improvements in retail fruit quality will be difficult to achieve in the short term.

NEXT STEP

The library tray system works well under controlled conditions, i.e. in the laboratory but needs to be tested on a commercial scale. There are several logistical issues to that need to be resolved and would require some technical input. For example:

- The number of samples to be taken per block / orchard / harvest needs to be assessed. This will depends on whether the aim is to tract quality per grower, per orchard or per block. The sample has to be representative of the target. The number and size of the samples needed to achieve this goal should be determined experimentally. In the New Zealand library tray system one tray of fruit is sampled per grower / farm per month (Woolf et al. 2009). In the South African Westfalia Fruit Estate system three trays are taken per fruit count per grower per cultivar per vessel (consignment). On average up to 18 trays of fruit are sampled per grower per season (pers comm. Dr Z. van Rooyen, Westfalia Technological Services, RSA).
- Sampling method: is taking fruit off the end of the pack line an accurate representation of a block / orchard / harvest round. Could fruit trays of fruit be taken off pallets, as is the practice with by the Westfalia Fruit Estate system (pers comm. Dr Z. van Rooyen, Westfalia Technological Services, RSA) or should a random fruit sample be taken over several hours during the day.

- Which fruit counts should be sampled. Is it adequate to sample the typical count for that harvest / block or should a range of fruit sizes be sampled.
- A simple system of collect, analyse and feed the data back to the growers needs to be developed. More importantly, a method of feeding information forward to marketers must be developed.
- A method of aiding the marketers to utilize the information provided needs to be developed.
- To maximize the benefits of such a system the library tray system should be combined with a traceability and an out-turn quality system in the market place at least for the first few seasons of implementation. This is similar to the out-turn quality program run by the New Zealand avocado industry (Lallu et al. 2005; Pak, Dixon & Cutting 2005). It may be necessary to place staff in the markets to monitor the out-turn fruit quality. Since this is a very large venture initially efforts may need to be limited to one or two of the major Australian markets only and expanded to other markets at a later stage.
- A cost benefit analyses of implementing a library tray system would be greatly beneficial in attainment commercial adoption.

Once the library tray system has been successfully adopted by some of the industry market leaders, it is hoped that other industry stack holders will follow suit. Time must be invested in 'selling' the idea to the rest of the industry. The New Zealand avocado industry identified 'industry buy in' as a high priority in their library tray adoption program (Woolf et al. 2009).

Standardization of the program will be essential. If assessment methods, storage regimes or reporting terminology are altered, the information produced could be greatly misleading. In order for the system to work successfully, it would need to be managed on an industry wide bases similar to the existing infocardo system. If achieved, it will be possible to monitor fruit quality trends over time and to implement targeted changes to the fruit handling systems on an industry wide scale. This would be of great benefit to all stakeholders in the industry and would be a powerful tool not only for expansion of existing markets but also to penetrate new domestic and export markets.

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Appendix 1

Ripe fruit inspection guide

Purpose and scope

This guide provides instructions for inspecting packed fruit after ripening to measure fruit performance. This test of ripe fruit performance on selected library trays reflects the performance of fruit that the retailer and consumers can expect after transport and ripening.

Monitoring ripe fruit performance enables problems in crop management, harvesting and packing to be identified. It also enables individual loads which have severe problems to be identified and managed so that customer satisfaction is maintained.

A ripe fruit inspection record must be completed for each block on each packing day and a record kept in a safe location.

Responsibilities

Quality controller

- Sample fruit for ripe fruit test, manage ripening process, and complete assessments.
- Complete a ripe fruit report for each block packed on each day, keep a record of the inspection results in a safe location and enter data on spreadsheet.
- Inform the Pack shed manager of the inspection results.

Pack shed manager

- Provide instructions to the quality controller about batches to inspect.
- Determining corrective actions if the quality controller detects severe problems with individual blocks/pack date.
- Inform the farm manager of individual block performance to improve farm and harvest management.

Facilities and equipment

Facilities

- A clean well lit area that has good access to ripening room but is safe and clear of main traffic areas.
- A ripening room that can be maintained at 22 C with an ethylene concentration of 10ppm. Racking to hold at least 7 days of samples.
- A suitable size inspection bench that is clean and clear of non essential material.
- Containers for disposal of fruit samples.

Equipment

- Sharp cutting knife and filleting safety glove. Copy of International Avocado Quality Manual, blank copies of Ripe fruit report, blank spreadsheet entry forms and files to store completed record sheets.

Inspection method

Sampling

- Sampling should be sufficient to give confidence in the results.
- Sample at least 3 trays from each batch. A batch is defined as fruit packed on the same day from each block.
- Select 3 trays of different counts of the most common pack sizes after packing.
- Record pack/sample date, variety, batch/block ID and total sample count on the Ripe fruit report.

Ripening

- Samples are held under continuous ethylene at 22 C for approximately 7 days and at this stage should be the medium to soft ripeness stage. This is indicated by the fruit firmness test where the fruit gives under slight thumb pressure.

Inspect sample and record results
Fruit are assessed twice. At 2-3 days after sampling the fruit are assessed only for skin spotting and at 7 days after sampling or when the majority of fruit are at the medium to soft ripeness stage the fruit are assessed for rots and stones in flesh.

On each occasion inspect each piece of fruit individually and record the assessment result.

At day 2-3, external skin is assessed for skin spotting.

At day 7 the fruit are individually assessed for fruit firmness and external skin is assessed for skin colour. The fruit are cut longitudinally and placed on the bench where individual fruit are assessed for stem end rot and vascular browning. The flesh is then scooped out and assessed for body rots and stones in flesh.

Results are recorded and the percentage of fruit for each assessment calculated. The percentage of fruit with no fruit rots is entered on the recording spreadsheet and the results communicated to the shed manager.

Assess inspection results

No matter how well managed an operation is, there will always be some disease and handling injury. Tolerances are established to take this into account. A tolerance is the maximum amount of out of grade product in a sample.

The tolerance for skin spotting is a maximum of 50% of fruit with more than 25% skin spotting.

The tolerance for stones in flesh is a maximum of 10% of fruit with any stones in flesh.

The tolerance for rots will vary according to the stage/date of harvest. The spreadsheet is used to calculate trends fruit with nil disease. A sample fails where the percentage of fruit with nil disease falls below 60% or where the result is 50% worse than the mean of the previous 20 samples.

Corrective actions

The results for individual blocks should be used by the farm managers to improve growing and handling systems.

Where a batch fails the tolerance, for rots or stones in flesh the batch should be re directed to an alternate customer or the customer should informed and remedial action negotiated.

Records

- Ripe fruit report
- Ripe fruit spreadsheet.

References

- Avocado ripening manual Deedi 2010.
- The International Avocado Quality Manual Plant and Food research 2009.

Appendix 2
Ripe fruit report

Block details

Block: Variety: Pack date:

Spotting assessment date: Number of sample fruit:

Rots assessment date:

Skin colour at day 7

1. Bright green	2. Dull green	3. 25% colour	4. 75% colour	5. Purple	6. Black
% of fruit	% of fruit	% of fruit	% of fruit	% of fruit	% of fruit

Firmness at day 7

1. Hard	2. Rubbery	3. Softening	4. Firm ripe	5. Medium to soft ripe -	6. Soft to over ripe
no give	slight give with strong thumb pressure	gives with strong thumb pressure	gives with moderate thumb pressure	gives with slight thumb pressure	gives with slight hand squeeze
% of fruit	% of fruit	% of fruit	% of fruit	% of fruit	% of fruit

Defects

	0%	**1 – 10%**	**10 – 25 %**	**25 – 100%**
Fruit spotting (At day 2)	% of fruit	% of fruit	% of fruit	% of fruit
Stem end rot				
Body rots				
Vascular browning				
Total Disease	% of fruit	% of fruit	% of fruit	% of fruit
	0	1-2 stones	3-6 stones	More than 6 stones
Stones in Flesh	% of fruit	% of fruit	% of fruit	% of fruit