Avocado quality monitoring via library tray system

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June 2009

A report prepared for,

Horticulture Australia Ltd (HAL) and the Australian Avocado Industry.
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Achieving high quality fruit out-turn of avocados can be a significant challenge for local and export markets alike. Library tray systems are used in many fruit industries to provide a means of monitoring and improving overall fruit quality. Generally a sample of fruit is taken at an appropriate point in the handling chain (most likely from the packing line) and held in the packhouse or a central location. Fruit quality of the sample is assessed on one or more occasions during storage and/or shelf life. Although such systems have been in widespread use around the world by fruit industries, there is a surprising lack of published information in this area. The library tray system has been used by the New Zealand avocado industry for a number of years and the experience gained in developing this process at an industry level is one of the best resources for information at our ready disposal.

The aim of this project was to determine the potential for use of a library tray system for tracking, and thus potentially improving Australian avocado fruit quality in the local and/or export marketplaces, by carrying out a literature review and survey of international fruit industry practices. An extensive literature search, including all likely web-based sources, was undertaken. Additional information on the topic was obtained by email and discussion with those who responded to a worldwide email of postharvest researchers and commercial personnel.

We have summarised library tray system experience in fruit other than avocado and from international avocado industries, but most detail is provided on the NZ experience since little detailed information is publicly available.

With respect to the library tray system, the report provides a review of:

- key drivers and aims
- practices and systems such as sampling, replication, storage conditions, ripening, assessment systems, data processing and reporting
- a statistical perspective on fruit sampling size
- key issues in relation to industry buy-in, politics and roles of packhouse versus industry staff
- other systems that could be put in place to maximise efficacy (e.g. in-market out-turn programmes).

Instigation of a library tray system has potential for improving quality of Australian fruit and an appropriate system should be considered by the Australian avocado industry.

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Introduction

Achieving high quality fruit out-turn of avocados can be a significant challenge for both local and export markets. A general lack of improvement over 5 years in fruit quality at retail level in Australia was noted in 1999 (Hofman and Ledger, 1999), and consumer research in 2005 indicated that some level of wastage still took place in one third of all avocado purchases. Wastage rates in export markets are likely to be of a similar magnitude. From recently conducted consumer research we know that any internal damage of avocados above 10% has an impact on future purchasing (Harker et al., 2007). Thus, we continue to see significant problems with the quality of avocados reaching the Australian consumer.

Australian avocado production is increasing at a rate of more than 15% per annum, and production in other countries is also increasing. Consumption must be increased in order to maintain returns to growers. Consistency of quality (including maturity and internal defects) is one area that needs to be addressed in order to achieve this. Growers can only guarantee a high level of quality if they are able to monitor the fruit from individual blocks and trees within their orchards.

A Library tray system is used in many fruit industries to provide a means of improving overall fruit quality. Generally a sample of fruit is taken from appropriate point(s) in the handling chain, and held in the packhouse or a central location and fruit quality assessed at one or more times during storage or shelf life. Although such systems are in widespread use around the world by fruit industries, there is a surprising lack of published information in this area. Most documentation associated with this is presumably held within commercial entities (packhouses or exporters) and thus is not publicly available.

A library tray system has been used by the New Zealand avocado industry since 2001 (Pak et al., 2005). The experience gained in developing a library tray system at an industry level is one of the best resources for information at the author's ready disposal. Our location in New Zealand allowed direct discussions with industry representatives and growers/packers.

The Australian avocado industry wishes to examine the potential for instigating a library tray system. Clearly it is wise to first learn as much as possible from systems currently being utilised by other avocado producing countries, as well as other fruit industries, and benefit from their experience.

Aim

By carrying out a literature review and survey of international industry practices, we sought to determine the potential for use of a library tray system for tracking, and thus potentially improving Australian avocado fruit quality in the local and/or export marketplaces.

Methodology

An extensive literature search of all likely web-based sources was undertaken. Published literature is not common in the area of library tray systems (we found only 5 publicly available references, these being from the New Zealand Avocado Industry Council). Most information and systems are contained in commercial entities such as packhouses or distributor/exporter groups. Thus, information on this topic was obtained primarily by email and discussions with people who responded to a worldwide email of postharvest researchers and commercial personnel (via the International Postharvest Email List which accesses over 500 people).

We gave priority to first finding as much information as possible on use of library trays by avocado industries, then as many other fruit industries as was feasible in the limited timeframe. Industry representatives were questioned by interview, phone or email (as appropriate), to determine the pros and cons of the system and any lessons that could be learned. Information from international respondents were often of a relatively general nature and are referred to as personal communications (e.g. “name”, pers. com.) since commercial sensitivity and intellectual property issues precluded access to in-house documentation.

Overview of Industry Practice

Other Fruit Industries

1. Aims / Motivations for use of a library tray system

Overall it appears that there are two main drivers for the use of library trays in fruit industries worldwide. The first and probably main driver is the “insurance” mentality. That is to say, the industry, packhouse or exporter wish to have a sample of fruit which can be examined should quality issues arise in the export market place. The second main driver, particularly in the more advanced and progressive companies/industries, is to have a predictive or diagnostic tool in a "tree to supermarket trolley" quality management system (Krajewski, pers. com.).

In providers to export markets, the motivation is most likely to be to counter claims (Arpaia, pers. com.) where poor outturns can be compared against library tray results. This may be a two edged sword for growers since some packhouse/exporters may use results to debit growers for the costs of repacking their fruit, if the library tray samples support a claim from the market agent for defects at point of sale, rather than such costs being pooled over all producers (Krajewski, pers. com.).

A good example of potential “predictive” benefit is that of “feeding forward” information to marketers enabling them to plan for potentially poor storing fruit which is on the way to the market. For example, simply being told ahead of time, NOT to plan to store for extended periods of time can have significant benefits and avoid loss of fruit quality, money and market credibility (Krajewski, pers. com.).

2. Practices

Sampling and replication: The most common practice is to remove a sample of ≅ one tray or box of fruit per line of fruit packed (i.e. one growing area on a given day). The level of fruit sampled is generally 20 to 50 fruit (depending on fruit type, size and value), which of course is a very low proportion of the total (<0.5%; Paull, pers. com.).

The point at which the fruit are sampled should be driven by both the financial resources available and questions such as:

1. How does overall fruit quality differ between packhouses?
2. How does overall fruit quality differ between individual growers?
3. Using averages of the above, how does overall fruit quality differ between growing regions?
4. Using further averages of the above, how does overall fruit quality differ over the harvest season, and between seasons/years?
5. How can we improve overall fruit quality (local and/or export)?
    - What can growers do to improve fruit quality at harvest?
    - How can harvesting and transport to the packhouse be improved?
    - How long can fruit be stored for and remain acceptable?
6. Who is at fault for poor outturn in the market?
    - Where is the main decrease in fruit quality occurring?

Although samples could theoretically be collected directly from the trees or picking bins in the orchard, or on arrival at the packhouse, by far the most common sampling point is after

grading (i.e. off the “drop” of the grading machine), or after packing (off the pallet). In general only one count size is sampled.

Storage and Assessment: Fruit is generally stored on site (in the packhouse coolstores) for one storage period at the standard industry temperature. The storage duration is most often selected to be the average duration that fruit are likely to be stored to reach an overseas market including some time period for in-market storage and distribution. Attention to storage temperature/environment is generally not likely to be rigorous (i.e. fruit stored in one area of the packhouse that is easy to access and may not reflect the average coolstore temperature or airflow conditions).

Assessment is generally carried out by trained packhouse staff after a standard shelf life period at 20°C. A visual assessment at removal from storage may also be carried out.

Standards, Actions and Reporting: The standards for reporting and actions are generally set on an individual packer or exporter basis (Krajewski, pers. com.). However, if there are phytosanitary issues (pest or disease), or chemical residue issues, then mandatory reporting and protocols are activated. Many fruit marketing companies have their own protocols and standards in place, and packers may sign undertakings to comply with the specific requirements of companies who are contracted to buy their fruit (Krajewski, pers. com.). Although some of these may have been publicly available in the past, most are now confidential.

Information dissemination is usually by phone or email, often with copies of inspection or fruit quality reports attached. Digital photos may also be used at this point. Issues of confidentiality are dealt with as stipulated in contracts, or as outlined in procedures and protocols that might be set up by the producers in question. Large growers may also use the library tray system to assess how their pickers are handling fruit. Growers may also be shown what their fruit samples look like in the event of dissent at unfavourable reports concerning their fruit. (Krajewski, pers. com.).

Linking to other systems: If maximum information and improved fruit quality is to be achieved, a library tray system is best combined with other systems such as product traceability, out-turn assessment and feedback from the marketplace (primarily from importers and wholesalers). Traceability is becoming an industry standard and is carried out to different levels of stringency depending on the market and country of origin. This should include maintaining information on at least the block that fruit were harvested from, and preferably other information such as grower information, picker, harvest date, and pack date. Higher levels of traceability are being instigated with the ability of consumers to “reach back” to find grower and supply chain information, with for example by the use of cell phones technologies linked to bar-code systems. However, a key system, combined with a library tray system, that can lead to improved information and thus improved fruit quality is “in market” out-turn assessment. This can be carried out at a number of levels. An example of a relatively simple cherry out-turn assessment sheet is shown in Appendix 1. Other industries may have detailed assessment systems in-market, and these may involve a full-time industry representative (as is carried out for avocados in Europe for the South African industry).

Table 1. Summary of use of library trays in fresh produce industries (other than avocado) internationally. (Information obtained via email respondents from the world-wide postharvest community.)

Country	Crop	Market (Local/export)	Assessors	Storage / Shelf life	Source
Hawaii	Pineapple Papaya Ornamentals	Local & Export Local & Export Local & Export	Packhouse Packhouse Packhouse	1-2 weeks storage + 1 wk vase life	Robert Paull (University of Hawaii)
Canada	Sweet Cherry	Local	Packhouse		Peter Toivonen (Ag Canada)
Peru	Mango Asparagus	Local & Export	Packhouse		Mary Lu Arpaia (University of California)
California	Citrus	Export	Packhouse	Visual (external) assessment for up to 4 weeks	Andrew Krajewski (International Citrus Technologies)
New Zealand	Cherry	Export	Packhouse	3-4 weeks storage, then immediately out of coolstore, and after 2 days. Quality, but can access for residue analysis	Duncan Mathers (Sarita Orchard Ltd)
New Zealand	Kiwifruit	Export	Packhouse	Storage	Bob Jordan (Plant & Food Research)
Israel	All fruit crops	Export	Packhouse		Susan Lurie, Volcani Research Centre
South Africa	Citrus	Export	Packhouse	Storage, up to 4 weeks	Andrew Krajewski (International Citrus Technologies)

NZ Avocado Industry

1. Introduction

The NZ experience of library trays provides a good learning opportunity for the Australian Avocado Industry because there is published information in this area (e.g. www.nzavocado.co.nz; Avocado Industry Council 2007, 2009) and the authors have access to industry body and grower personnel to interview. In addition, although NZ has a stronger export focus, there are many similarities between the two industries.

The NZ Avocado Industry Council (AIC) has spent a considerable amount of energy and revenue developing an industry-wide library tray system. This has been running now for nearly 10 years (Henry and Dixon, 2001; Dixon and Pak, 2002). AgFirst have become the main commercial entity that carries out more than 90% of the library tray assessments. They are a commercial company that specialises in providing "independent high quality horticultural services and solutions" (http://www.agfirstbop.co.nz/maturity/) and work across a wide range of crops.

The impetus for establishing the system in New Zealand came out of quality problems at out-turn in spring 1999 in the USA market. The programme was developed and recommended as best practice in 2000/2001 (Henry and Dixon, 2001), and established as compulsory for export lines in the 2003/2004 season.

2. Aims

The aims of the programme are four-fold:

- The main aim is to provide feedback to growers on the quality of their fruit. There is no incentive to do something about a problem unless you are aware of it and generally growers would otherwise not receive direct feedback unless fruit quality is extremely bad and fruit is rejected
- Pinpointing problems / issues. This can provide an early warning system (e.g. incidence of fuzzy patches (skin damage which might be rots) in 2004), provide trends over a season and between seasons, and be used to solve issues commercially
- Providing a snapshot at key times in the export season
- Providing R&D directions and focus.

3. Practices

It should be noted that the library tray system employed by the AIC has developed over a number of years with changing practices. The following outline is the current system which has been arrived at after robust "road testing" and is outlined in Avocado Industry Council Best Practice Guides (Avocado Industry Council, 2007). The number of fruit assessed each year in this system is between 20,000 – 30,000 fruit.

Sampling and replication: One tray (consisting of ≅ 20 fruit = 5.5 kg) of fruit is removed from the end of the grading line (i.e. after grading and weighing) and fruit should be sampled over the entire duration of the packing time for that grower line (i.e. not simply one tray removed from the pallet stack). One sample (one tray) each month is required, which translates into 6-8 times in the season (season can be 7 – 9 months long) for the larger growers (although clearly this will depend on the harvest schedule. It should be noted that some growers may pick weekly. The fruit is then coolstored on site till it is collected by AgFirst staff.

Information collected: Key information is collected including, property ID, region, harvest date, count size, packer, and time delay from pick to pack.

Storage and Assessment: Fruit is stored on site (in the packhouse coolstores) and the commercial company (AgFirst) that is contracted to assess the fruit liases with packhouses to uplift the samples on a regular basis (although it may be as long as a week or two that fruit are held in the packhouse coolstore). AgFirst staff drive weekly to pick up fruit and transport it in a small 5°C coolstore (≅ 50 trays of fruit) directly to the AgFirst facilities in Katikati (Bay of Plenty near Tauranga) where they are coolstored till assessment. Travel time to Whangarei from the AgFirst facility (Katikati) is ≅ 5 hours drive (one way) and ≅ 8 hours drive to the far north. Fruit are stored at 5°C for 4 weeks (from the time of harvest) and the ethylene concentration is monitored weekly, with weekly venting. If a concentration of over 0.03ppm ethylene is found, then more regular venting is carried out, as much as daily if required. The time to assessment is based on the time from harvest.

Assessment is carried out by a limited number of AgFirst trained staff who use the AIC Avocado Assessment Manual to assess fruit quality. Fruit is assessed at removal from storage ("Green assessment") where the external appearance is examined, with particular emphasis on skin damage. The key disorders examined here are fruit firmness and colour, physical damage and fuzzy patches ("Irregular shaped black/grey spots or patches on the skin of the fruit where the edges of the black/grey areas are defined by fuzzy or indistinct edges, i.e. it is difficult to detect the boundary between healthy and affected tissue" and discrete patches ("Irregular shaped black/brown spots or patches on the skin of the fruit with clearly defined sharp or discrete edges"). Digital photos are taken at this time which may be used in discussion and/or feedback to growers, packhouses or exporters. Photos are only taken of unsound fruit (i.e. those showing significant levels of disorders).

Fruit are held at 20°C in an air conditioned laboratory and relative humidity is monitored (generally ≅ 60-70%). Trays of fruit are placed in a single layer (with rare exceptions) to ensure maximum air-flow and even temperatures. Ethylene had been monitored in the past but was not found to build up significantly, and thus is not monitored currently. Once each fruit ripens to a standard firmness, external quality is rated and internal fruit quality assessed after cutting fruit. The ripeness stage selected is a Firmometer value of 80-100 (using a 300g weight). (See White et al. (2009) for description of fruit firmness measurements.)

Standards, Actions and Reporting: Standards for the whole library tray system procedure are set out in the AIC Avocado Quality Manual and the "Fruit quality Best Practice Manual" (and other in-house industry documents; Avocado Industry Council 2007), and the fruit quality assessment and disorder assessment systems are set out in AIC Avocado Assessment Manual.

The AIC has invested significant time and IP in the development of an access-based system for entry and reporting of fruit quality data (both from the library tray system and from offshore out-turn assessments). For the library tray system, the data is generated in an "Entry Module" by AgFirst, then emailed to the AIC in an importable form and the data uploaded to the AIC database. Reports are generated by AIC staff on the basis of this data. Reports are generated and emailed to recipients (the database is neither online nor accessible to other parties). Reports are generated on a number of levels: industry-wide, packhouse, and grower.

Report to Grower: There are three graphs generated for each grower (Figure 1 shows two of these) and these provide progressively more detailed information on the fruit quality results. The first is a graphical summary of the grower's fruit quality data in relation to rest of the industry. The distribution of each disorder is standardized to allow comparison of quality relative to other growers for each disorder i.e. the focus is on relative performance rather than absolute quality. Incidence of the unsound fruit in the sample compared to the average

for the packer and the overall industry average. An interpretation guide is provided on the AIC website (Avocado Industry Council, 2009).

Report to Exporters: Comparison of library samples with samples taken at out-turn, serves to identify any problems which may have arisen as a consequence of the shipping or handling system, once the fruit has left the packhouse.

Report to Packers: An AIC-funded project is underway attempting to relate differences in handling methods between packers to determine the extent that they may have contributed to quality differences.

The AIC has provided popular articles to assist the industry with interpretation of the results (Figure 1 is from such an article). In addition, at the NZ Avocado Industry Packshed Forum (held twice a year), oral reporting is carried out to packhouses with discussion.

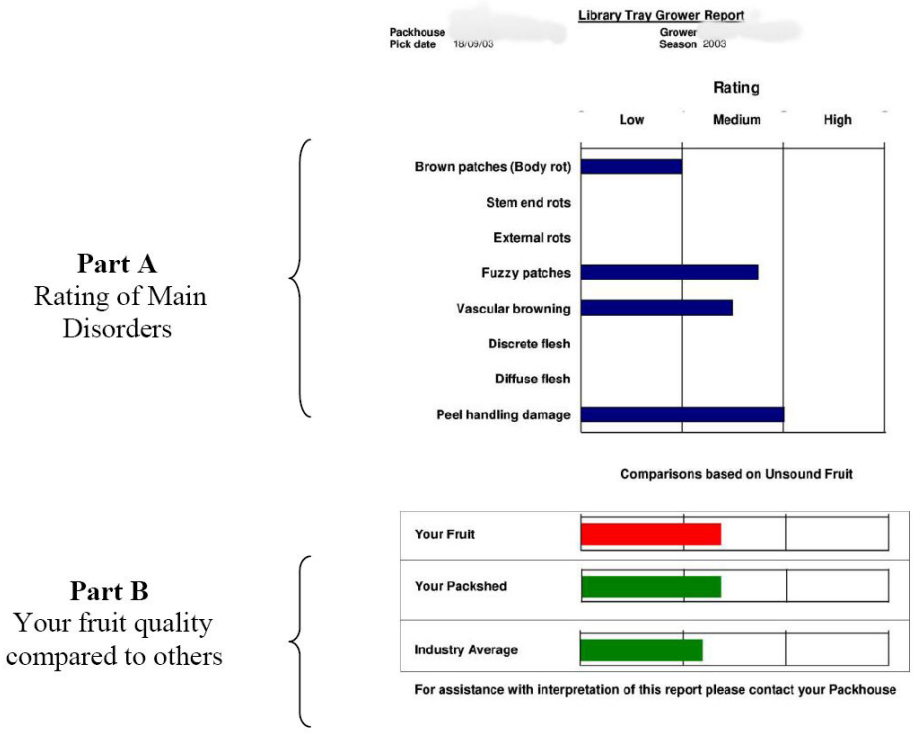

Figure 1. Examples of the grower-based report provided by the AIC (Figures from "Grower Library Tray Reports An interpretation Guide"). In this example, the grower's fruit are demonstrating slightly higher proportion or unsound fruit (more fruit disorders) than the industry average, but similar to the grower packhouse.

As noted elsewhere, the AIC uses the library tray system as a means of improving overall fruit quality by making practical recommendations to growers and packers. Following are examples of the sort of recommendations that are made by the AIC (AIC, Fruit Quality Best Practice Manual, 2007). Although these are not made solely on the basis of the library tray system, the system has contributed significantly to such developed knowledge:

1) To Growers:
    - Apply preventative fungicides regularly
    - Create an unfavourable environment for infection
    - Remove inoculum sources

2) To Growers and Packers
    - Minimise weight loss
    - Minimise field heat in fruit
    - Avoid picking wet fruit
    - Minimise fruit damage

2) To Packers
    - Avoid condensation on fruit
    - Minimise weight loss
    - Remove field heat

Comments/limitations

It should be remembered that although the library tray system is intended to simulate the export process (in terms of temperature and time), it is not a complete replication and one expects that fruit quality of the library tray fruit will be better than export fruit (since temperature control should be superior and there is a lack of physical damage that occurs during even the best transport)

Overall, for small growers results are likely to be less reliable, but generally for larger growers the library tray trends in average fruit quality fits with the industry trends (AIC, pers. com.).

In the New Zealand system the use of pooled payment for growers effectively works against the library tray system. That is to say, poor fruit quality results do not have a direct impact on returns to the grower, and thus a grower (or even packhouse) response can be “yes, I see my fruit quality is lower than average, but that doesn’t worry me, I am only interested in my returns”.

One issue found in the New Zealand system has been the unease of the exporters with the fact that the AIC has information on their fruit quality, even though confidentiality is maintained.

Some of the key improvements that were made over the years by the AIC have been:

1. Central/one point of fruit quality assessment. Although this is not regulated (since it is the packhouses responsibility to assess the fruit), almost all packhouses choose to use the one provider (AgFirst). The main reason for centralization was the variability in assessment techniques – use of a Firmometer was made mandatory – and all but one packhouse considered Agfirst to be a cheaper alternative. It was noted that the data collected prior to AgFirst was generally not relied on greatly in any analysis (AIC pers. com.).

2. Transport of fruit from packhouse to central assessment facility. This was changed to be by AgFirst staff rather than courier due to problems with reliability and recognition of the importance of maintaining coolchain.

3. Improvement in the quality, extent and speed of reporting.

The current cost for each assessment is NZ$74 (≅ AUD60), which includes the cost of fruit (≅ NZ$20).

Even some of the apparently minor issues can make significant differences. For example, previously fruit was moved from packhouses to AgFirst by courier but breakdowns in this system has lead AgFirst to uplift all fruit, even though this involves significant time cost in terms of travel and staff.

Discussion

Interpretation - Whose role is this?

There is currently some discussion within the New Zealand industry with regards to how to enhance the usefulness of the information from the library tray system for the grower and packer. Both the AIC and industry see a need for not only reporting the data (fruit quality by grower, or averaged grower or packhouse), but digging down to the reasons for any differences identified (examining grower spray diaries, weather patterns, practices on the day etc).

The challenge to achieve this is one of resourcing, particularly for the collection, analysis and interpretation of the generated data. Firstly, to adequately “drill down” to grower/harvest level there needs to be a significant increase in the amount of information collected (e.g. rainfall, temperature, handling/transport issues etc), and of course this data must be “robust” and accurate. The information then needs to be assessed in light of the library tray results (and preferably any out-turn results that are available from the AIC or exporter). The perspective of the AIC is that this is best done at the packhouse level since packhouse staff such as Grower Liaison Officers (or similar) are the ones that know orchards and growers best, are best placed to obtain information, and best placed to “tech transfer” the information and recommendations back to the grower. While this is likely to work best for packhouses who run under a single exporter (e.g. Team Avocado) with strong support structures and cohesion, it is significantly more problematic to instigate in smaller packhouses, those who operate as “service packers”, or those packing to multiple exporters.

Alternatives to a system of “routine sampling of all growers through the whole industry” could be to focus on the larger growers and packhouses (thus continuing the line of information that has been obtained, albeit on a more limited basis).

Lessons learnt

In discussion with the AIC they were asked what they would do differently with the wisdom of hindsight. They said that there were two key points. Firstly they would spend more time on getting industry buy-in at all levels; grower, packer and exporter. Secondly, they would manage the industry expectations from the system to ensure that they are realistic.

Outturn Monitoring Program

In order to maximise information and improve fruit quality in the markets, the AIC has carried out outturn monitoring in key markets over the years. Initially (early 2000), an AIC staff member was based in USA for 4 months taking samples of fruit from USA handlers each week. Photographs and reports were sent back to New Zealand and data compared back to the library tray programme activities using the centralised database system.

With the decline in volumes to the USA market, outturn monitoring has been moved to Australia, and may be carried out in Japan in the future if this market increases.

Other Avocado Industries

1. **Aims**

The most common motivation appears to be an insurance mentality, i.e. to be able to refer to the library tray should there be out-turn problems in the market. However, some use the system to drive improved fruit quality (South Africa).

2. **Practices**

Generally, one tray of fruit is obtained from the packing line and held in storage for the "typical" storage period at standard industry temperatures. Fruit are assessed by trained packhouse staff. Other than the New Zealand industry, probably only the South African industry has developed some form of standardisation for fruit assessment since nomenclature and photos of fruit disorders has been used in out-turn assessments over the years.

In South Africa, sampling has been more extensive (possibly due to great financial resources) with five trays of fruit (≅ 16 fruit / tray) taken from the line. From each tray, eight fruit (i.e. a third of the fruit) are sampled at the following times:

1) Before coolstorage (i.e. immediate assessment - no coolstore)

2) Immediately after storage (28 days after harvest)

3) After ripening following storage

Fruit are stored for 28 days (average time to arrival in Europe is 24 days). Reporting is carried out as a summary of all quality parameters per consignment and a running summary of averages as the season progresses. Reports are provided to the grower (or field manager), to the technical team (a range of industry players) and marketing teams. Further statistical analysis is carried out at the end of the season and correlations made between seasons and blocks (Gawie Eksteen; pers. com.) and this information made available to the wider industry (generally reported at the annual grower conference).

Table 2. Summary of use of library trays in avocado industries internationally (from international email respondents).

Country	Market (Local/export)	Assessors	Storage / Shelf life	Source
Peru	Local & Export	Packhouse		Mary Lu Arpaia (University of California)
Chile	Local & Export	Packhouse	28 days – two count sizes	Mary Lu Arpaia (University of California)
California		Packhouse		Mary Lu Arpaia (University of California)
South Africa	Export	Packhouse	28 days	Gawie Eksteen, (GJ Eksteen Advisory Services)

Key Issues for Consideration

KEY FACTORS IN THE SAMPLING, ASSESSMENT AND REPORTING SYSTEM

The key factors for consideration are standardisation and representation. If one or both of these factors are not achieved, then the information obtained is, at best, less applicable, and at its worst seriously misleading. If the fruit sampled is not representative of the overall crop then results have progressively less applicability to the overall crop. For example, if only one tray is randomly removed from a line, or one sample taken from a picking bin, there is a high chance that this will reflect a picker, block, or within-block effect. Another example would be where packers have been known to use second class or local market fruit (rather than export fruit) as a cost reduction technique. Clearly such fruit are less likely to represent the export crop in a range of quality measures.

Similarly, an absolute key is the standardisation of sampling, storing/ripening, and assessing methods. This is particularly important for avocado where, for example, ripening at higher temperatures (e.g. 25°C) results in higher rot levels, while temperatures of 15°C can minimise rot incidence (Hopkirk et al., 1994). Thus, if packhouses use different ripening temperatures, they will obtain significantly different rot levels that do not reflect inherent preharvest/grower factors. Ripening temperature will of course also influence the time to ripeness, as will ethylene levels in the shelf life environment. Standardisation must also be applied to all other areas wherever possible and practicable.

Perhaps the most important question to ask is what information and outcome does the Australian Avocado industry seek. Clearly issues of funding / cost come into this equation.

1. **Sampling**

Where to sample from: Clearly the choice of where fruit are sampled from in the harvest and packing process is important. Most significantly it influences the information obtained and the applicability of the information. This is perhaps best illustrated by thinking of how one would go about finding out the relative importance of handling damage on fruit quality. In this case one would consider sampling from multiple locations along the supply chain (from the tree, from picking bags, from the picking bin in the orchard, and finally from the bin in the packhouse). Each sampling point in this process will answer different questions, for example, is it the dumping of fruit into the picking bin that is the problem, or is it the transportation of the bin by tractor from the orchard?

Given that the brief of this work is to summarise the use of library trays, by definition this means that fruit are not collected from the marketplace (since this would then be a market survey, as carried out in the AvoCare projects by Hofman et al.), we consider the packhouse to be the last commercially feasible point in the handling chain to sample from, although if the export market is the key focus, then one might obtain fruit from a central marketing location (say exporter or port).

There are potentially a number of places in the harvest and packing chain where fruit can be sampled for use in a library tray system:

- From the orchard/tree
- From the picking bin in the orchard
- From the picking bin in the packhouse on arrival
- From the picking bin after the holding period prior to storage (which could be at ambient or coolstored)

- Prior to, or after, the grading table
- After cleaning/brushing and weighing (i.e. from the “drops” of the packing machine)
- From a pallet of fruit (in trays or boxes)

The most sensible point and the one most commonly sampled is somewhere during the packing process. Overall, the most common sampling point occurs after grading and sizing, and generally from fruit of the most common fruit size (count size). This way the sample reflects fruit quality of fruit of a standard size and fruit grade (freedom from blemishes/wounds etc). The simplest is by removing a tray of fruit from a pallet stack, but representation will be compromised.

Sampling can be carried out in either of three general ways. Sampling of a single sample of fruit at one time from one bin or tray, sampling from a number of points at one time (e.g. from multiple bins or trays at one time), or sampling from one point over time taking, say, every 1000^{th} fruit, or one fruit every 10 minutes during packing of the line. It is suggested that the latter approach would be the best approach to ensure fair representation.

Number of fruit to sample: The number of fruit sampled will clearly influence the validity of the results and is influenced by the level of the disorder one is aiming to measure, and of course the robustness of the result from a statistical point of view. When selecting an appropriate sample size a number of factors can influence the decision. Such factors include economic constraints, which could prevent large numbers of fruit being sampled, while for statistical accuracy a large number of fruit may be required.

A Statistical Perspective: An example of the latter would be to consider that if a “margin of error” of no more than ± 5% was wanted around the estimated incidence then a sample size of 385 or more would achieve this 95% of the time. A smaller sample size increases the chance that the margin of error will be greater than 5%. This number was calculated assuming simple random sampling and a conservative estimate that the true incidence is 1 out of every 2 fruit having a disorder.

Another factor influencing sample size is the type of statistical model planned to be used in the analysis. A common method for dealing with incidences is to use an approximation, called the normal approximation (Brown et al., 2001), which may not be valid when the sample size is small and the sample incidence is either very low or very high. One rule of thumb is that the minimum of p and 1-p times the sample size is greater than 5 (Brown et. al., 2001). In other words, if we have at least 5 fruit with the disorder and 5 without then the normal approximation can be used.

One other concern could be limiting the chance of a ‘bad’ sample, for example having a sample which fails to detect a disorder when in fact it is present in the population.

If we take 5 incidence levels 5%, 10%, 15%, 50%, and 75% and take samples of 20, 60 and 100 fruit for each incidence level we would expect to obtain the range of observed incidences shown in Table 3.

Table 3. Effect of sample size on expected range of measured incidences compared to the true incidence.

True incidence	Sample size	Expected range of observed sample incidences	
5%	20	0%	15%
5%	60	0%	12%
5%	100	1%	10%
10%	20	0%	25%
10%	60	3%	18%
10%	100	5%	16%
15%	20	0%	30%
15%	60	7%	25%
15%	100	8%	22%
50%	20	30%	70%
50%	60	37%	63%
50%	100	40%	60%
75%	20	55%	90%
75%	60	63%	85%
75%	100	66%	83%

The expected range is where we would expect a sample incidence to lie in 95% of the time. For example if we had a true incidence of 15% and took a large number of random samples of 20 fruit we would expect that the sample incidences would be between 0 and 30% at least 95% of the time. The lower bound of 0% indicates that there is a reasonable chance of having a sample with no defects present; this chance is approximately 1 out of 20. However for all other sample sizes/incidence combinations this chance is less than 1 out of 10,000. The table also indicates that as the sample size increases the range of observed incidences moves towards the true incidence. The smaller the true incidence, naturally the more likely a 'clean' sample is. This could be even worse if we had a true incidence of 10%, here just under one out of every 8 samples of 20 fruit would have no defects, while if the true incidence was even lower at 5% it would be over 1/3 of the samples.

In summary it can be seen that with a low true incidence and a small sample size there is a very real danger of not detecting the defect in the sample. By increasing the sample size we reduce the probability of an undetected disorder. For larger incidences this is not so much of an issue. All calculations assumed that each fruit had the same chance of being defective and they were independent, meaning that if one fruit had the disorder then it didn't make the other fruit more or less likely to develop the disorder.

Sample size selection: The number of fruit sampled must also be balanced against cost of fruit, cost to sample fruit, but more importantly cost of labour to assess the fruit. In New Zealand the cost to assess one tray of fruit and receive basic reporting of data is NZ$75 (≅ AU$60).

Generally one tray of fruit (≅ 20 fruit) is considered acceptable in commercial terms, but a higher level of replication will yield more reliable results. One possible way of increasing the information obtained is to sample one tray from each of the two or three most common fruit sizes.

Frequency of sampling: The issues with respect to sampling frequency are similar to that of the number of fruit sampled. The greater the number of sampling times, then the greater reliability of the data. Generally, most sampling is carried out for each pack-line of fruit for

the orchard in question, or on a monthly basis. However, again, this depends on the question one is seeking to answer; is it grower to grower variability, packhouse effects, time in the season, or indeed season to season variability that one is seeking to understand?

2. Storage and ripening: Selection and environment

Number of assessment times during storage and ripening: Many different times could be selected to assess fruit quality, and indeed more information and robustness of results will be achieved by multiple sampling/storage times. This could include a non-stored sample (ripened directly without storage), one or two storage times, and finally a visual (non-destructive) assessment at removal from storage (which can then be ripened for internal fruit quality assessment).

Other than the selection of timing (and number) of storage/assessment times, the choice of conditions, and standardising of the storage and ripening conditions are critical to the results obtained and their translation into improved fruit quality.

Storage. It is well known that the duration of storage has very large effects on fruit quality, with short storage (≅ 1 week) generally leading to some improvement of quality (most likely due to faster ripening), while storage times of 21 to 28 days lead to reduced quality (mostly due to rots - under Australian conditions), and then for over ≅ 28 days leading to large reduction in quality due to physiological disorders such as diffuse flesh discolouration (flesh greying, Woolf et al., 2004). The very large effect of longer storage times that can occur are illustrated in Figure 2.

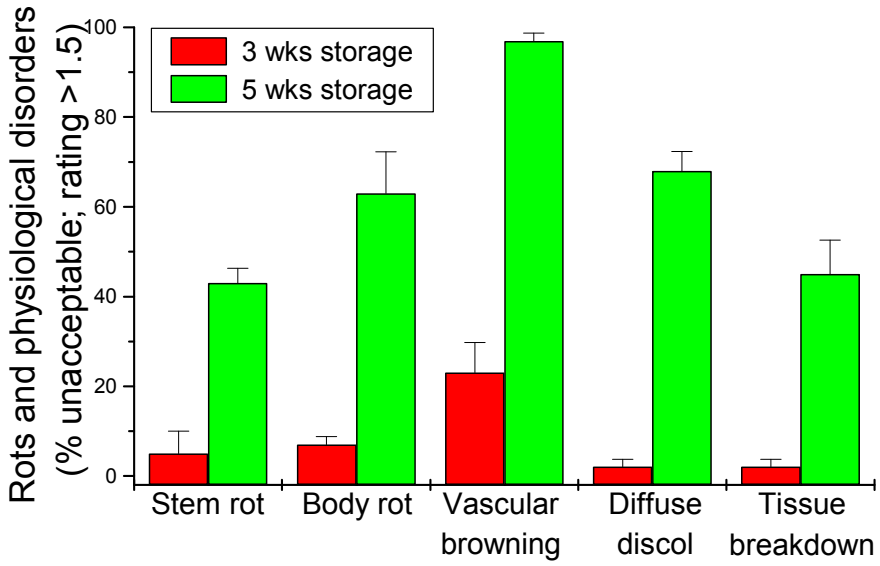

Figure 2. Severity of stem rot, body rot, vascular browning, diffuse discolouration and tissue breakdown in 'Hass' fruit stored for 3 and 5 weeks at 5.5°C and assessed when fully ripe (Average Firmometer value using a 200g weight = 80). (November harvest). (From White et al., 2000.)

The storage duration selected should clearly reflect the commercial conditions that the library trays are trying to emulate. For export markets which generally require seafreight, a duration of storage can be chosen which reflects the average time required for harvest, packing, ship loading, seafreight (ship voyage), and some average time "in market". For NZ

export, a time of 21 days is used for fruit destined to Australia, and 28 days to the USA. Other countries such as South Africa and Chile also use a duration of 28 days (Table 2).

Storage temperature is also of significant importance, since temperature differences of as little as 1.5°C can lead to large differences in fruit quality (White et al., 2000; Figure 3). Although differences in optimum storage temperature can change during the harvest season, one storage temperature is generally used for storage.

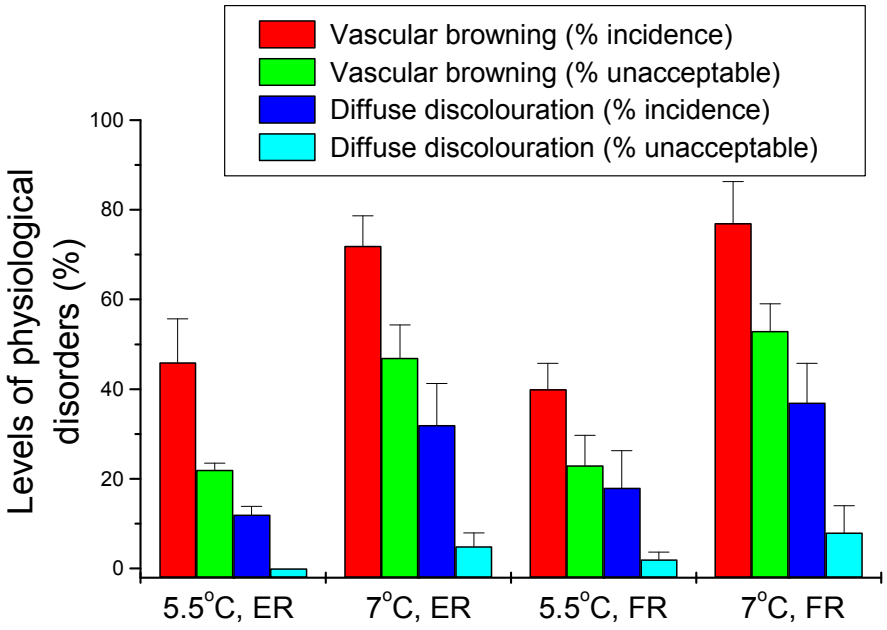

Figure 3. Incidence and severity of vascular browning and diffuse discolouration in 'Hass' fruit stored for 3 weeks at an air temperature of 5.5 and 7°C and assessed for quality at either an early (ER) or fully ripe (FR) stage of firmness (average Firmometer value using a 200g weight = 60 or 80, respectively; November 1999 harvest; White et al., 2000).

Avocados are sensitive to ethylene at low (i.e. storage) temperatures (Zauberman and Fuchs, 1973) and can promote ripening and internal disorders (particularly internal chilling injury disorders such as diffuse flesh discolouration). Thus, the concentration of ethylene in the storage environment should be minimised, and the concentration recommended by the AIC (0.03ppm) is a reasonable threshold. Weekly venting of the coolstore is recommended

Ripening. The environment used for ripening (simulated shelf life) is another important factor which requires standardisation in order to obtain valid results. Key factors for ripening are temperature and ethylene levels.

Ripening temperature has significant effects on both the shelf life (time to ripen), but more importantly the level of rots. Hopkirk et al. (1994) showed that ripening at 15°C leads to significantly less rots, and that 25°C leads to more rots than 20°C. Further work (Cutting and Banks, pers. com.) showed that temperature differences as little as 2.5°C (i.e. 22.5°C) resulted in statistically significant increases in rots. Thus, ripening temperature must be carefully controlled using good airflow since avocados produce significant heat during ripening, and even relatively small stacks of trays (4-5 high) can lead to temperature differences between trays.

As is well known, ethylene hastens ripening of avocados (Gazit and Blumenfeld, 1970) and during ripening they produce large amounts of ethylene (one fruit in a 1 litre container can generate 5-10ppm ethylene in one hour). These factors can therefore confound results if fruit are placed in a ripening environment that has differing ethylene levels. Since shorter ripening times lead to reduced disorders in general, but particularly rots, it is important to standardise and minimise ethylene levels in the ripening environment. A concentration of <0.1 ppm is recommended.

Relative humidity (RH) and carbon dioxide should also be considered during the ripening phase of avocado fruit. If possible, the RH should be maintained at as constant a level as possible (≅ 60-80%), but this can be difficult with changes in weather conditions (e.g. higher outdoor temperatures will lead to more cooling and thus lower humidity and *visa versa* if ambient temperatures are below 20°C). Carbon dioxide can lead to slowing of fruit ripening, although we have found the levels that are below human safety levels (≅ < 2-3%) are unlikely to have significant effects on ripening times or fruit quality.

Clearly with the range of factors noted above (and the following issue of standardisation of assessors), using one centre for assessment would be preferable. Our observations of ripening procedures used in the past in NZ packhouses are that large differences in temperature occur easily unless very careful attention is paid to air-conditioning and temperature systems. However, this area is usually outside the core function of the packhouse, and thus typically less attention is focused on this process.

3. How to Assess

Standardisation of the assessment technique and terminology is fundamental to a robust library tray protocol. There are a wide range of terminologies for disorders around the world, and many of them are confusing and ambiguous. It was this fact and the lack of standardisation of firmness measures that lead us to develop an assessment manual in the AvoCare programme (The AvoCare Assessment Manual - White et al., 2001). This manual has been further developed over the years (funded by HortResearch and the California Avocado Commission) as “The International Avocado Quality Manual” (White et al., 2005) and now a further refined version has been printed (White et al., 2009) and can be purchased from the UC Davis, Postharvest Technology Research & Information Center (email: postharvest@ucdavis.edu). We believe that use of this manual in Australia is a pragmatic and cost effective solution to achieve both assessment and terminology standardisation. The NZ AIC uses its own version of an assessment manual (The AIC Fruit Quality Assessment Manual) to assess fruit in the NZ library tray system. The AIC manual uses a slightly different rating scale to that of The International Avocado Quality Manual and some differences in terminology.

Depending on the information required, an unripe or “green” assessment may be carried out, typically on removal from coolstore (i.e. when fruit are green). This is carried out to provide an assessment at a stage that importers/retailers are likely to see fruit, and as a means of determining levels of handling damage (i.e. physical damage to the skin) and early indications of rots.

Stage of ripening at assessment. As illustrated below in Figure 4 (and noted in Figure 3), the stage of ripening used is important since most disorders, particularly rots, increase significantly with ripening. It is therefore important to standardise the stage or ripening by use of a manual or system to define the stage of ripeness (e.g. White et al., 2005). Most importantly, well trained assessors must be used, and have a non-subjective method (e.g. penetrometer of Firmometer) to calibrate and check the ripeness decisions made by the assessors on a regular basis. We have found that a well trained assessor can rapidly and adequately determine ripeness using the “hand firmness” technique, although regular calibration is still required.

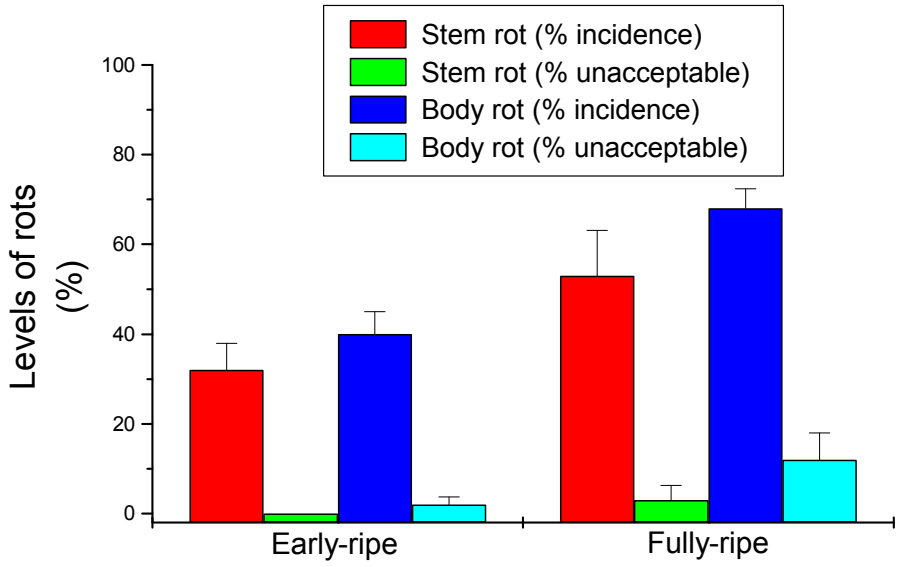

Figure 4. Incidence and severity of stem rot and body rot in 'Hass' fruit stored for 3 weeks at 5.5°C and assessed for quality at either an early or fully ripe stage of firmness (average Firmometer value using a 200g weight = 60 or 80, respectively; (November 1999 harvest; White et al., 2000).

4. Reporting / Use of Information

Reporting information can be carried out in a number of ways, and the target audience must be kept in mind. Issues to consider are the level of detail, the confidentiality of growers/packhouses/exporters, and the investment in data systems that are willing to be made. For example, should the system be a relatively simple spreadsheet based calculation of each disorder, or involve a more complex database system? Another possible avenue for information dissemination is the "Infocado" system already established with AAL.

The level of detail and relative simplicity of reporting may also impact on the speed of reporting, and, in general the faster the reports can be distributed the better.

"POLITICAL" FACTORS IN THE PROCESS

Given that the request for this review of library tray systems is being made by an industry body (AAL) rather than a packhouse or exporter, it is important to mention the more "political" issues which are inherent in implementing such a system.

A key issue to consider is the buy-in of the whole industry. Thus, adequate consultation should be carried out during the development of the proposed system, and workshops would be a logical path to move forward. As noted by the AIC, clarifying and managing the expectations are important to the longevity and outcomes of the programme. If the library tray system is developed and implemented well, it should actually be able to provide a sense of "trust" between the different commercial players since some objective measures of quality are available, particularly if linked to an out-turn monitoring programme.

Consideration needs to be given to the "stick" or "carrot" approach to the programme and the effectiveness of each. It is likely that a punitive system is less likely to be successful and is more likely to lead to bad reactions by growers and industry players.

The manager of AgFirst (AgFirst carry out the majority of the assessments in New Zealand) commented that the industry body should have regular input in to the fruit storage and assessment process (Ian Stevens, pers. com.). This comment was made because it is thought that it is required so that all parties can have full confidence in the system, particularly since some assessments (e.g. external disorders) may involve some measure of subjectivity and/or interpretation.

Recommendations

An overall perspective that should be borne in mind as the Australian industry moves forward is that a library tray system should exist not for its own sake, but to fulfil a clearly defined and useful role.

The “Library Tray System” concept can be interpreted in many ways depending on the objective. It is therefore very important to clearly define the objective of the exercise to make sure the correct questions are asked so that appropriate answers for practical implementation are found. The number of orchards and/or blocks needed to be sampled must be carefully selected along with where in the handling and packing chain the fruit are sampled from. Finally, careful selection of storage duration and temperature is required along with careful assessment of the fruit.

Data covering many seasons becomes even more valuable if compared with climatic conditions and preharvest procedures (irrigation, fertilization, rootstock, crop load, etc.), but the cost of collecting and analysing such information must be balanced.

One of the challenges for implementation of a library tray system to the Australian industry is the very large distances between growing regions. This means that a single point of assessment is logistically difficult and costly. Therefore, greater attention to standardisation of systems will be even more important. Countries such as New Zealand and South Africa both have a strong export focus and legislative support of a range of systems. This makes implementation of a library significantly easier than a country like Australia where the vast majority of fruit are sold on the local market.

Clearly the “buy-in”/commitment and willingness of either the individual growers, grower groups, packhouses, exporters or the industry body (AAL) to pay are key issues. Key to success is interpretation of the data and active interaction between all steps of the market and AAL.

It might be useful to plan a programme that involves different levels of rigour and depth over a number of years. This might involve initially providing a wider industry overview, then focus on key growers (good and bad), individual packhouses, and work through to define the key steps required for the programme. Consistent assessment of “reference” orchards / lines is required to verify improvements.

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Appendix

The following is an example of a document used to link an off-shore quality inspection with an on-shore library tray system tracking quality problems in cherry exports (New Zealand).

apexfresh

Quality Inspection Report

LOAD	EXPORTER	Freshco	IMPORTER	WLH	INSPECTION REF.	QF0820
	VESSEL NAME	Tasman Provider	VOYAGE NO.	110801	Load Date	12-Jan-08
	CONTAINER NO.	CRLU3159050	Discharge Date	22-Jan-08	Devanning Date	28-Jan-08
	Place of Inspection	WLH coolstore	Date of Inspection	28-Jan-08	Name of Inspector	Joseph Hsu

SAMPLE DETAILS	**Sample No.**	**1**	**2**	**3**	**4**	**5**
	Variety	Bing	Stella	Stella	Bing	Bing
	Pack Type	5kg	5kg	5kg	5kg	5kg
	Size	28mm	26mm	28mm	30mm	30mm
	Grower No.	S4084	S4032	S4032	S4084	S4052
	Pack House	Sarita	Molyneux	Molyneux	Sarita	Molyneux
	Run No.	27	589-2222	590-2222	27	534-2121
	Pallet	4845	no	no	4845	no
	No. of ctns in container					
Condition		"No. (in random sample of 100pc)"				
	Rots & Mold	1				
	Cuts (Wounds)	2	5	30	6	4
	Pitting	17	42	33	6	11
	No Stem					
	Soft	**1**				
	Stem/Calyx Split					
	Other (specify)					
	Total Spoilt Fruit	**20**	**47**	**63**	**12**	**15**
	% age Spoilt Fruit	**20.0%**	**47.0%**	**63.0%**	**12.0%**	**15.0%**
Quality	Size **Undersize**	1	2			
	Size **Oversize**					
	Total Cosmetic Defects	**1**	**2**	**0**	**0**	**0**
	% age Cosmetic Defects	**1.0%**	**2.0%**	**0.0%**	**0.0%**	**0.0%**
	TOTAL CUMULATIVE	**21**	**49**	**63**	**12**	**15**
	%AGE CUMULATIVE	**21.0%**	**49.0%**	**63.0%**	**12.0%**	**15.0%**
TECHNICAL	**Pressure (lb-force)**					
	Soluble Solids					
	COMMENTS(temp)					

Quality Inspection Report QF0820 *1*