Investigating efficient harvesting systems that improve product safety and quality

Ross Skinner
Almond Board of Australia (ABA)

Project Number: AL10009

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Level 7
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Telephone: (02) 8295 2300
Fax: (02) 8295 2399

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Investigating Efficient Harvesting Systems that Improve Product Safety and Quality

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Study Tour: Investigating Efficient Harvesting Systems that Improve Product Safety and Quality

Ross Skinner
Almond Board of Australia CEO

Almond Board of Australia
PO Box 2246
9 William Street
Berri SA 5343
T: 08 8582 2055
F: 08 8582 3503
E: rskinner@australianalmonds.com.au
W: www.australianalmonds.com.au

Key Personnel

Brendan Sidhu, Almond Board of Australia Chairman & Managing Director Jubilee Almonds
Ben Brown, Almond Board of Australia, Industry Development Manager

Purpose of Report

This Final Report has been prepared following the conclusion of the project Investigating Efficient Harvesting Systems that Improve Product Safety and Quality. The project summarises the outcomes of a study tour and industry workshop; and the critical next steps to improving the Australian almond industry's harvesting systems and product safety and quality.

Acknowledgements

This project has been facilitated by HAL in partnership with the Almond Board of Australia (ABA). It has been funded by the Australian almond industry levy and voluntary contributions from Jubilee Almonds. The Australian Government provides matched funding for all HAL's R&D activities.

Disclaimer

March 2012

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1 Media Summary

The Australian almond industry has sought to further enhance its quality reputation and safeguard itself from food safety risks.

Australia is the second largest exporter of almonds, exporting to more than 30 countries around the globe. In the next 3 years production will double to more than 80,000 tonnes. The Australian almond industry has developed and adopted world's best practices and reached a point where it is producing greater yields than the Californian industry, achieving an industry average of 2.97 tonnes per hectare, and product quality that is highly regarded.

However, rain during the 2010 and 2011 harvest led to significant crop losses, estimated to be greater than $20million in 2010. Product integrity has been potentially compromised, with mycotoxin (i.e. *Aspergillus*) and bacterium (i.e. *Salmonella, E. Coli, Listeria*) contamination major concerns.

Several factors are thought to contribute to food safety risks: insect damaged fruit; diseased fruit; the current harvest practices of shaking the fruit onto the ground and collecting the fruit once the hulls have dried; and uncontrolled climate storage of harvested product.

This project undertook a study tour, industry workshop, and preliminary R&D by the School of Advanced Manufacturing and Mechanical Engineering at the University of South Australia.

As a result of the activities undertaken a clear list of R&D opportunities were developed and a new R&D program established. The R&D program aims to develop a more efficient production system that would see: almonds collected at the point of harvest without contacting the ground; harvested fruit dried to the appropriate moisture equilibrium (e.g. 5%); controlled climate storage of harvested and dried product; and optimal quality sorting of product.

Following the successful completion of the proposed R&D program and industry adoption, the Australian almond industry will have further enhanced its product quality and ensured food safety.

2 Technical Summary

The Australian almond industry has sought to further enhance its quality reputation and safeguard itself from food safety risks.

Australia is the second largest exporter of almonds, exporting to more than 30 countries around the globe. In the next 3 years production will double to more than 80,000 tonnes. The Australian almond industry has developed and adopted world's best practices and reached a point where it is producing greater yields than the Californian industry, achieving an industry average of 2.97 tonnes per hectare, and product quality that is highly regarded.

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Several factors are thought to contribute to food safety risks: insect damaged fruit; diseased fruit; the current harvest practices of shaking the fruit onto the ground and collecting the fruit once the hulls have dried; and uncontrolled climate storage of harvested product.

This project aimed to investigate an efficient production system that would see: an integrated pest and disease management program; the product collected at the point of harvest without contacting the ground; harvested fruit dried to the appropriate moisture equilibrium (e.g. 5%); controlled climate storage of harvested and dried product; optimal quality sorting of product; and develop the prioritised direction for R&D projects.

The key research findings from the project were:

- New almond varieties are being released across the world that may suit a new production system of shaking and catching almonds.
- Almonds that prematurely fall (i.e. windfalls) to the ground prior to harvest is likely to be the largest barrier to shake and catch almond harvesting equipment.
- The side-by-side harvesting machinery produced in California (e.g. OMC Catchall VII) was the closest machinery that is currently available for shaking and catching almond trees; however, there are several challenges involved such as windfalls, tree architecture and row access. Modifications to the machine are likely to be required.
- The Tenias machine from Spain was the closest harvesting machinery that currently is available for shaking and catching young almond trees; however, the main challenge will still be windfalls. This machine will also be unsuitable for large trees.
- Techniques and equipment partially exists for the successful drying of almonds that have either been purposely harvested early or accidentally wet by rain.
- Techniques and equipment partially exist for the successful controlled climate storage of processed almonds.
- The Australian and Californian almond industries are keen to work more collaboratively on mutually beneficial interest such as certain R&D topics, food safety, market assurance, etc.
- There are considerable challenges and therefore R&D opportunities that exist in developing a more advanced almond production system that ensures high quality product and food safety.
- There are considerable engineering solutions that will improve product handling, storing, and sorting that will further enhance product quality and safety.
- A new R&D proposal has been developed that will go a long way towards a more holistic and advanced almond production system.

The key recommendations for the Australian almond industry are:

- The almond breeding program includes the assessment of windfalls in the selection criteria, with low or nil windfalls the objective.
- It will be important the industry continues to look at a more holistic approach to R&D priorities and therefore a requirement for ongoing overlap between R&D projects or programs.
- There were R&D priorities developed from the workshop and ensuing industry consultation that have not been contracted and will require investment once levies become available from 2013/14.

3 Introduction

The Australian almond industry is predominantly planted to Californian varieties which, whilst widely accepted in the market place, are vulnerable to food safety concerns. The food safety concerns arise from their soft shell, lack of shell seal and ground harvesting techniques. This project is to scope the opportunities for improvement of almond harvesting and more broadly, the production system.

Almond orchards are generally planted with up to four incompatible varieties which require cross-pollination, and also vary in maturity dates and consequently require different harvesting dates.

Varieties are to be kept separate at all times in the harvesting process, with "mixed nuts" receiving severe financial penalties.

The current harvest techniques and machinery have been imported directly from California and involve several steps to harvest the produce from the trees and retrieve it from the orchard. The steps include:

- Readiness of almonds for harvest assessed at approximately 5% kernel moisture.
- Shake almond fruit to the orchard floor.
- If kernel moisture content is not consistently 5%, leave almond fruit on the orchard floor until ready.
- Sweep and blow almond fruit across the orchard floor forming wind rows.
- Straddle the wind rows of almond fruit and pick it up using another type of equipment.
- Store the "dry" almond fruit in stockpiles, ready for primary processing (i.e. hulling, shelling and sizing).

Fruit moisture management and avoiding contact with the orchard floor during the harvest process provide ideal opportunities for minimising food safety incidents. This was particularly evident in 2010 where rain events during harvest led to spoilage of a significant tonnage of almonds. The value of the spoiled fruit was estimated to exceed $20million. Fruit that was recovered still had an increased risk of mycotoxin contamination. As such, the Australian almond industry required a review of current harvesting procedures and equipment, and research opportunities to shake, catch, retrieve and de-hull in a one pass procedure.

An allied issue is that to facilitate the pick-up of fruit from the ground, agronomic practices considered beneficial for soil health and water use efficiency are forgone. By developing a shake and catch system these practices such as cover crops, mulching, organic fertilisers etc could be adopted to deliver significant benefits from a yield and input efficiency perspective.

To deliver the objective of a single pass harvesting system it is envisaged that it will involve an agricultural engineering solution to de-hulling, and an efficient dehydration and storage system. It may also require an agronomic solution to retaining fruit on trees until harvest and/or drying them in situ prior to harvest.

Lessons from other industries indicate a holistic approach to developing production systems is required, particularly when focusing on engineering solutions.

This project was identified as a high priority in the almond strategic investment plan and a second year (i.e. 2011) of poor harvest conditions has provided an environment where industry commitment to addressing this area is very strong.

This project is a scoping study to identify and quantify the benefits and costs, and develop the best bet direction for a second stage research project.

4 Materials and Methods

To best develop a plan to take this research area forward, the following was proposed:

- Study Tour - undertake a study tour of relevant harvesting equipment in Spain and California. In addition, review current variety and rootstock releases.
- Workshop - conduct a two day scoping workshop.
- Student Project - support a student project to begin preliminary research into mechanical engineering solutions within the supply chain. Project is to be supervised by Associate

Professor John Fielke, Director of the Agricultural Machinery Research and Design Centre in the School of Advanced Manufacturing and Mechanical Engineering, University of South Australia.

- Future R&D - prepare a R&D proposal to expand on the findings of the previous activities.

5 Results

5.1 Study Tour

A two week study tour was undertaken by the project team to investigate various alternative machinery to mechanically harvest tree crops and manage high moisture; and new almond variety releases that may assist a new production system.

A brief summary of the key outcomes of the study tour were:

- Improved nursery techniques for grafting winter budwood.
- Discuss the final details required to complete a formal evaluation agreement for several Spanish almond varieties and rootstocks.
- More confidence that Independence, a variety increasingly being planted in California, is worth evaluating in Australia.
- Almonds that prematurely fall (i.e. windfalls) to the ground prior to harvest is likely to be the largest barrier to shake and catch almond harvesting equipment.
- The side-by-side harvesting machinery produced in California (e.g. OMC Catchall VII) was the closest machinery that is currently available for shaking and catching almond trees; however, there are several challenges involved such as windfalls, tree architecture and row access. Modifications to the machine are likely to be required.
- The Tenias machine from Spain was the closest harvesting machinery that currently is available for shaking and catching young almond trees; however, the main challenge will still be windfalls. This machine will also be unsuitable for large trees.
- Techniques and equipment partially exists for the successful drying of almonds that have either been purposely harvested early or accidentally wet by rain.
- Techniques and equipment partially exist for the successful controlled climate storage of processed almonds.
- The Australian and Californian almond industries are keen to work more collaboratively on mutually beneficial interest such as certain R&D topics, food safety, market assurance, etc.

The key implications for the Australian almond industry are:

- Improved tree production for nursery stakeholders.
- Improved rootstock and varietal availability following independent evaluation.
- Great understanding of the challenges and opportunities in adopting shake and catch harvesting techniques.
- Improved product quality by adopting product drying and storage.
- Improved international relationships.

A full report on the itinerary and findings of the study tour is located in Appendix 1.

5.2 Workshop

A workshop was organised for 16th and 17th August 2011 in Adelaide, South Australia. The 16th August was a social function in the evening to welcome everyone and the 17th August was the main workshop agenda.

The workshop participants were specifically invited based on their industry role (i.e. committee membership) or their skill set for those who were from outside the industry. The workshop was very well attended with 34 participants and only 7 apologies.

The workshop program consisted of presentations that set the scene by: attempting to outline a "normal" weather pattern for the period of almond harvest; describing experiences from the mechanisation and change in production system of the dried grape industry; a marketing view of product quality; experiences of a tree fruit contract mechanical harvester using both traditional almond harvesting equipment and shake and catch machinery; industry trials of alternative harvesting equipment; potential technological advances in almond processing; and highlights from the study tour.

The participants were then divided into separate groups that spanned the current and newly proposed almond production system: production; harvest; aeration/dehydration; hulling on-farm; storage; processing; and marketing. Each group were asked to discuss the opportunities to maintain or improve yield, reduce production input costs, reduce crop loss, improve product quality and reduce food safety risks. Following this they were asked to rate their discussions for feasibility of R&D and uptake by industry.

The R&D outcomes from the day's proceedings are summarised across the annual production cycle in Table 1.

Table 1: Summary of workshop R&D initiatives across the annual almond production cycle

Annual Production Cycle	R&D Initiative
Dormancy	• Improve methods of orchard sanitation. E.g. engineering solutions to remove mummies. • Introduce almond varieties with lower chill requirement to assist earlier harvest and avoid autumn rains. E.g. introduce harvest date as breeding selection criteria and evaluate overseas cultivars.
Bud Burst	• Promote evenness of bud burst to promote evenness of fruit maturity at harvest. E.g. Dormancy breaking chemicals, irrigation practices, nutrition practices, tree architecture, light interception and bud development.
Flowering	• Increase flowering efficiency, i.e. flowers to canopy size ratio, there by promoting a compact, efficient tree. E.g. introduce as a breeding selection criteria, evaluate overseas cultivars, irrigation practices, nutrition practices, tree architecture, light interception and bud development.
Fruit set	• Introduce self fertile and self pollinating (i.e. flower autogamy) almond varieties to remove the challenges of multiple passes for harvest and the mixing of harvested almonds. E.g. selection criteria within the Australian almond breeding program and evaluate overseas cultivars.

Vegetative Growth	• Improve tolerance to diseases. E.g. introduce varieties with good disease tolerance, particularly rust tolerance, thereby avoiding premature leaf drop and the side effects of bud development, etc; Research disease management strategies such as chemical choice and spray application. • Improving sustainable soil practices through organic matter, manures, cover crops, etc.
Fruit Growth	• Improve tolerance to pests and diseases. E.g. breed or evaluate varieties with good pest and disease tolerance, particularly varieties with a good shell seal, tolerance to insect damage and hull rot - thereby reducing mummification, avoiding point of infections, reducing crop loss, improving orchard sanitation and improving crop quality. • Research pest and disease management strategies with respect to irrigation and nutrition practices, chemical choice and spray application. • Improving sustainable soil practices through organic matter, manures, cover crops, etc.
Hull Split	• Improve the choice of varieties with improved shell seal. E.g. breed or evaluate varieties with adequate shell seal.
Fruit Maturation	• Improve the choice of varieties with earlier harvest to avoid the autumn rains. E.g. introduce harvest date as breeding selection criteria and for evaluate overseas cultivars. • Increase the choice of varieties with minimal or no windfalls. E.g. introduce as breeding selection criteria and evaluate overseas cultivars. Research the potential for new management strategies to minimise chemical applications and the potential for earlier ('greener") harvesting. • Improve the evenness of fruit maturation. E.g. canopy structure, tree architecture, light interception, etc. • If avoiding windfalls is a function of earlier harvest, at what point can "immature" fruit be harvested and dehydrated with no negative effects on fruit quality. Understand the causes and thresholds that lead to deteriorating product quality, in particular "soft" "doughy" fruit, unappealing browning of kernel skin, etc.
Harvesting	• Reduce or eliminate fruit contact with the ground. E.g. Evaluate and/or modify existing harvesting equipment or alternatives from other industries. Focus on achieving a one pass collect off the ground and/or shake and catch, reducing operator fatigue, increased efficiency, improved automation, improved guidance, yield mapping, the role of orchard design, tree densities, tree architecture, etc. • If shake and collect is successful, investigate efficient techniques to harvest and salvage saleable windfalls.
On-Farm Storage	• Improve methods and practices of de-hulling and storing both dried and "wet" fruit on-farm. E.g. conditioning hulls for optimum de-

	hulling and contaminant removal/pre-cleaning on farm, silo storage, bunker storage, "bag" storage, dehydration, aeration, etc. • If de-hulling on-farm is successful, research techniques to re-use the hull as a soil amendment or fuel source (i.e. biofuel or co-generation) for dehydration.
Hulling & Shelling	• A desktop review of current equipment, processes and technology available from the most common and current hulling and shelling manufacturers. • A more thorough investigation of a hulling and shelling plant(s) to quantify and develop a better understanding of the sources of chips and scratches, i.e. on arrival (i.e. on farm) and/or at what stage(s) through the processing. • Storage in controlled environment to manage moisture; biological and physical contamination; shell and kernel damage. • Techniques to re-use the hull and shell as a soil amendment or fuel source (i.e. biofuel or co-generation) for dehydration. • Aeration / dehydration at huller and sheller of whole fruit. • Aeration / dehydration at huller and sheller of kernel. • Investigate the potential of de-husking (e.g. pin rollers) at the beginning of the lines to optimise in-shell yield and minimise what is being asked of the shear rolls and shear rolls over belts. That is, don't ask shear rolls to hull and shell, maybe use a pin roller for hulling and shear rolls for shelling. • Early removal of stones and other smaller contaminants prior to hulling and shelling. • Techniques and equipment to optimise flow and through put of product between stages. • Techniques and equipment to size grade in-shell product (i.e. small, medium & large) after the de-husking to enable more accurate setting of the shear roll tolerances. Then run the size grades through specifically adjusted shear rolls. • Investigate the shear rolls, shear roll over belts and cushioning to examine the cause of the damaged kernel and determine more optimum settings. If settings can be improved, investigate more efficient alternatives such as multiple stacks of shear rolls, etc. If settings can't be improved investigate other alternatives to shell almonds. • Investigate efficient physical cleaning processes via screening and air separation - after shelling but prior to sizing to remove broken shell, etc. This has a high success rate for cleaning product and can remove 90+% of most physical contaminants. Laser cleaning is not an appropriate sorting procedure here. • Size graded product (i.e. small, medium & large not full industry sizing at this stage) over gravity tables once passed through the first

	physical clean. • Investigate efficient physical cleaning processes via screening, air separation & gravity tables - after size grading to small medium & large, to remove mouldy kernel, etc. Mostly based on density. This also has a high success rate for cleaning product and can remove 99+% of most physical contaminants. Laser cleaning is not an appropriate sorting procedure here. • Techniques and equipment to better size product to full range of industry sizes (i.e. 20/22, etc). • Performance and settings for laser cleaners removing discoloured contaminants from product already sized to full range of industry sizes. This is done prior to secondary processing.
Secondary Processing	• Performance and settings for repeat laser cleaning to remove chips, scratches, insect and rodent damage from industry sized product, at the packers, based on customer orders and specifications. However; ideally, if you have already: a) identified the causes of the chips and scratches and made machinery modifications to alleviate the issues, and b) laser sorted based on mould, the last laser sort will just be tuned (but highly tuned) to insect and rodent damage. Let packers decide the quality and value of pack but remove them of the pressure to clean contaminated product.
Marketing/Consumer	• Investigate the causes and therefore reduce detrimental colour, moisture, mould, kernel and shell staining, microbial contamination, physical contamination, chips and scratches. • Determine objective measurements for assessing product quality. • Determine and validate differences between Australian almonds and Californian almonds to assess whether there is a point of difference to obtain a competitive advantage in the market, e.g. flavour, colour, etc.

The outputs from the workshop have resulted in a new R&D post harvest super project outlined in section 5.4 and Appendix 5.

A full report on the workshop agenda and papers is located in Appendix 2.

5.3 Student Project

To assist the direction of the initial student project, a short preliminary review of the Australian almond processing industry was undertaken in March and April 2011 by Associate Professor John Fielke, Andrew Burge and three mechanical engineering undergraduates from the School of Advanced Manufacturing and Mechanical Engineering, University of South Australia University. As a result of the review, a brief report was completed (Appendix 3) and student projects were developed.

The main recommendations from the processing industry review were based on the following equipment principles and in the following order:

1. Uniform flow rate of kernels into the line (t/hour).
2. Early removal of sticks.

3. Removal of any metal and large contaminants before entering the processing line to avoid damage/inefficiency.
4. Accurate screening with large deck(s) (e.g. intermittent jumping screen) to remove all small stones (much smaller than in-shell almonds but are of similar size once almonds are shelled) prior to hulling and shelling.
5. Hulling and shelling without damage to kernels (repeated multiple times with cleaning).
6. Cushioning impacts of kernels to eliminate scratches and chipping.
7. Size grading of kernels (small, medium and large) and removal of splits using intermittent jumping screens.
8. Use of gravity tables to remove stones, shell and shrivelled kernels on size graded product. They will work better with similar size kernels.
9. Final air separation.
10. Final size grading.
11. Laser scanning to remove mouldy kernels (this could be run off-line, prior to storage of hulled and shelled product). Mouldy kernels can be a large percentage of the crop and should be removed prior to storage and accumulated for use in alternative products.

Chipped and scratched almonds are an inefficiency of the processing line and these must be minimised or preferably eliminated.

Following the improved hulling and shelling stage there is the opportunity to produce a product that does not contain:

- Foreign material (stones and other material).
- Chips and scratches as their sources have been eliminated.
- Mouldy, discoloured kernels that have a higher risk of spreading more mould and food safety issues.

This will eliminate the need for the packers to search and remove contaminants, mouldy, chipped and scratched almonds, and will leave them with a final check and removal of any insect/rodent damage and ensuring food safety.

As a result of this review, one student project *Identifying sources of mechanical damage in almond processing* by Samuel Tok (Appendix 4) has been completed under the supervision of John Fielke. A summary of the specific findings of the project were:

- The probable sources of mechanical damage were the primary processing (i.e. hulling and shelling) facilities once the kernel has been removed from the husk and shell.
- The size of the in-shell almonds and its kernel did not increase in thickness or depth proportionally with the thickness and depth of the whole in-husk fruit.
- The energy levels to cause damage by an anvil, almond point and almond point with an offset were 46.7mJ, 11.5mJ and 7.1mJ, respectively.
- The 46.7mJ required to produce damage in almond kernels using the anvil corresponds to dropping an almond kernel from a height of 3.9 m.
- An impact velocity of 5.5 m/s will damage 1 in 10 kernels and at 19 m/s all of the tested almond kernels were damaged.

This student project indicates the almond kernels should be kept inside their shells prior to hulling and shelling, to prevent damage. The shear rollers and belts of the hulling and shelling machines are causing damage to the almond kernels and further studies should be carried out to improve the hulling and shelling process in order to reduce mechanical damage to the kernels.

In addition to Samuel's thesis, there are two additional student projects underway which will add further information and improvement to the primary and secondary processing of almonds.

5.4 Future R&D

Following the study tour, workshop and preliminary projects by University of South Australia, a R&D brief for a 'Super Project' was developed (Appendix 5). The project brief called for R&D in the areas outlined in Table 2.

Table 2: R&D topics included in the advanced production super project and current status of industry investment and contracting

Value Chain Sector	R&D Topic	Current Status
On-Farm	• Fruit maturation and windfalls – understanding the physiology.	Have not begun discussions with preferred R&D provider. Not endorsed by almond IAC for 2012/13 funding.
On-Farm	• Harvest equipment – improvements to current equipment and evaluation of alternatives.	Growers have undertaking preliminary evaluations in the 2012 harvest.
Post Harvest	• Storage, aeration and drying – new techniques for managing high moisture product.	HAL proposal AL12003 submitted.
Post Harvest	• De-hulling on-farm – improving handling and storage efficiencies and provide opportunities for waste renewal on-farm.	HAL proposal AL12003 submitted.
Post Harvest	• Primary and secondary processing – investigate improved settings for current equipment and new alternative equipment to reduce chips and scratches in the processed kernel.	HAL proposal AL12003 submitted.
Post Harvest	• Alternative uses of waste – investigate novel alternative uses for almond hull and shell that subsidise cracking costs.	Australian Centre for Renewable Energy, Emerging Renewable Program - project application submitted.
Post Harvest	• Quality assurance and product reward/penalty assessment – investigate a more rewarding payment scale based on a smooth/sliding scale as opposed to the current bracket payment schedule	Applied for by University of South Australia. Not endorsed by almond IAC for 2012/13 funding.

6 Discussion

This project was developed with the aim of maintaining and improving the Australian almond industry's high quality product.

The industry importance and interest in this project was evident by the high degree of participation at the workshop and with the majority of the future R&D areas being endorsed by the IAC for the 2012/13 investment plan. With production estimated to double by 2015; these projects will offer considerable value to industry.

This project was only a small investment in comparison to the high value achieved already, particularly with reference to the new relationships formed with the University of South Australia.

The project has provided a significant stepping stone towards the development of an advanced almond production system that ensures product quality and food safety.

7 Technology Transfer

Communication of the progress and results of this project have occurred through several avenues:

- A detailed study tour report was compiled and made available to industry, particularly the ABA Board, almond IAC and four sub-committees (i.e. plant improvement, production, processing and marketing committee's).
- Articles have been written for the industry's newsletter *In a Nutshell* to outline the progress of the study tour, workshop outcomes and future R&D initiatives.
- Associate Professor John Fielke presented the University's industry review and research outcomes at the 2011 Australian Almond Conference.
- Samuel Tok's student thesis has been circulated and provided to the primary and secondary almond processors.
- The ABA formed the processing committee, its last sub-committee across the value chain. The committee had its inaugural meeting on 2 August 2011 and has been integral in the development of the new R&D super project proposal and transfer of the initial findings from this project.

8 Recommendations

It will be important the industry continues to look at a more holistic approach to R&D priorities and there is ongoing overlap between R&D projects or programs.

The new R&D initiatives that have been developed as a result of this project are very exciting and will go a long way towards improving and ensuring product quality and food safety, even in years of less than ideal weather conditions at harvest. However, there were R&D priorities that were developed from the workshop and ensuing industry consultation that have not been contracted and will require investment once levies become available from 2013/14.

9 Acknowledgements

The project team would like to acknowledge the financial investment of Horticulture Australia Limited, the Australian almond industry and Jubilee Almonds. In addition, we would like to acknowledge the in-kind support of University of South Australia, our industry stakeholders and overseas hosts who were very accommodating and gave up their valuable time and information freely.

10 Appendix 1 – Study Tour Final Report

Study Tour:

Investigating Efficient Harvesting Systems that Improve Product Safety and Quality

Ben Brown

Almond Board of Australia Inc

Project Number: AL10009

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Study Tour: Investigating Efficient Harvesting Systems that Improve Product Safety and Quality

Ben Brown
ABA Industry Development Manager

Almond Board of Australia
PO Box 2246
9 William Street
Berri SA 5343
T: 08 8582 2055
F: 08 8582 3503
E: rskinner@australianalmonds.com.au
W: www.australianalmonds.com.au

Key Personnel
Ross Skinner, Chief Executive Officer
Brendan Sidhu, ABA Chairman

Purpose of Report
This Study Tour Report has been prepared following the conclusion of travel to Hong Kong, England, Spain and United States. The project summarises the outcomes of the study tour and how they relate to improving the Australian almond industry's harvesting systems and product safety and quality.

Acknowledgements
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Disclaimer

June 2011

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1 Media Summary

The Australian almond industry has sought to further enhance its quality reputation and safeguard itself from food safety risks.

Australia is the second largest exporter of almonds, exporting to more than 30 countries around the globe. In the next 3 years production will increase from 38,000 to more than 80,000 tonnes. The Australian almond industry has developed and adopted world's best practices and reached a point where it is producing greater yields than the Californian industry, achieving an industry average of 2.97 tonnes per hectare, and product quality that is highly regarded.

However, during the past 2 years rain at harvest has led to significant crop losses, estimated to be greater than $20million in 2010. Product integrity has been potentially compromised, with mycotoxin (i.e. *Aspergillus*) and bacterium (i.e. *Salmonella, E. Coli, Listeria*) contamination major concerns.

Several factors are thought to contribute to food safety risks: insect damaged fruit; diseased fruit; the current harvest practices of shaking the fruit onto the ground and collecting the fruit once the hulls have dried, and uncontrolled climate storage of harvested product.

This project aims to investigate an efficient harvest system that would see an integrated pest and disease management program, the product collected at the point of harvest without it contacting the ground, harvested fruit dried to the appropriate moisture equilibrium (e.g. 5%), controlled climate storage of harvested and dried product, optimal quality sorting of product, and develop the prioritised direction for R&D projects.

In addition, the study tour was necessary to finalise the evaluation agreements and PBR applications for several Spanish rootstocks and cultivars, and to further enhance international relations.

The key outcomes of the study tour were:

- Improved nursery techniques for grafting winter budwood of scion material.
- Discuss the final details required to complete a formal evaluation agreement for several Spanish almond varieties and rootstocks.
- More confidence that Independence, a variety increasingly being planted in California, is worth evaluating in Australia.
- Almonds that prematurely fall (i.e. windfalls) to the ground prior to harvest is likely to be the largest barrier to shake and catch almond harvesting equipment.
- No harvesting equipment exists to currently allow Australian almond orchards to be harvested without almonds shaken to the ground.
- The Tenias machine was the closest harvesting machinery that currently is available for shaking and catching young almond trees; however, there the main challenge is windfalls.
- The OMC Catchall VII was the closest harvesting machinery that currently is available for shaking and catching almond trees; however, there are several challenges involved such as windfalls, tree architecture and row access.
- Techniques and equipment exist for the successful drying of almonds that have been purposely harvested early or accidentally wet by rain.
- Techniques and equipment exist for the successful controlled climate storage of processed almonds.
- The Australian and Californian almond industries are keen to work more collaboratively on mutually beneficial interest such as certain R&D topics, food safety, market assurance, etc.

The key implications for the Australian almond industry are:

- Improved tree production for nursery stakeholders.
- Improved rootstock and varietal availability following independent evaluation.
- Great understanding of the challenges and opportunities in adopting shake and catch harvesting techniques.
- Improved product quality by adopting product drying and storage.
- Improved international relationships.

2 Expected Outcomes

The study tour was undertaken with several objectives:

- Investigate nursery propagation techniques for the three rootstocks.
- Investigate new almond varieties and rootstocks from Spain and US.
- Finalise the evaluation and commercialisation arrangements of IRTA's four new cultivars and CITA's three rootstocks.
- Investigate improvements to the current almond harvest system that would maintain and enhance Australia's product quality and safeguard the industry from food safety risks.
- Investigate alternative almond and fruit tree harvesting equipment.
- Investigate alternative almond processing techniques/equipment to manage higher moisture content.
- Enhance international relations with the Almond Board of California.
- Enhance international relations with other key stakeholders in the Spanish and US almond industries.

The results of the discussions and the implications for the Australian almond industry are provided with reference to the key value chain headings from the Almond Industry's Strategic R&D Plan.

3 Results of Discussions and Implications

3.1 Pre-Farm

3.1.1 Biosecurity

Nothing to report.

3.1.2 Breeding and Evaluation

3.1.2.1 Spain

Spanish government research stations, IRTA (Ignasi Batlle, Francisco Vargas, Eliecer Lopez and Xavier Miarnau) and CITA (Rafael Socias and Jose Alonso) were visited to obtain an update on their cultivar breeding programs. Government funding and the amount of active crossing and breeding for almond cultivars have decreased for both IRTA and CITA. Both programs are concentrating their efforts on evaluation of current and promising cultivar releases.

Spanish breeding programs, in particular IRTA, are focussing on the following objectives:

- Late flowering (frost mitigation)

- Self fertility and self fruitfulness (reduce pollination draw backs)
- Nut quality (hard shell, absence of doubles, good kernel appearance)
- High production capacity and good balance between tree growth and production
- Sufficient vigour
- Easy tree training and pruning
- Tolerance to hard conditions (e.g. pests, diseases and drought)

Francisco Vargas has officially retired from IRTA but is still employed at 0.2 (1 day/week) to complete the almond breeding program. Ignasi Batlle is now the director of all IRTA's tree and fruit breeding programs.

Discussions were held with IRTA regarding an agreement to test and for the first right of commercialisation of their almond cultivars. The tree sales for the four recent releases (i.e. Vayro, Marinada, Constanti and Tarraco) are going well and increasing each year, with sales also occurring in North Africa and Argentina also. The agreement was to be drafted between IRTA (Eliecer Lopez) and the ABA with the following concepts:

- Cultivars will include Vayro, Marinada, Constanti and Tarraco.
- 5 year term for testing, at the conclusion of which a decision is to be made regarding the commercialisation of the cultivars.
- PBR is to be lodged by IRTA and the ABA as the first date of tree sale was 30/10/2007.
- IRTA has requested a minimum number of tree sales (and therefore royalties), with the ABA to provide the initial number and instigate discussions.

IRTA has two additional cultivars that are showing promise with characteristics of later flowering, high productivity and easier tree training.

CITA recent releases include Belona, Soleta and Mardia. They are Marconna types with Belona and Soleta flowering at similar dates (i.e. approx +5 days of Nonpareil) and Mardia flowering quite late (i.e. approx +25 days of Nonpareil). Belona and Mardia's shape is particularly similar to Marconna. Soleta is particularly good for minimal windfalls. Guara and Belona have more windfalls.

For additional information on IRTA and CITA cultivars, see Chapter 3.2.1.2.1 and 3.2.1.2.2.

3.1.2.2 US

Zaiger's Genetics and Burchell Nurseries were visited to investigate new rootstock and varietal releases or promising selections.

Zaiger's Genetics has two rootstocks (Atlas and Vicking) and one cultivar (Independence) that have been released and show good promise. Independence is a relatively new release and there is a small planting in Hillston, NSW which was planted in 2009. Zaiger's indicated approximately 3,000,000 Independence trees have been sold to date and approximately 750,000 trees are on order. Zaiger's continue to make controlled crosses for new almond varieties but suitable releases with sufficient beneficial characteristics are difficult to achieve and have been minimal. Key selection criteria for Zaiger's include:

- Early harvest.
- Self fertility.
- Good efficiency between tree growth and fruit production.
- Good shell seal.

Dave Wilson Nursery and Graham's Factree are Zaiger's US and Australian commercialisers, respectively.

Burchell Nurseries has one rootstock (Cornerstone) and two recent cultivars (Supareil and Capitola) that showed good promise. In addition, there are several "Nonpareil types" and "Carmel types" that are being evaluated with the following key selection criteria:

- Hull rot tolerant.
- Low windfalls.
- Self fertile.
- Good shell seal.
- Good efficiency between tree growth and fruit production.
- High bloom density/flower counts per m^2 canopy area.
- Harvest mid to late February (S. Hemisphere).

Mossmont Nursery is Burchell's Australian commercialiser.

For additional information on Zaiger and Burchell releases, see Chapter 3.2.1.2.3 and 3.2.1.2.4.

3.1.3 Tree Production

3.1.3.1 Spain

The nursery elviverodeabel of Caspe, Zaragoza was visited. Elviverodeabel was a nursery specialising in potted, "mini-grafting" (i.e. 3-5mm diameter propagation material). Due to its location to CITA, it appeared to mostly produce CITA releases (i.e Guara, Soleta, Belona and Mardia), grafted on GF677 (INRA) or Garnem (CITA) rootstocks. Average almond tree cost was approximately 3.30€ each, including royalty.

Rootstocks were purchased from *in vitro* tissue culturing laboratories such as Agromillora.

The potted nursery consisted of a single shade house, irrigated with overhead sprinklers, and manoeuvrable (i.e. rollers and guided tracks) and elevated benches for propagation.

The type of pot was considered critical; the pots had to include root trainers in the inside of the pot to alleviate root bounding. Peat moss was the planting media used in the pots. The trees supplied were approximately 60cm plus the height of the pot and were dispatched in boxes. The small size of the tree enabled the trees to be planted by a mechanical tree planter (Figure 1) towed behind a tractor with one person feeding the planter with trees and a second person walking behind the tractor and machine ensuring the graft union is above the soil surface.

The nursery used two types of grafts: 1) v-graft for grafting of winter budwood, and 2) chip budding for grafting of spring, summer and autumn budwood. Recommendations for some of the key practices for the cutting, storage and grafting of budwood are listed below.

Question	Answer
What is the best period for cutting winter scion budwood?	June and July, S. Hemisphere
What is the storage duration of winter scion budwood?	Until the end of December, S. Hemisphere
What is the preferred diameter when cutting winter budwood?	Must match the size of the rootstock diameter, normally approximately 4-6 mm in diameter
How is the winter budwood to be cut?	The winter budwood is to be cut with a terminal bud left on the end of each stick, to avoid drying of the wood
How is the winter budwood best treated?	Prior to cutting, spray the budwood trees with a solution of a fungicide (e.g. Captan) and bactericide (i.e. copper). Allow to dry and begin cutting.
How is the winter budwood best stored?	Once the winter budwood has been cut, wrap tightly in plastic film, place in a coolroom at 1.5-2.0°C, and place in an open carton box. The winter budwood is not to be stored with any moisture due to fungal contamination.
What is the preferred method of grafting winter budwood?	v-grafting
What is the preferred period for v-grafting winter budwood?	June and July, S. Hemisphere
Can winter budwood be used for grafting after June and July?	Yes, a chip bud can be used with winter budwood from August to end of November, S. Hemisphere.
What is the preferred method of grafting summer budwood?	Chip grafting
What is the preferred period for chip grafting summer budwood?	24 of December to 10 of April, S. Hemisphere

Figure 1: Example of a mechanical tree planter used to plant the potted trees from elviverodeabel nursery, Caspe, Zaragoza.

Figure 2: Shade house structure and spray irrigation at elviverodeabel nursery, Caspe, Zaragoza.

Figure 3: Bench systems at elviverodeabel nursery, Caspe, Zaragoza.

Figure 4: Potted almond tree, potted root system, and root training pots (clockwise) at elviverodeabel nursery, Caspe, Zaragoza.

Figure 5: V-graft using winter budwood and chip bud using spring budwood at elviverodeabel nursery, Caspe, Zaragoza.

Figure 6: Dispatch of potted almond trees at elviverodeabel nursery, Caspe, Zaragoza.

3.1.3.2 US

Prunus breeder Zaiger's Genetics of Modesto, California was visited. Zaiger's have bred two rootstock varieties that have showed good propagation from hardwood cuttings. The protocols included:

- Harvest hardwood material in May, S. Hemisphere.
- Cuttings are ideally 400mm in length and pencil thickness (i.e. 6-8mm). The thicker the cutting, the more difficult to match the size with scion budwood at grafting.
- Dip the base of the cuttings in 2,000ppm K-IBA solution, buffered to pH6.
- Invert and cover the cuttings in fruit bins filled with peat moss.
- Place fruit bins in greenhouses to root.
- Plant rooted cuttings in the field, ready for grafting.

3.2 On-Farm

3.2.1 Pre-Plant

3.2.1.1 Soil remediation & preparation

Grant Zaiger from Zaiger's recommended the R&D conducted by Michael McKenry (UC, Riverside) when considering best practices when replanting following Nemaguard rootstock.

John Slaughter from Burchell Nursery indicated great success had been achieved in almond (or *prunus*) replant orchards where trees had been cut at the trunk and the wound painted/sprayed with glyphosate to kill the trees. The benefit was thought to have resulted from the beneficial interaction between killing the root system and the soil biology. John indicated research in this area had been conducted by University of California.

3.2.1.2 New Cultivars

3.2.1.2.1 IRTA – Vayro, Marinada, Constanti, Tarraco

See Appendix 1 for detailed information.

Spanish, hard shelled varieties. Vayro and Marinada are recommended to be planted together, and Marinada and Tarraco are recommended to be planted together. Vayro and Marinada are the primary varieties in their respective plantings, with both combinations to be planted in configurations of approximately 70-80% of the primary variety, and 20-30% of the secondary variety.

Vayro, Constanti and Marinada are self fertile, Tarraco is non-self fertile.

Vayro crops on spurs and 1 year old wood.

Constanti, Marinada and Tarraco crops on spurs.

Marinada is a smaller tree, very precocious and more suited to higher densities.

Tarraco is slightly susceptible to *Monilinia*.

Yields on the trial plots are averaging 2T/Ha of kernel with approximately 350mm annual rainfall, 2-2.5ML/Ha of irrigation and fertiliser applications of 30:15:40 (N:P:K) per 1,000kg/in-shell product.

3.2.1.2.2 CITA – Belona, Soleta, Mardia

See Appendix 2 for detailed information.

Spanish, hard shelled varieties.

Belona and Soleta are characterized by their kernel quality and by the possibility of becoming a commercial alternative to the two traditional almond cultivars in the Spanish market, Marcona and Desmayo Largueta, to which they are comparable in their aspect and industrial quality but different from them in their late blooming date, tolerance to frosts, and, mainly, self-compatibility.

Belona is the best variety for blanching and cracking with little damage. The fruit does have some windfalls, similar to Guara, another CITA release.

Soleta has a kernel that fills the shell tightly and thus does damage a little more than Belona. Soleta has minimal windfalls.

Mardia is a new almond cultivar released because of its good agronomical traits and very late blooming time, 2 weeks later than 'Felisia', the latest blooming cultivar released so far. It is characterized by its slightly upright growth habit, early ripening, high and regular bloom density, autogamy (S6Sf genotype), high fruit set, tolerance to diseases, hard shell, large kernel, very high content of oleic acid, and low content of linoleic acid.

Commercial orchards were visited with 100% plantings of both Soleta and Guara.

3.2.1.2.3 Zaiger's Genetics - Independence

See Appendix 3 for detailed information.

Independence has been evaluated for 10 years, but oldest commercial planting was planted in 2006 by Grant Zaiger, which has 18 acres of a 100% planting of Independence on Nemaguard rootstock. Independence typically blooms at the same time as Nonpareil and harvests 3-7 days earlier than Nonpareil. It is a soft shell variety, has a better shell seal than Nonpareil, very spur bearing, very precocious, self fertile with good autogamy, and good industrial properties (e.g. blanching).

5th leaf orchard (2010 harvest) at Grant Zaiger's produced a yield of 1,650kg/ha of kernel, with a crackout of 31%. Orchard was not intensively managed and consisted of flood irrigation and planted at only 250 trees/ha. No bees were installed through the bloom period. A commercial orchard with a source of bees and alternative pollen was located adjacent to Zaiger's orchard, but the shape of Zaiger's orchard was long and skinny, with the area of our visitation approximately 150 metres away from the boundary. Refer to photos for assessment of 2011 crop with these features in mind.

A 3rd leaf orchard (2010 harvest) at another planting (88 trees) produced a yield of 635kg/ha of kernel, with no neighbouring bees or alternative almond pollen sources for approximately 3.2km's.

Figure 7: 6th leaf 'Independence' almond cultivar on nemaguard rootstock, Grant Zaigers orchard.

3.2.1.2.4 Burchell Nursery – Supareil and Capitola

See Appendix 4 for detailed information.

Supareil is a "hardish" shell variety (possibly Peerless x Nonpareil heritage), has good shell seal, blooms with or slightly ahead of the Nonpareil, harvests 7 days later than Nonpareil, and its kernel characteristics shows promise of being blended with Nonpareil.

Capitola has been evaluated for over 15 years and is promoted as a replacement for Monterey. Capitola is a "hardish" shell variety, blooms slightly ahead of Nonpareil, blooms and crops on 1 year old wood and spurs, and harvests 3-8 days later than Nonpareil. In comparison, Monterey harvests 30 days later than Nonpareil. The kernel of Capitola is larger than Monterey.

3.2.1.3 New Rootstocks

3.2.1.3.1 CITA – Garnem, Felinem and Monegro

See Appendix 5 for detailed information.

Felinem, Garnem, and Monegro are three almond peach hybrid rootstocks released to address the problems of *Prunus* growing in Mediterranean conditions not solved by the presently available rootstocks (e.g. GF557, GF677, Adafuel, and Adarcias). These new rootstocks are characterized by red leaves, good vigour, easy clonal propagation, resistance to root-knot nematodes, adaptation to calcareous soils and other Mediterranean agroecological conditions, and graft compatibility with the whole range of peach and almond cultivars as well as some plum and apricot cultivars.

3.2.1.3.2 Zaiger's Genetics – Atlas and Vicking

Atlas and Vicking are (peach x almond x apricot x plum). They both can be produced by hardwood cuttings (refer to Chapter 3.1.3.1), exhibit good vigour, anchorage, produce good fruit size and a nematode resistance similar to Nemaguard.

Atlas has advantages of being slightly more vigorous, but disadvantages of being intolerant to wet soil conditions and delays fruit maturity in some summerfruit varieties.

Vicking has advantages of more tolerance to wet soil conditions, and verticillium and bacterial cankers.

The root system of both rootstocks are not to be dried between nursery dispatch and planting to ensure successful take.

Figure 8: Zaiger rootstock fields, propagated from hardwood cuttings. Green leaf rootstocks were Vicking and red leaf rootstocks were Citation.

3.2.2 Agronomy

John Slaughter from Burchell Nursery recommended a product called Anti Stress 550.

Anti-Stress is a non-toxic, water diluteable polymer coating which is applied as a liquid spray. Once dried, an elastic membrane is formed covering the entire plant surface. John indicated the product has several uses; provide some frost protection, suppresses mite activity, and acts as an anti-transpirant by reducing moisture loss from leaves.

Anti-Stress is reported as being non-toxic, biodegradable, environmentally friendly and provides protection from 45 to 60 days.

For further information contact Mark Hendrickson at Polymer Ag on mark@polymerag.com or 559 495 0234.

3.2.3 Harvest

3.2.3.1 Harvest machinery

3.2.3.1.1 Pattenden Machinery Ltd, Ledbury, UK

Pattenden manufacture an apple cider, ground harvesting machine. Although designed for cider apples the collection head of rods, not mesh, worked very well. The head of rods coupled to a second floating head of rods enabled the pickup to be very effective and gentle in lifting windrowed product as it did not bulldoze product along. This concept was felt to be worthwhile investigating.

Simple right angle changes of direction with adjustable clearance height guards provided cleaning of the harvested product as the waste continued out on the belt under the guard. The machine was well built, but light to medium weight structure by comparison to US harvesters. The operator praised its capacity not to tear up soils in wet conditions. The designer praised the air-cooled Deutz engines as a highly reliable power plant.

Figure 9: Pattenden Falcon Cider Apple Harvester.

3.2.3.1.2 Tenias, Zaragoza, Spain

Tenias is a family owned, agricultural and industrial machinery manufacturer located in Ejea de Los Caballeros, Zaragoza, Spain. The tour visited Tenias to investigate the relatively recent development of their continuous moving, over the row almond harvester which shakes, de-hull's and collects product. A video of its operation was obtained from the visit.

The machine was originally developed for their family almond orchards due to the time and cost involved in harvesting with the traditional inverted umbrella method. A total of five machines have been developed, and customers include other commercial orchards.

The orchard needs to be developed specifically for the Tenias to obtain maximum efficiency, including precise row straightness, minimum row width, etc. The harvesting speed is approximately 2km/hr or 5-6 trees/min, and crop removal is approximately 50 tonnes of in-shell product/day. The on-machine storage of harvested product is approximately $2m^3$ per hopper or 550kg/in-shell per hopper. The current speed of the machine is limited due to the time taken to de-hull the product. The de-hulling feature is most successful when the kernel moisture is equivalent to <12%.

The harvested product stored in the hoppers is unloaded at the end of the row by tipping it into the bucket of a front end loader and then empties into a truck.

A summary of the orchard operational dimensions of the Tenias compared to the traditional vibrating umbrella is provided below. The dimensions of the Tenias make it suitable for younger (e.g. <5 years old) Australian trees but the higher Australian yields could limit the machines performance, in particular there is a lack of on-machine storage for harvested fruit and inappropriate unloading and logistics. Tenias are however, willing to work on the development of the machine for Australian conditions.

Machine	Orchard Dimensions for Operation			
	Row Width	Tree Width	Tree Height	Trunk Height
Vibrating Umbrella	>6m	>6m	<5m	>1m
Tenias	>5.5m	>3m	<4.5m	>1m

Figure 10: Tenias, over the row, continuous moving almond harvester, Spain.

Figure 11: Vibrating umbrella harvesting almonds, Spain.

3.2.3.1.3 US

Improvements to the traditional Californian almond harvest equipment have been minimal since previous industry trips. US manufacturers indicated a willingness to partake in more significant changes but did not indicate an obvious willingness to undertake this potentially expensive business risk. The most significant improvements, recently made to the Californian equipment have been:

- Double-sided sweeping (e.g. Exact E1000 and Flory Super V60 Series) which had reduced the number of sweeping passes from approximately 3 up and back, passes per tree to 1-2 per tree.

Figure 12: Exact Harvesting Systems, E-1150 single-sided sweeper (double-sided sweeper was not present for a photo).

Figure 13: Flory Industries, Flory Super V60 Series, doubled sided sweeper.

- Dust minimisation in the pick-up machine, which is specific to the Exact Harvesting Systems (i.e. E-4000 Eco Clean). The machine consists of two features; 1) the dust is passed through a brush sprayed with a mist of water to coagulate the dust into small balls of soil which is then dropped out of the machine to the orchard floor, and 2) an air-lock exists in the cleaning system that enables the leaf matter and the remaining soil to be disposed out the side of the machine under no velocity. The brush system is available as an additional extra to the traditional pick-up at a cost of approximately US$30,000. Reducing the dust and improving air quality also had additional advantages of reducing dust born pests and spores being transferred to canopy and improved photosynthesis and transpiration. Exact were also working on a conditioner for the 2011 US harvest with similar properties to Jack Rabbits Prepajack but doesn't require a harvester to pick the product up off the ground and is connected to a tractor’s 3 point linkage. Exact advised they had looked at fewer pass methods but felt it became too complicated, and were happy to work with Stew Martin on equipment modification to suit Australia.

Figure 14: Exact Harvesting Systems, E-4000 Eco-Clean dust minimisation system. Left picture indicates the mechanism for wetting the soil and the brush to dispose of the wet soil. The right photo indicates the shoot for the debris disposal following the air lock mechanism.

- The OMC shaker consists of a shaking head that automatically senses the almond tree trunk and has a feature to set a pre-determined shake time.
- Flory and Weiss McNair had a new rod based pick-up belt rather than the traditional mesh dirt chain. This provided for improved cleaning and less wear.

A summary of the discussions held with the Californian machinery manufacturers is provided below:

- Exact now supplying Paramount Farms with equipment. Exact advised they had looked at fewer pass harvesting methods but felt it became too complicated. They were happy to work with Stew Martin on equipment modification to suit Australia.
- Flory not inclined to invest in developing new equipment but asked to be kept in the loop. They had a large hammer mill mulcher for prunings to overcome the zero burning policy in California and the cost of removing pruned material from the orchard. This equipment has not been imported to Australia, but may be a good for orchard replacement work.
- Jackrabbit advised they were keen to take on board suggestions to suit Australian market.
- OMC advised they had produced an over the row (2 row) harvester that had very limited applicability. OMC were happy to work collaboratively but did not have the concepts on the board. Their shake and catch side-by-side units (i.e. OMC Catchall VII) were probably the most appropriate method to harvest almonds without the need to shake to the ground, however there was several challenges in almond orchards with this equipment such as tree architecture, machinery damage caused by almond trees and their architecture and the time and concentration required by the operators to line up both machines and travel down either side of the machine. An improvement on this unit if it were suitable for almond harvesting could be, the catching unit could have a sweeper and blower for windfalls as it currently a slave to the shaker and has little work to do. OMC advised they were working on shake and catch side-by-side units controlled by triangulation to increase efficiency. OMC also had umbrella catcher which advised was reliable and easy to service.

3.2.3.2 On-farm product storage

3.2.3.2.1 Almont Orchards, Chico, CA

Mark and Fred Montgomery were visited in Chico. They are a family operation, farming approximately 700 acres of almonds, 300 acres of walnuts, and have their own dehydration and hulling (in-shell) facilities.

Montgomery's dehydration and hulling facilities were of great interest. Montgomery's and the area of Chico, are familiar with product drying due to the wetter climate and the mandatory requirement of drying walnuts, a significant crop in this region. Montgomerey's planned to install their hulling facility in at least two stages, with the aim of expanding as their orchard production increased. However, the first stage has only been installed and the second won't be required due to the highly efficient output being achieved, with the success attributed to the dehydration process prior to hulling. The dehydration was conducted by two methods:

- Batch Drying – This system involved small trailers with false bottom floors, a connection for heated air to be blown in the bottom of the trailer and blown up through the trailers, recaptured near the roof of the shed via a plenum and blown back through the trailers again. The trailers are only 2/3 filled with product to enable quick drying, and only used for emergencies when the product became very wet from rain. Very wet product (e.g. >20%) would take approximately 24 hours to dry using this process.

Figure 15: Montgomery's batch driers, clockwise from top - drying trailers, heating unit and plenum, connecting shoot to false bottom floors, and drying trailer with false bottom floor.

- Bulk Drying – This facility was more elaborate than the trailers, but at the same time was also very simple and very effective. The bulk drying facility was installed with the same objective of only using it to dry larger volumes of product with kernel moisture levels of approximately 12-14%; however, it produced such a significant increase in through-put of hulled (in-shell) product, it is used every season regardless of the climatic conditions. The bulk drying facility consisted of:
    a. Pre-cleaner to remove foreign material from the harvested product. This was considered a critical component in efficient drying times.

b. A partially insulated shed in which eight silos (2 rows of 4) storing 15 tonnes each (120 tonnes total).
c. An outside central boiler.
d. Radiators acting as the heat exchange unit located at the base of each silo.
e. A fan located below each of the silos to suck through air heated by the heated water running through the radiator, and pushed up through each silo. The first cycle of air had the option of being expelled to atmosphere (outside the shed) and disposing of the moisture laden air. Subsequent cycles of dry air were recirculated through the silos by closing the vent to atmosphere.
f. Temperature monitoring with a drying threshold of 54°C not to be exceeded at the top of the silo. Commonly, 52°C at the top of the silo was the temperature at which drying was ceased.
g. A cooling chamber which consisted of a vented hopper and fan. Once dried, the product was conveyed into the other side of the shed, away from the heated air and passed through a vented hopper that also consisted of a continuously moving labyrinth, at which time a fan sucked ambient temperature through vents on the side walls and expelled it to atmosphere. The cooling chamber was critical to remove the last layer of moist air that may have been brought to the outside of the hull in the drying process. This process was also a critical step in ensuring a crisp hull and "finishing off" the product. The final product measured 4-5% kernel moisture. The drying of product from 12-14% to 4-5% kernel moisture took approximately 6 hours and the cooling chamber process took approximately 20 minutes.

Apart from increased through-put, there were additional advantages of drying moist product; it provided more flexibility at harvest and enabled harvest to begin earlier ("greener") and finish earlier, and allowed product to be picked up and managed if wet by rain.

Once dried and cooled, the product was hulled to produce an in-shell product using a Pin Roller. The Pin Roller was recommended for an in-shell product as it was very effective at removing only the hull, yielding approximately 96-97% in-shell product. However, it was not suited to producing raw kernel as the pins damaged the product. The traditional sheer roller was not as high yielding for in-shell product and more suited to raw kernel.

Once the product had been dried and cooled, the in-shell line had a capacity of 2.5 tonnes of finished in-shell product per hour. Both the drying and hulling facility was managed by one person who had a central control room located within the hulling section of the shed.

The drying and hulling facility was designed and manufactured by Montgomery's and Wizard Industries (http://www.wizardmanufacturing.com/). Montgomery's recommended to now use Doug Hallgren at Hi-Tech Industrial Services (ph: 530 893 2044).






Figure 16: Montgomery's bulk drying facility, clockwise from top left – pre-cleaner, central boiler, heat exchange (water pipes, radiators and fans), silos, vented cooling tower, pin roller, hulling line, control panel, and power boards.

3.2.3.2.2 Jesse Equipment Manufacturing, Chico, CA

The Jesse Modular Dryer was a recent development by Jesse. It was developed specifically for the drying of walnuts but is also suitable for other free flowing products such as pecans, pistachios, garlic and possibly almonds. Each modular holds 14m^3 (500 cubic feet) and consists of its own 7.5hp blower and burner to maintain consistent airflow and temperature. Each blower provides a consistent optimised airflow of 35 c.f.m per Cu. Ft. of capacity. The blower and burner are located high on the equipment to ensure it recycles the warmest air and if needed, the blower will use ambient air only. The structure is a diamond shape that is hollow in the middle and has a 762 mm width column with the inner and outer walls perforated – all allowing for a large surface area to volume ratio and a quick, uniform drying procedure. The left hand and right hand outside walls are solid galvanized metal.

Figure 17: Jesse Modular Dryer suitable for walnuts, pecans, pistachios, garlic and other free flowing product. Clockwise from top left: modular dryer, blower, commercial installation of a modular system, and the perforated outside column wall.

3.3 Post Harvest

3.3.1 Primary Processing

3.3.1.1 Off-farm product storage

UNIO, an almond co-operative was visited to observe the off-farm storage of almonds. The facility could either receive in-shell product direct from the growers or receive whole fruit and undertake the de-hulling themselves. The majority of almond growers have their own de-hullers due to the cheap and simple equipment required for hard shell varieties.

Figure 18: Almond de-hullers for hard shell varieties, UNIO Almond Corporation, Reus, Spain.

The facility could receive product at 25% kernel moisture and dry drown to 8% using two silos, each with a fuel powered burner. The warm air is blown into the base of each silo and to maintain consistent drying, the product could be turned over by conveying product from the base of the silo and depositing it back into the top of the silo. The same conveyer system also transports the dried product into storage silos located either within the shed or silos situated outside the shed.

Figure 19: Almond drying facility, UNIO Almond Corporation, Reus, Spain.

In-shell product is commonly stored at 8% kernel moisture in 200 tonne silos and isn't shelled until an order is received. The storage silos are climate monitored and controlled, and in addition the hard shell provides a natural method of storage.

Prior to shelling, the in-shell product is re-wet to 12-15% shell moisture to optimise effective and efficient shelling with minimal damage. As a general observation, shelling of hard shell varieties was said to be very effective and resulted in minimal kernel damage compared to soft shell varieties.

Natural kernel that was shelled was also stored in climate monitored and controlled silos with kernel moistures at 6%.

The climate monitoring and control was achieved using a PC software system. The drying, storage silos and conveying system was manufactured by Jubus Industries, Reus, Spain.

Figure 20: Controlled climate silos for storage of in-shell product awaiting shelling, or raw kernel, UNIO Almond Corporation, Reus, Spain.

3.3.2 Secondary Processing

Nothing to report.

3.4 Market

Nothing to report.

3.5 Risk Management

3.5.1 Food Safety

Nothing to report.

3.6 Operating Environment

3.6.1 International Collaboration

A meeting was held with Richard Waycott and Julie Adams, the President and Vice President of the Almond Board of California (ABC) respectively. The purpose of the meeting was to further establish links, and action previous correspondence surrounding collaborative R&D, food safety, trade barriers, market development and any other items of relevance.

The discussions with the ABC covered the following topics and information:

- The ABC had increased its promotional spend from US $2million to US $40million as the crop production has increased. The current spend was split US $20million to domestic programs and US $20million to export.
- The possibility of Australian almonds joining with Californian almonds in joint marketing promotions. This was unlikely to take place due to the wish to maintain and enable product differentiation.
- The Californian almond price was being undermined by sellers looking for cash flow. The price of almonds was considered well below what it should and could achieve, relative to other nut crops.
- Demand elasticity was an area identified for further research.
- The Californian 2011 harvest would likely be larger than the estimated 1.85 billion pounds. The early assessment of poorer northern valley crops were felt to be better than first thought.
- Sharing information on each other's R&D programs was agreed. First action was for Bob Curtis to come to the 2011 Australia Almond Conference and spend time gaining an understanding of the Australian research program.
- The most appropriate strategy to progress the food safety standards proposed for India.
- Assistance with sharing information on orchard testing and control of salmonella in field and storage.
- Richard Waycott was to present at the 2011 Australian Almond Conference.

4 Dissemination of Information

The information will be disseminated via a number of avenues:

- Jubilee Almonds and Century Orchards Board Meetings – 15th July 2011
- Processing Committee Meeting – 2nd August 2011
- Advanced Production Systems, Industry Workshop – 17th August 2011
- Almond Board of Australia Executive Meeting - 31st August 2011
- Almond Industry Advisory Committee – 1st September 2011
- Australian Almond Conference – 27th and 28th October 2011
- Study Tour Final Report – Circulation to industry & uploaded to almond industry website

5 Recommendations

The following recommendations are provided:

5.1.1 Breeding and Evaluation

Selection criteria and breeding characteristics which are not currently included as high priorities in the Australian almond breeding program but should be given strong consideration are:

- Hull rot tolerance – a significant disease for the almond variety Nonpareil, but a disease that is variety specific and has known chemical control. This disease causes "stick tights" and unharvested fruit, and consequently an economic loss. In addition, the resulting mummified fruit is a host for pest and disease issues for the following seasons. Some of the US breeding programs are successfully selecting for hull rot tolerance.
- Low windfalls – premature windfalls prolong the soil contact time, are more prone to moisture increases from irrigation and rainfall and are consequently a significant risk to the food safety of almonds.
- Early harvest – should provide benefits such as a reduction in annual water requirement by removing the crop earlier, and an option for managing late summer and autumn rainfall.

5.1.2 Tree Production

Investigate the most appropriate procedures for cutting, storage and v-grafting of winter budwood Small and medium in diameter) in the production of almond trees. This will potentially; reduce the peak demands on scion material availability from budwood repositories in spring, reduce the demand on nurseries to produce a suitable 1 year old tree from a spring graft, and provide a cost effective alternative for nurseries and orchards to the more expensive 2 year old trees. The cost and suitability of almond nursery trees would be further enhanced if rootstocks were found to be suitable for hardwood cutting propagation (e.g. GN rootstocks, Atlas, Vicking, etc) and bench grafting, such as the wine grape industry.

The use of a shade house to obtain greater control over tree growth rates and uniformity would also be advantageous.

5.1.3 Soil remediation & preparation

Investigate the various methods and recommendations employed by Californian orchards when replanting almonds orchards with a previous history of almonds or other woody crops. This will be particularly important as the majority of the Australian almond industry is planted on sandy textured soils prone to nematodes, and a large percentage of the Australian industry will require replanting all at the same time – in approximately 15-20 years.

5.1.4 New Cultivars

Several new almond cultivars were observed during the study tour. The four recent releases from IRTA have several interesting characteristics and a test agreement was agreed between the ABA and IRTA to evaluate the cultivars and have the first right of commercialisation for Australia. Vayro, Constanti and Tarraco have already been imported to Australia while Marinada is currently in Post Entry Quarantine. The recommendation is to finalise the arrangements of the test agreement and as the agent, apply for PBR in Australia on behalf of IRTA.

It is also recommended to arrange a test agreement and import Belona, Soleta and Mardia from CITA in Spain to evaluate in Australian conditions and to investigate their commercialisation potential.

In California, several varieties were observed or discussed, and from what is currently available for commercialisation, Independence had the greatest potential. Independence is licensed in Australia to Grahams Factree nursery who should be contacted to obtain several trees to evaluate and compare in the next available secondary evaluation of the Australian almond industry's breeding program. It is also understood there is a small evaluation planting of Independence currently within the Australian almond industry, which is to be confirmed and a request for evaluation sought.

5.1.5 New Rootstocks

The recommendations for rootstocks are to finalise the PBR application for the GN rootstocks Garnem, Felinem and Monegro, and to ensure Atlas and Vicking are included in the industry's upcoming rootstock evaluation trial.

It is also recommended to trial various rooting techniques for the GN rootstocks and investigate their suitability to bench grafting as is the case in the wine grape industry.

5.1.6 Agronomy

It is recommended to trial Anti Stress 550 and investigate its claims, in particular frost mitigation.

5.1.7 Harvest Machinery

It is recommended to investigate and accurately quantify the amount of almonds that prematurely fall to the ground prior to harvest and therefore the challenge to shake and catch harvesting of almonds. In addition, it is recommended to trial the OMC side-by-side harvesting equipment in almond orchards.

5.1.8 Primary Processing

Investigate and trial equipment and procedures for drying almonds that have been harvested at kernel moistures greater than 6%, and subsequently trial the most appropriate methods for storing almonds.

5.1.9 International Collaboration

Richard Waycott and Bob Curtis are to be invited to speak at the 2011 Australia Almond Conference and spend time gaining an understanding of the Australian research program and discuss mutually beneficial collaborative R&D efforts. It is also recommended to work collaboratively regarding food safety practices and standards.

6 Acknowledgements

The study tour members would like to acknowledge the financial investment of Horticulture Australia Limited, the Australian almond industry and Jubilee Almonds. In addition, we would like to acknowledge our overseas hosts who were very accommodating and gave up their valuable time and information freely.

7 Itinerary

DATE	DAY	LOCATION	CONTACT	TOPIC
12th May	Thursday	Depart Melbourne		
13th May	Friday	Arrive Hong Kong		
		Hofex 2011		
14th May	Saturday	Hofex 2011		
		Depart Hong Kong		
15th May	Sunday	Arrive London		
		Ledbury	Robert Chapman, Pattenden Machinery	Apple cider harvesting machinery
		Depart London		
		Arrive Barcelona		
16th May	Monday	Constanti	Paco Vargas, Eliecer Lopez & Xavi Miarnau	Commercialisation, Cultivars, Orchards
		Constanti	Paco Vargas, Xavi Miarnau & Inigo Vargas	Orchards
		Reus	Vicenc Ferre, Xavi Miarnau & Inigo Vargas	Spanish almond co-operative
		Reus	Jordi Busquets, Xavi Miarnau & Inigo Vargas	Almond dehydration & storage
17th May	Tuesday	Lleida	Paco Vargas, Xavi Miarnau & Inigo Vargas	Cultivar trials & orchards
18th May	Wednesday	Caspe	Rafael Socias, Jose Alonso, Xavi Miarnau & Antonio Poblador	Orchards & Tenias harvesting machine
		Caspe	Rafael Socias, Jose Alonso, Xavi Miarnau & Antonio Poblador	Nursery
		Zaragoza		
19th May	Thursday	EJEA DE LOS CABALLEROS	Tenias	Tenias harvesting machine
		Zaragoza	Rafael Socias, Jose Alonso, Jesus Tenias &Fernando Gimenez	Cultivars & rootstocks
		Barcelona		
20th May	Friday	Depart Barcelona		
		Arrive New York		
21st May	Saturday	New York		Personal time
22nd May	Sunday	Depart New York		
		Arrive San Francisco		
23rd May	Monday	Exact	Doug Flora	Harvest machinery
		Flory	Marlin Flory	Harvest machinery
		Jack Rabbit	Earl Anderson	Harvest machinery
24th May	Tuesday	Zaiger Genetics	Grant & Floyd Zaiger	New varieties, rootstocks

		Burchell Nursery	John Slaughter	New varieties, rootstocks
		ABC	Richard Waycott, Julie Adams & Bob Curtis	R&D, Marketing, Food Safety
25th May	Wednesday	Weiss McNair	Larry Demmer	Harvest machinery
		Jesse Manufacturing	Gary Hubbard, Larry Demmer	Processing machinery & dehydration
			Mark & Fred Montgomery, Larry Demmer	Almond & walnut growers with dehydration, hulling & shelling
		OMC	Don Mayo	Harvest machinery
		Arrive San Francisco		
26th May	Thursday	San Francisco		Personal time
27th May	Friday	Depart San Francisco		
		Depart Los Angeles		
29th May	Sunday	Arrive Melbourne		
		Depart Melbourne		
		Arrive Mildura		

8 Contact List

NAME	ORGANISATION	TOPIC / EXPERTISE	ADDRESS	PHONE	MOBILE	EMAIL
Antonio Polador Soler	Elviverodeabel	Spanish Nursery	Ctra. Caspe-Maella km57	(976) 63 05 06		info@elviverodeabel.com
Chris Harr	Jessee Manufacturing	Processing Manufacturer	2434 Dayton Rd Chico			charr@jesseemfg.com
Don Mayo	OMC	Machinery Manufacturer	2700 Colusa Highway Yuba City, CA 95993	(530) 673 2822	(530) 304 4008	dm@shakermaker.com
Doug Flora	Exact Corporation	Machinery Manufacturer	5143 Blue Gum Avenue, Modesto, CA, 95358	(209) 544 8600	(209) 649 7535	doug@exactcorp.com
Earl Anderson	Jack Rabbit	Machinery Manufacturer	471 Industrial Ave, Ripon, CA, 95366	(209) 599 6118	(209) 765 4375	earl@jackrabbit.bz
Eliecer Lopez	IRTA	Director: R&D Business Development	Passeig de Gracia 44 3r E-08007 Barcelona SPAIN	(902) 78 94 49		eliecer.lopez@irta.eu
Fernando Gimenez Perez	La Berne Agro Pecuaria	Almond Grower	Avda. Fernando el Catolico, 27 50600 EJEA DE LOS CABALLEROS SPAIN	(976) 67 77 34		laberne.fernando@hotmail.com
Francisco Vargas	IRTA	Research Director: Fruit Breeding	Mas de Bover. Ctra. Reus-El Morell, km3.8 E-43120 Constanti SPAIN	(977) 32 84 24		francisco.vargas@irta.eu
Gary Hubbard	Jessee Manufacturing	Processing Manufacturer	2434 Dayton Rd Chico	(530) 342 2909		ghubbard@jessemfg.com
Grant Zaiger	Zaiger Genetics	Plant Breeders	1219 Grimes Ave Modesto, CA 95358	(209) 522 5813		zaigergenetics@comcast.net
Ignasi Batlle	IRTA	Research Director: Fruit Breeding	Mas de Bover. Ctra. Reus-El Morell, km3.8 E-43120 Constanti SPAIN	(977) 32 84 24		Ignasi.batlle@irta.es
Jesus Tenias Sancho	Tenias	Machinery Manufacturer	Joaquin Costa, 43 50600 EJEA DE LOS CABALLEROS SPAIN	(976) 67 71 50		jtenias@tenias.com
John Slaughter	The Burchell Nursery Inc	Almond Nursery	6705 S. Clovis Ave Fowler, CA,93625	(559) 834 1661	(559) 285 3113	john@burchellnursery.com
Jordi Busquets Tarrats	Jubus	Processing Manufacturer	Ctra. De Alcolea, s/n 43206, REUS, Spain	(977) 326 080		jordibusquets@jubus.com

NAME	ORGANISATION	TOPIC / EXPERTISE	ADDRESS	PHONE	MOBILE	EMAIL
Jose Alonso	CITA	Researcher, Fruit Breeding	Avda. Montanana, 930 50080 Zaragoza SPAIN	(976) 716 310		jmalonsos@aragon.es
Julie Adams	Almond Board of California	Vice President, Industry relations, global technical & regulatory affairs	Suite 1500, 1150 Ninth Street, Modesto, CA, 95354	(209) 343 3238	(209) 640 1664	jadams@almondboard.com
Larry Demmer	Weiss McNair	Machinery Manufacturer	531 Country Drive, Chico, CA, 95928	(530) 891 6214	(530) 518 9223	ldemmer@weissmcnair.com
Mark & Fred Montgomery	Almont Orchards	Almond Grower	3108 Burdick Rd, Chico, CA, 95928	(530) 891 6626		almontorchards@yahoo.com
Marlin Flory	Flory	Machinery Manufacturer	4737 Toomes Rd, Salida, CA, 95368	(209) 545 1167	(209) 652 7820	mflory@floryindustries.com
Rafael Socias	CITA	Research Director: Fruit Breeding	Avda. Montanana, 930 50080 Zaragoza SPAIN	(976) 716 313		rsocias@aragon.es
Richard Waycott	Almond Board of California	CEO, Peak Industry Body	Suite 1500, 1150 Ninth Street, Modesto, CA, 95354	(209) 343 3215	(209) 402 7707	rwaycott@almondboard.com
Robert Curtis	Almond Board of California	Senior Manager, Production Research	Suite 1500, 1150 Ninth Street, Modesto, CA, 95354	(209) 549 8262	(209) 604 0385	rcurtis@almondboard.com
Vicenc Ferre Puig	Unio Corporacio Alimentaria	Almond Co-operative	c/ Joan Oliver, 16-24 43206 REUS SPAIN	(977) 33 00 55		v.ferre@unio.coop

9 Appendix 1 – IRTA Almond Cultivars

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'Vayro', 'Marinada', 'Constantí', and 'Tarraco' Almonds

Francisco Vargas[1], Miguel Romero, Joan Clavé, Jaume Vergés, Josef Santos, and Ignasi Batlle
Institut de Recerca i Tecnologia Agroalimentàries (IRTA), Mas de Bover, Ctra. Reus-El Morell, km 3,8. E-43120 Constantí, Reus, Tarragona, Spain

Almond [*Prunus amygdalus* Batsch syn. *P. dulcis* (Mill.) D.A. Webb] is the main tree nut crop in world production. Successful almond production requires cultivars adapted to the environmental conditions of the growing region. Thus, in wide areas of the Mediterranean Basin, cultivars have to be adapted to avoid late spring frost by late flowering. In California, delayed flowering can help to avoid rain damage at bloom time. A number of agronomic and commercial features (self-compatibility, production, vigor, growth and branching habit, training and pruning ease, disease resistance, nut quality, and so on) are also very important in almond production.

The availability for making crosses of a range of cultivars (late flowering and self-compatible from Apulia, southern Italy, very late blooming from Ukraine, high nut quality from Spain and France, and so on) and selections derived from controlled crosses have enhanced the prospects of almond breeding (Godini, 1996; Grasselly and Crossa-Raynaud, 1980; Socias i Company, 1990; Vargas et al., 1984). With these aims, in the almond breeding program of IRTA Mas de Bover, active since 1975, more than 35,000 seedlings have been raised and a few cultivars selected. The first cultivars registered from this program were 'Masbovera', 'Glorieta', and 'Francolí', which are widely grown in Spain (Vargas and Romero, 1994).

Four new late-blooming almond cultivars, 'Vayro', 'Marinada', 'Constantí', and 'Tarraco', have been released. 'Vayro', 'Marinada', and 'Constantí' are self-compatible and self-fruitful. 'Tarraco' instead is self-incompatible and thus it needs cross-pollination. The four cultivars are very productive, giving consistent yields. Nut quality is good, with near absence of double-kernel nuts. The almond shells are hard, reducing worm damage (and thus preventing aflatoxin contamination) and also avoiding bird damage. They are well suited to the European industry based on hard-shelled cultivars. The four cultivars are easily trained and pruned and adapt to mechanical harvesting (easy nut removal).

Origin

'Vayro' (Breeder's reference IRTAMB A21-323), 'Marinada' (IRTAMB A23-57), 'Constantí' (IRTAMB A22-120), and 'Tarraco' (IRTAMB A21-169) are seedlings selected from different crossing origin. In Figure 1, the pedigree of the four cultivars is presented. The crosses were made in 1991 to 1994. The four selections have been assessed during 9 to 12 years at Mas de Bover, Tarragona, and since 2000 are being evaluated at different locations in Spain.

Description

Main vegetative and agronomic characteristics are presented on Tables 1 and 2. Table 3 shows some important commercial nut traits (Figs. 2–5). In the three tables, widely grown reference cultivars ('Desmayo Largueta', 'Ferragnes', 'Guara', 'Marcona', 'Masbovera', and 'Nonpareil') are included for comparison. In Table 4, the productive performance of the three self-compatible cultivars ('Vayro', 'Marinada', and 'Constantí') compared with two self-fertile and highly productive standard cultivars ('Lauranne' and 'Guara') is given.

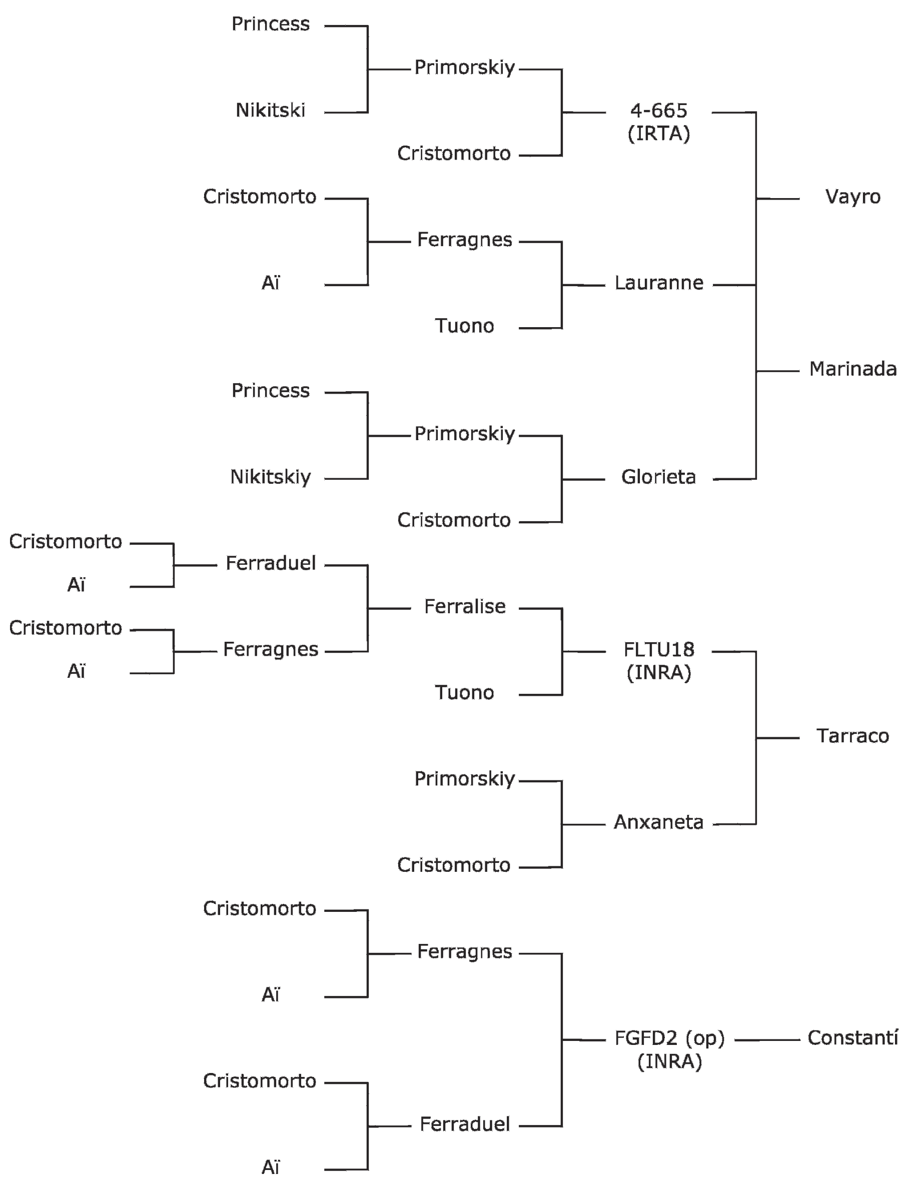

Fig. 1. Pedigree of the four new almond cultivars released by IRTA.

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IRTA's public almond scion breeding program is partially conducted under three INIA (Spanish Ministry of Science and Technology) projects (SC97-049, RTA01-081, RTA04-030, and TRT06-021).
[1]To whom reprint requests should be addressed; e-mail francisco.vargas@irta.es

Table 1. Blooming date, self-compatibility, production (yield potential and precocity), and harvesting season.

Cultivar	Mean blooming date (STD)[z]	Self-compatibility (*S* genotype[y])	Yield potential[x]	Bearing precocity	Harvesting season
New:					
Vayro	26.6 (7.8)	Yes (S_9S_f)	Very high	Early	Early
Marinada	35.1 (10.7)	Yes (S_5S_f)	Very high	Very early	Mid
Constantí	27.4 (9.5)	Yes (S_3S_f)	High–very high	Early	Mid
Tarraco	36.1 (11.2)	No (S_1S_9)	Very high	Very early	Mid
Reference:					
D. Largueta	0	No (S_1S_{25})	Mid–high	Mid-late	Late
Ferragnes	29.4 (8.9)	No (S_1S_3)	High–very high	Mid	Mid
Guara	27.7 (9.3)	Yes (S_1S_f)	High–very high	Early	Early
Marcona	15.6 (5.3)	No ($S_{11}S_{12}$)	High	Early	Mid
Masbovera	29.8 (9.8)	No (S_1S_9)	High–very high	Mid	Mid
Nonpareil	18.0 (7.1)	No (S_7S_8)	Low–mid	Mid	Early

[z]Mean full blooming date (and standard deviation) of 9 years (1998–2006) at Mas de Bover as number of days from Desmayo Largueta full bloom (mean, 30 January).
[y]López et al. (2006) for the reference cultivars.
[x]Nonpareil is not well adapted to Catalonian environmental and growing conditions (low production).

'Vayro'. It was bred from a '4-665' × 'Lauranne' cross made in 1991. It is late-flowering, self-fertile, very productive, and precocious. The tree shows very strong vigor and medium branch density, bearing nuts mainly on spurs. It seems tolerant to *Phomosis amygdali*. The kernel is nice, without doubles, having medium size and a pointed shape.

'Marinada'. It is a seedling from a 'Lauranne' × 'Glorieta' cross made in 1994. It flowers very late, is self-fertile, highly productive, and very precocious. The tree shows midvigor and has medium–upright growth and medium–scarce branch density, bearing nuts mainly on spurs. The kernel is nice, without doubles, medium size, and rounded.

'Constantí'. It is an open-pollinated seedling from the selection 'FGFD2', obtained in 1993. It is late-flowering, self-fertile, productive, and precocious. The tree is vigorous and it has a medium–upright growth. Its branch density is medium, bearing nuts mainly on spurs. The kernel shape is round.

'Tarraco'. It was bred from the cross 'FLTU18' × 'Anxaneta' made in 1991. It blooms very late, it is self-incompatible, highly productive (heavy and consistent bearer), and very precocious. The tree shows midvigor and has medium–upright growth and branch density is medium–scarce bearing nuts mainly on spurs. It seems tolerant to *Phomosis amygdali*. The kernel is large, nice, without doubles, and has an oblong shape.

All four cultivars ('Vayro', 'Marinada', 'Constantí', and 'Tarraco') have shown heavy and consistent cropping in experimental trials.

Fig. 2. 'Constantí' almonds.

Fig. 3. 'Marinada' almonds.

Fig. 4. 'Tarraco' almonds.

Fig. 5. 'Vayro' almonds.

Table 2. Tree vigor, growth habit, branching density, bearing habit (mostly), and training and pruning ease.

Cultivar	Vigor	Growth habit	Branching density	Bearing habit	Training	Pruning
New:						
Vayro	Very strong	Medium	Mid	On spurs	Very easy	Easy
Marinada	Mid	Medium–upright	Mid–scarce	On spurs	Very easy	Very easy
Constantí	Strong	Medium–upright	Mid	On spurs	Very easy	Easy
Tarraco	Mid	Medium–upright	Mid–scarce	On spurs	Very easy	Very easy
Reference:						
D. Largueta	Mid	Spreading	Mid–high	On 1-year-old shoots	Medium	Medium
Ferragnes	Strong	Medium–upright	Mid	On spurs	Very easy	Easy
Guara	Mid	Drooping	Scarce	On spurs	Difficult	Easy
Marcona	Mid	Medium	High	On 1-year-old shoots	Easy	Medium
Masbovera	Very strong	Medium–upright	Mid	On spurs	Very easy	Easy
Nonpareil	Mid	Medium	Mid	On 1-year-old shoots	Easy	Easy

Table 3. Nut characteristics.[z]

Cultivar	No.	Nut wt	Kernel wt	Shelling percentage	Double kernels	Kernel appearance
New:						
Vayro	29	4.2 (0.5)	1.19 (0.15)	28.4 (2.6)	0.1 (0.3)	7.0 (0.5)
Marinada	24	4.2 (0.5)	1.30 (0.19)	31.1 (3.6)	0.3 (0.6)	6.8 (0.6)
Constantí	32	4.5 (0.6)	1.20 (0.16)	26.8 (2.7)	1.4 (1.6)	6.2 (0.6)
Tarraco	17	5.4 (1.1)	1.68 (0.25)	31.5 (4.2)	0.1 (0.3)	6.9 (1.0)
Reference:						
D. Largueta	85	5.0 (1.2)	1.34 (0.27)	27.2 (2.3)	1.4 (2.2)	6.7 (1.2)
Ferragnes	262	4.4 (0.7)	1.49 (0.22)	33.8 (3.4)	0.1 (0.5)	6.4 (0.9)
Guara	84	3.8 (0.7)	1.31 (0.23)	34.6 (5.1)	11.6 (11.1)	6.3 (0.7)
Marcona	209	5.1 (1.0)	1.33 (0.19)	26.4 (2.5)	2.7 (3.6)	6.5 (0.8)
Masbovera	170	4.9 (0.9)	1.35 (0.29)	27.8 (3.2)	0.4 (1.1)	6.4 (1.0)
Nonpareil	14	2.0 (0.3)	1.24 (0.11)	62.7 (4.9)	3.3 (3.4)	7.1 (0.8)

[z]Mean values (and SD). No. = number of samples analyzed (during 9 to 30 years), nut weight (g), kernel weight (g), shelling percentage (%), double kernels (%), and note on kernel appearance (scale 1–9, with 9 being the highest mark).

Table 4. Mean year and accumulated production of kernel (kg/tree).[z]

Cultivar	2002	2003	2004	2005	2006	Accumulated production (2002–2006)
New:						
Vayro	0.61 b	4.04 b	5.39 a	5.54 a	6.35 a	21.93 a
Marinada	1.66 a	5.16 a	2.50 b	5.23 a	4.57 abc	19.13 ab
Constantí	0.57 b	3.74 b	2.27 b	4.59 a	2.74 c	13.91 b
Reference:						
Guara	0.32 b	3.59 b	2.16 b	5.21 a	4.80 ab	16.08 ab
Lauranne	0.47 b	3.99 b	3.87 ab	5.31 a	4.14 bc	17.76 ab

[z]Self-compatible cultivar trial at Corbins, Lleida, under deficit irrigation conditions. Trees planted at 7 m × 6 m in 1995 and regrafted in 2000. Randomized blocs design, three repetitions and five trees per plot. Comparison of means by Duncan's multiple range test. Values with the same letter are not significantly different (95%).

Use

As to establishing new almond orchards and design according to flowering time and vigor (related to tree spacing), two cultivar pairs can be considered: 'Marinada' and 'Tarraco' (very late-blooming and midvigor) and 'Vayro' and 'Constantí' (late-blooming and strong vigor). They set better crops when bees are placed in their orchards.

Availability

The four cultivars bred by IRTA are in the process of being registered by the Oficina Española de Variedades Vegetales (OEVV) belonging to the Spanish Ministry of Agriculture, Fish and Food (MAPA). The cultivars can be propagated under royalty agreements with IRTA. Limited amounts of virus-free budwood for research purposes are available from IRTA Mas de Bover after signing a nonpropagation agreement (www.irta.es). IRTA has granted a multiplication license for the four cultivars to ALMERIPLANT (www.almeriplant.com).

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10 Appendix 2 – CITA Almond Cultivars

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‘Belona’ and ‘Soleta’ Almonds

Rafael Socias i Company[1] and A.J. Felipe

Unidad de Fruticultura, CITA de Aragón, Apartado 727, Zaragoza, Spain

Additional index words. *Prunus amygdalus*, breeding, autogamy, fruit quality

‘Belona’ and ‘Soleta’ are two new almond [*Prunus amygdalus* Batsch, syn. *P. dulcis* (Mill.) D.A. Webb] cultivars from the breeding program of the Unidad de Fruticultura, CITA de Aragón. They are characterized by their kernel quality and by the possibility of becoming a commercial alternative to the two traditional almond cultivars in the Spanish market, ‘Marcona’ and ‘Desmayo Largueta’, to which they are comparable in their aspect and industrial quality but different from them in their late blooming date, tolerance to frosts, and, mainly, self-compatibility.

Since the beginning of almond research in Zaragoza in 1966, the most important problem detected in Spanish almond growing was its low productivity attributable to the occurrence of frosts at blooming time or later, to deficient pollination, and to drought, because almond was mostly grown in nonirrigated conditions (Felipe, 2000). As a consequence, the main aim of the subsequent breeding program was the development of late-blooming and self-compatible cultivars. The first three cultivars released were ‘Aylés’, ‘Guara’, and ‘Moncayo’ (Felipe and Socias i Company, 1987), with ‘Guara’ having represented more than 50% of the new almond orchards in the last years (MAPA, 2002). Later, three more cultivars were registered in 1998, ‘Blanquerna’, ‘Cambra’, and ‘Felisia’ (Socias i Company and Felipe, 1999), with ‘Blanquerna’ having very good productivity and kernel quality and ‘Felisia’ very late blooming time (Fig. 1). Breeding, however, has continued, pursuing autogamy and fruit quality, aiming at defining the best end use of each cultivar (Socias i Company et al., 2006) and taking into account the preference of the Spanish market for ‘Marcona’ and ‘Desmayo Largueta’.

Origin

Both cultivars come from the cross done in 1988 of ‘Blanquerna’, a self-compatible seedling from the self-compatible Italian cultivar Genco by the French cultivar Belle d’Aurons characterized by its kernels of excellent quality. This cross was made with the aim of using a self-compatibility source other than ‘Tuono’, so far the most used parent in almond crosses (Socias i Company, 2002).

Autogamy

Self-compatibility was tested as soon as the original seedlings produced the first flowers by examining the arrival or not of pollen tubes at the ovary after self-pollination (data not shown). The selections of the cross with the nuts and kernels of highest ratings were recovered and autogamy was studied on three grafted trees of each selection during several years as a result of the large variability found between years in field trials for fruit set (Socias i Company et al., 2005). Table 1 shows the average results of 4 years for three pollination treatments in the field: self-pollination, cross-pollination with cross-compatible pollen of ‘Marcona’, and bagging, applied as described by Socias i Company et al. (2005). Selections F-4-25 and F-4-43 showed a very low level of self-compatibility as shown by the low fruit sets after self-pollination and bagging in agreement with the previous observations on pollen tube growth. Selections F-4-9 and F-4-35 showed good fruit set after self-pollination, but not after bagging, as a result of their flower morphology not allowing natural autogamy. The four other selections continued their evaluation resulting from their sufficient level of autogamy (Grasselly et al., 1981), which, together with their bloom density, may ensure a commercial crop. The *S*-allele genotype of both cultivars has been determined as $S_f S_{23}$ (O. Kodad, unpublished data).

Performance

Field behavior has been evaluated in the three grafted trees of the almond collection and in two external trials. One of the most important points considered was resistance to frosts. Especially important was the observation in 2003, with a frost of –2.5 °C for 5 h on 18 March. Whereas cultivars considered as resistant to frosts such as ‘Guara’ (Felipe, 1988) experienced a yield reduction rated at 50%, the four selections under study experienced different levels of losses: in F-3-34 and F-3-35, the decrease was similar to the levels observed in ‘Guara’, but in ‘Belona’ and ‘Soleta’, the reduction was only 20% to 30%. All selections were at similar phenologic stages, thus showing different susceptibility to negative temperatures. This fact must also be related to their blooming time, which in Zaragoza takes place on average a few days before ‘Guara’ (dates in Fig. 1 referred as 50% of open flowers).

Ripening time is later than in ‘Guara’, which allows the succession of harvest of the different cultivars. The average ripening date in Zaragoza is 23 Aug. for ‘Guara’, 8 Sept. for ‘Belona’, and 17 Sept. for ‘Soleta’, following the same order for ‘Marcona’ and ‘Desmayo Largueta’ (Table 2). Nut fall before harvest has been very low, but nuts fell easily when shaken.

Tree training has been easy without the problem of bending branches with ‘Guara’. Adult trees show an intermediate vigor and a good equilibrium between vegetative growth and production; thus, pruning may be reduced more in ‘Soleta’ than in ‘Belona’. ‘Soleta’ is slightly susceptible to *Polystigma*, but ‘Belona’ is quite tolerant.

The external trials have shown the good adaptation of ‘Belona’ and ‘Soleta’ to different growing and weather conditions. A trial in Aniñón (Zaragoza) at 800 m above sea level (asl) and with a very cold climate has had good production even in years with late frosts. A trial in El Pinós (Alacant), at 575 m asl but with a milder climate, has shown their very good production as well as vegetation (G. Valdés, unpublished data). Blooming and

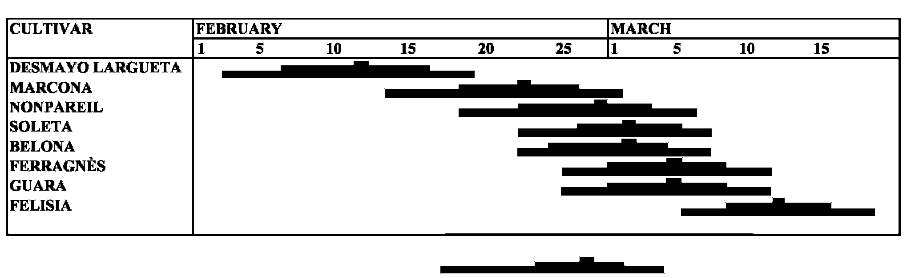

Fig. 1. Average blooming dates (7 years) of the new cultivars in comparison with those usually grown. Percentages refer to the amount of open flowers.

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[1]To whom reprint requests should be addressed; e-mail rsocias@aragon.es

Table 1. Fruit sets obtained in eight almond selections depending on the pollination treatment (4-year average).

	Fruit set (%)[z]		
Selection	Self-pollination	Crosspollination	Bagging
F-3-34	48.7 a	43.0 a	23.5 b
F-3-35	33.2 b	51.9 a	26.5 b
F-4-9	34.1 a	35.7 a	5.2 b
Soleta	29.8 a	33.9 a	13.6 b
Belona	37.3 b	45.8 a	12.8 c
F-4-25	1.6 b	19.4 a	0.1 b
F-4-35	49.3 a	50.6 a	5.1 b
F-4-43	0.5 b	30.9 a	0.4 b

[z]Differences among treatments for each selection followed by different letters are significant at the 0.05 level (least significant difference).

Table 2. Characteristics of the new cultivars.

Trait	Belona	Soleta
Selection number	F-4-12	F-4-10
Clone number	502	503
Growth habit	Drooping	Drooping
Vigor	Intermediate	Intermediate
Average blooming date	2 Mar.	2 Mar.
Flower color	White	White
Flower size	Intermediate to large	Intermediate to large
Fruiting	Mostly on spurs	Mostly on spurs
Bloom density	Dense	Dense
Pollination	Autogamous	Autogamous
Ripening date	8 Sept.	17 Sept.
Nut shape	Round	Oblong
Average nut weight	3.62 g	3.63 g
Shelling percentage	32% to 34%	32% to 34%
Double layers in shell	No	No
Kernel shape	Round	Elliptic
Average kernel weight	1.3 g	1.27 g
Double kernel percentage	0	0
Kernel aspect	Good	Good
Kernel shrivelling	No	No
Taste	Good-sweet	Good

ripening dates observed in these locations have been, as expected, earlier in El Pinós than in Zaragoza but later in Aniñón.

Industrial Quality

The essential traits of 'Belona' and 'Soleta' have been reported in Table 2. Quality has been a decisive criterion in the selection process. Nuts and kernels show a very good aspect and good size without double kernels. The shell is hard, adapted to the Spanish industry. Shape has been carefully considered, because the 'Belona' nut is very similar to that of 'Marcona', but the kernel is longer and thinner (Fig. 2). The 'Soleta' kernel is very similar to that of 'Desmayo Largueta', although not the nut (Fig. 3). Industrial cracking has been carried out by the Cooperative "Frutos Secos Alcañiz" and has shown very good results without the presence of a double layer in the shell. The presence of broken kernels has been low with an outstanding behavior of 'Belona'. Kernel percentage is high for a hard-shell cultivar because the kernels fill the inner shell space. In 2005, when a small nut size was observed in most growing regions, kernel size reduction was lower than nut size decrease with an increase of 4 points in the average shelling percentage.

Because the main use of 'Marcona' is as blanched kernels, the Cooperative "Frutos Secos Alcañiz" carried out the blanching of 'Belona', obtaining very good results with the lower increase of broken kernels and the absence of unblanched kernels probably resulting from the thinner kernels of 'Belona' (Table 3). Kernel taste is very good with a slight sweetness.

Similarly, the characteristic trait of 'Desmayo Largueta' kernels is their use for roasting, because the seedcoat is easily removed after roasting. The industry "Almendras Castillo de Loarre" proceeded to a similar operation for the two new cultivars and 'Desmayo Largueta', obtaining very good results for 'Soleta'. Kernel taste, both raw and roasted, is very good.

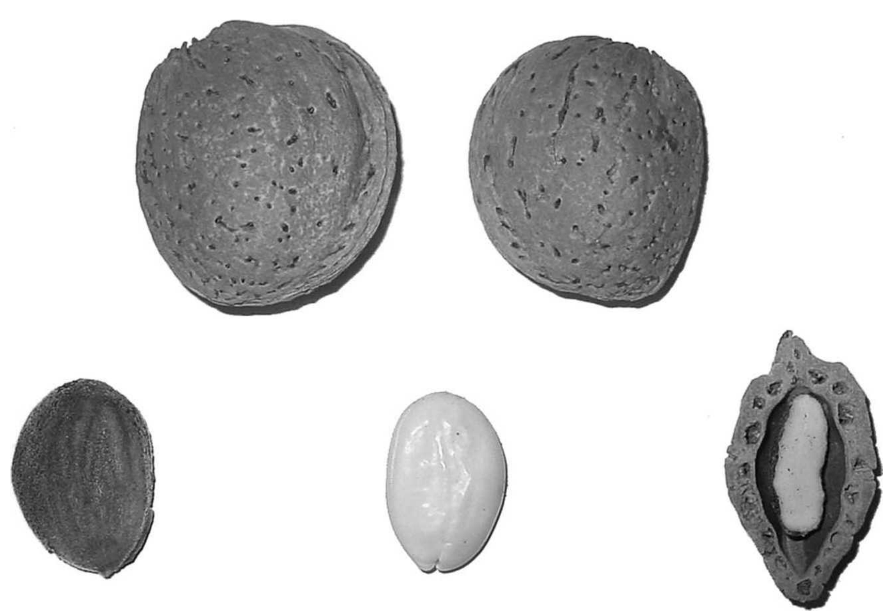

Fig. 2. Fruits of 'Belona' almond.

Composition

The chemical composition of the kernels of the new cultivars has been determined to establish the best utilization opportunities of each one. Their content in fatty acids is very high, higher than in 'Marcona' and 'Desmayo Largueta' (Table 4), a very interesting trait for "turrón" (nougat) production. As a consequence of the inverse relationship of fatty acids and protein, the protein content is lower. The percentage of oleic acid, that of higher quality for fat stability and nutritive value in the lipid fraction, is especially high in 'Belona', over 75% (Table 4). This cultivar also shows a very high content of tocopherols (both of α-tocopherol and total tocopherol), although not as high as in 'Marcona (Kodad et al., 2006), indicating good storage quality because tocopherols have an important role in avoiding rancidity and in nutrition for their vitamin E activity.

Availability

These two cultivars were presented with patents on 27 Oct. 2005 at the Spanish Registry of Protected Cultivars and are

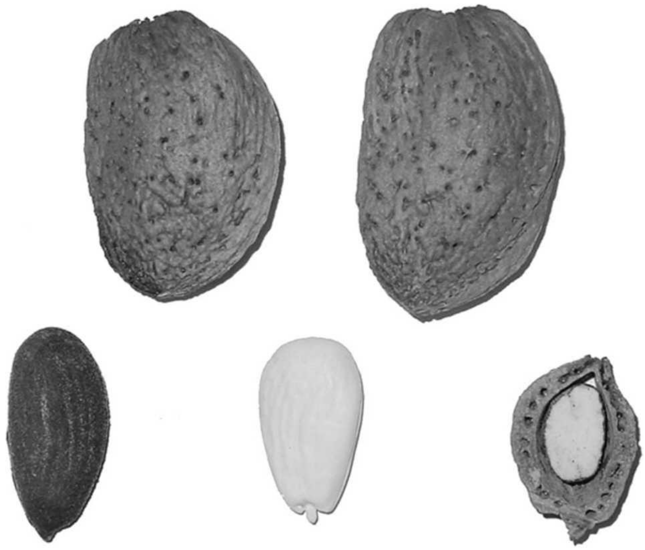

Fig. 3. Fruits of 'Soleta' almond.

Table 3. Blanching of Belona kernels in comparison with the commercial Spanish cultivars.

	Before blanching		After blanching		
Cultivar	Percent moisture	Percent broken kernels	Percent moisture	Percent broken kernels	Percent unblanched
Belona	5.2	4.6	5.7	23.6	0
Marcona	7.5	1.5	8.6	22.6	0.6
Desmayo Largueta	6.5	1	7.5	30	2.4
Comuna	6.5	1	8.0	26	2.8

Table 4. Chemical composition of the new cultivars in comparison with Marcona and Desmayo Largueta.[z]

Cultivar	Protein (% dry wt)	Fat (% dry wt)	Oleic acid (% oil)	α-tocopherol ($mg \cdot kg^{-1}$ oil)	Total tocopherol ($mg \cdot kg^{-1}$ oil)
Marcona	23.8	59.7	71.3	463.3	500.5
Desmayo Largueta	24.5	58.9	72.2	304.3	336.2
Belona	16.4	65.4	75.6	418.4	455.6
Soleta	20.0	61.8	69.2	214.0	242.3

[z]Data from Kodad et al. (2006).

available to nurseries though provisional licenses by GESLIVE (Av. Generalísimo 25-1°, 28660 Boadilla del Monte, Madrid, Spain).

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'Mardía' Almond

Rafel Socias i Company[1], Ossama Kodad, José M. Alonso, and Antonio J. Felipe

Unidad de Fruticultura, Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA), Av. Montañana 930, 50059 Zaragoza, Spain

Additional index words. Prunus amygdalus, breeding, late blooming, self-compatibility, fruit quality, productivity

***Abstract*. 'Mardía' is a new almond cultivar released because of its good agronomical traits and very late blooming time, 2 weeks later than 'Felisia', the latest blooming cultivar released so far. It is characterized by its slightly upright growth habit, early ripening, high and regular bloom density, autogamy (S_6S_f genotype), high fruit set, tolerance to diseases, hard shell, large kernel, very high content of oleic acid, and low content of linoleic acid.**

The almond (*Prunus amygdalus* Batsch) breeding program of the Centro de Investigación y Tecnología Agroalimentaria of Aragón aims to develop new self-compatible and late-blooming cultivars to solve the main problem detected in Spanish almond growing, its low productivity, as a result of the occurrence of frosts at blooming time or later and to a deficient pollination (Felipe, 2000). The first three cultivars released from this breeding program were Aylés, Guara, and Moncayo (Felipe and Socias i Company, 1987), 'Guara' having represented more than 50% of the new almond orchards in the last years (MAPA, 2002). Later, three more cultivars were registered in 1998, Blanquerna, Cambra, and Felisia (Socias i Company and Felipe, 1999), 'Blanquerna' being of very good productivity and kernel quality, and 'Felisia' of very late blooming time (Fig. 1). Two more cultivars, Belona and Soleta, were registered in 2005 (Socias i Company and Felipe, 2007) characterized by their high kernel quality and considered possible commercial substitutes for the two preferred cultivars in the Spanish market, Marcona and Desmayo Largueta. The last release from this breeding program is 'Mardía', recently registered because of its good horticultural and commercial traits.

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We appreciate the technical work of J.M. Ansón, M.T. Espiau, J. Búbal, and A. Escota as well as the collaboration of the industries "Frutos Secos Alcañiz" and "Castillo de Loarre," the growers of the external trials, mainly J.L. Sánchez and J.A. Espiau, and the collaboration of J.L. Espada and P. Castañer (Centro de Transferencia Agroalimentaria de Aragón) and G. Valdés (Estació Experimental Agrària, Elx) in the experimental orchards.

[1]To whom reprint requests should be addressed; e-mail rsocias@aragon.es

Origin

'Mardía' (selection G-2-25, clone 541) comes from the cross of 'Felisia', a self-compatible and late-blooming release of the Zaragoza breeding program of small kernel size (Socias i Company and Felipe, 1999), and 'Bertina', a late-blooming local selection of large kernel size (Felipe, 2000). This cross was made with the aim of using two late-blooming almond cultivars, one of them carrying the late-bloom allele *Lb* (Socias i Company et al., 1999), of very different kernel size and genetically very distant to avoid the problems related to inbreeding depression (Alonso and Socias i Company, 2007).

Blooming Time

Blooming time has been a very important evaluation trait. As an average, its blooming time is 25 d later than 'Nonpareil', 20 d after 'Guara', and 13 d after 'Felisia', the latest blooming cultivar released so far (Fig. 1). The consistent late blooming time is the result of very high chilling and heat requirements (Alonso and Socias i Company, 2008; Alonso et al., 2005), much higher than in any other almond genotype (Table 1). Flowers are of small size and white with epistigmatic pistil both on spurs and on 1-year shoots. Bloom density is regular and high (Kodad and Socias i Company, 2008b).

Autogamy

Self-compatibility was tested as soon as the original seedlings produced the first flowers by examining the arrival or not of pollen tubes at the ovary after self-pollination (data not shown). Sets after self-pollination and autogamy were studied on three grafted trees of each selection during several years as a result of the large variability found between years in field trials for fruit set (Socias i Company et al., 2005). Average set after artificial self-pollination was 17.9%, higher than after crosspollination, 15.7%, showing a good self-compatible behavior, although this difference was not statistically significant. Average set in bagged branches was 9.8%, higher than the threshold of 6% indicated by Grasselly et al. (1981) for autogamy, and 23.7% for open pollination. These sets (Kodad and Socias i Company, 2008a) are lower than those considered for a commercial crop in Californian cultivars (Kester and Griggs, 1959), but ensure a good crop level because of the high bloom density of this selection, resulting in high productivity (Kodad and Socias i Company, 2006). Its *S*-allele genotype has been determined as S_6S_f (Kodad and Socias i Company, 2008a).

Performance

Field behavior has been evaluated with three grafted trees in an experimental plot and in three external trials. One on the most important points considered was the behavior in relation to spring frost injury. Especially important were the observations in 2003 and 2004 with severe frosts in most almond-growing regions of Spain. Whereas cultivars considered as resistant to frosts such as Guara (Felipe, 1988) sustained important yield reductions, 'Mardía', as a result of its extremely late blooming season, did not sustain any damage (Kodad and Socias i Company, 2005).

Tree training has been easy because of its slightly upright growth habit (Kodad and Socias i Company, 2008b) without the problem of bending branches of 'Guara'. Thus, induction of lateral branching is recommended during the first years. Adult trees show an intermediate vigor and branching intensity as well as a good equilibrium between vegetative growth and production, thus allowing reduction of pruning. Field observations in the different locations showed its tolerance to *Polystigma* and other fungal diseases.

Ripening time is early, although later than in 'Guara', which allows the succession of harvest. Nut fall before harvest has been very low, but nuts fell easily when shaken. Yield rating has been slightly lower than for 'Guara' (7 versus 8 on a 0 to 9 scale).

The external trials have shown its good adaptation to different growing and weather conditions, maintaining a high level of bud density in all locations (Kodad and Socias i Company, 2008b). A trial in Aniñón (Zaragoza) at 730 m above sea level and of very cold climate has had good production even in years with late frosts. A trial in El Pinós (Alacant), at 575 m above sea level but with a milder climate, has shown their very good production as well as vegetation (G. Valdés, unpublished data). Blooming and ripening dates observed in these locations have been, as expected, earlier in El Pinós than in Zaragoza, but later in Aniñón.

Industrial Quality and Composition

Nut and fruit evaluation has been done through 7 years according to the IPGRI and UPOV descriptors. Nuts show a very good aspect and good size (4.9 ± 0.5 g). The shell is hard (shelling percentage of 24%), adapted to

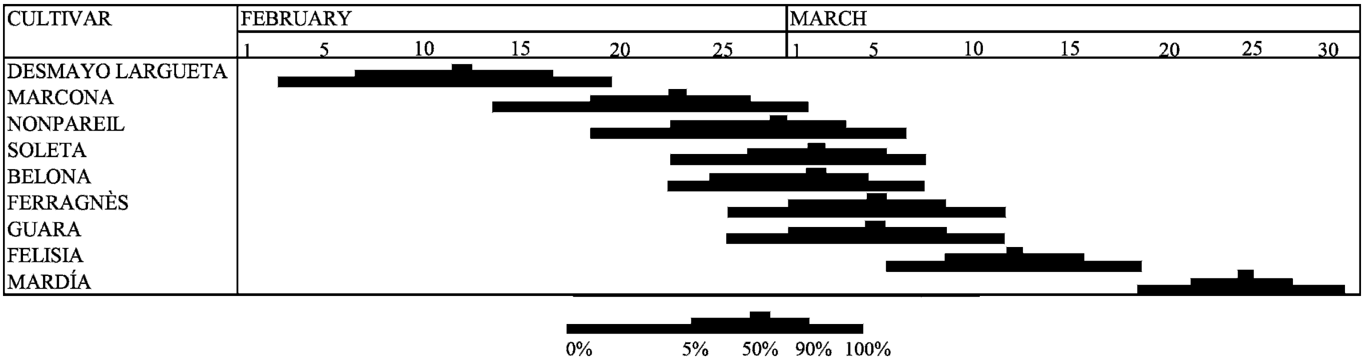

Fig. 1. Mean flowering time of 'Mardía' as related to other cultivars (7-year average). Percentages refer to the amount of flowers opened.

Table 1. Chilling and heat requirements of 'Mardía' as related to other cultivars.[z]

Cultivar	Chilling requirements (CU)[y]	Heat requirements (GDH)[x]
Desmayo Largueta	428	5,458
Marcona	428	6,603
Nonpareil	403	7,758
Belona	353	7,741
Soleta	340	7,872
Ferragnès	444	8,051
Guara	340	8,159
Felisia	329	9,465
Mardía	503	10,233

[z]Alonso et al., 2005; Alonso and Socias i Company, 2008.
[y]Chilling units.
[x]Growing degree hours in °Celsius.

Fig. 2. Nut and kernel of 'Mardía'.

the Spanish industry. Kernels also show a very good aspect and good size (1.2 ± 0.2 g), heart-shaped, without double kernels (Fig. 2). Industrial cracking has been carried out by the Cooperative "Frutos Secos Alcañiz" and has shown very good results without the presence of double layers in the shell. Kernel breakage at cracking has been low with 86.2% of whole kernels.

The chemical composition of the kernels has been determined to establish their best use opportunities. The content in protein is medium and that of oil is high, similar to that of 'Marcona' (Table 2), a very interesting trait for "turrón" (nougat) production. The percentage of oleic acid, that of higher quality for fat stability and nutritive value in the lipid fraction, is especially high (Kodad and Socias i Company, 2008c), close to 75% (Table 2). The content in linoleic acid, of lower quality than the oleic acid, is low, showing a very high ratio of oleic/linoleic acids (4.5) as another index of high oil quality. The amount of tocopherol is lower than in other cultivars (Kodad et al., 2006), indicating the need for rapid processing of kernels after cracking.

Roasting has been tested by the industry "Almendras Castillo de Loarre" for appetizer use. Behavior has been good, although less than in the favorite one in the Spanish market, 'Desmayo Largueta'. Kernel taste, both raw and roasted, is excellent.

Availability

This cultivar has been presented to patent on 11 Dec. 2007 at the Spanish Registry of Protected Cultivars and is available to

Table 2. Chemical composition of 'Mardía' as compared with other cultivars.

Cultivar	Protein (% DW[z])	Oil (% DW[z])	Oleic acid (% oil)	Linoleic acid (% oil)	Oleic/linoleic acid ratio	α-tocopherol ($mg \cdot kg^{-1}$ oil)	γ-tocopherol ($mg \cdot kg^{-1}$ oil)	δ-tocopherol ($mg \cdot kg^{-1}$ oil)	Total tocopherol ($mg \cdot kg^{-1}$ oil)
D. Largueta	24.5	57.35	70.65	20.55	3.44	304.3	15.3	1.66	321.3
Marcona	23.8	59.10	71.75	19.40	3.70	463.3	18.5	1.87	483.7
Nonpareil	13.0	60.47	67.72	23.28	2.91	400.0	27.8	1.57	429.4
Belona	16.4	65.40	75.60	12.73	5.94	418.4	15.4	2.18	436.0
Soleta	20.0	61.80	69.20	19.70	3.51	214.0	13.3	1.51	228.8
Ferragnès	25.4	57.53	70.20	20.10	3.49	377.5	18.7	1.84	398.0
Guara	29.3	54.33	63.10	25.70	2.46	385.4	15.7	1.76	402.9
Felisia	27.0	56.32	68.05	22.10	3.08	250.6	18.2	1.73	270.6
Mardía	19.8	59.10	74.95	16.55	4.53	201.5	12.1	1.23	214.8

[z]Dry weight.

nurseries though provisional licenses by Geslive, A.I.E. (C. Juan de Mena 19-3°-D, 28014, Madrid, Spain).

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11 Appendix 3 – Zaiger Almond Cultivars

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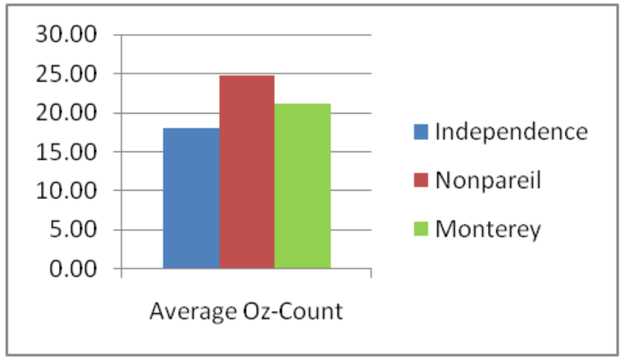
Modesto, CA 95358

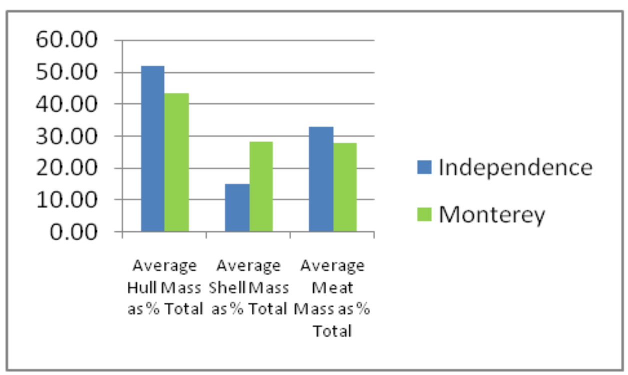
209.522.1075

Independence Self-fertile Almond

- One Harvest
- Fine Flavor
- Blanches Well
- High Quality Nut
- Harvest 3-7 days prior to Nonpareil
- Excellent Producer

Variety	Sample Size	Average Oz-Count	Hull Mass as % Total	Shell Mass as %	Meat Mass as %
Independence	832	18.04	51.89%	15.12%	32.89%
Nonpareil	8,657	24.70			
Monterey	5,531	21.08	43.20%	28.43%	27.99%





12 Appendix 4 – Burchell Nursery Almond Cultivars

Burchell Nursery Introduces
The Supareil Almond

Nonpareil type
Pollinates Nonpareil
Size of tree: 90% of Nonpareil
Bloom: +1 to 2 days after Nonpareil
Harvest: +7 to 10 days after Nonpareil

Production:

Planted January 2002
(24X18=100 trees per acre) 10 acres planted

		Lbs./acre	Rejects	Chip
2007	Nonpareil	1,457	.4	4.6
	Supareil™	1,388	.6	4.1
2008	Nonpareil	2,548	.0	3.0
	Supareil™	2,346	.8	3.8

****

Price Comparison

Variety	Nut Buyer 1 * Purchase Price 2008	Nut Buyer 2** Purchase Price 2008
Nonpareil	$1.70	$1.95
Carmel	$1.20	$1.20
California	$1.10	$0.77

	Pounds per acre	Price per pound	Dollars per acre
Supareil	1867.00	$1.75	$3,267.25
Non Nonpareil Types	2000.00	$1.35	$2,700.00
Non Nonpareil Types	2200.00	$1.35	$2,970.00
Non Nonpareil Types	2420.00	$1.35	$3,267.00

With Supareil production of 1867 lbs per acre (2 year average) and potential extra revenue for nuts as opposed to non nonpareil varieties, you would have to yield 2420 lbs per acre (at $1.35 per pound) to achieve the same income.

* VH
** TAP

Burchell Nursery has gathered this information to assist you with your selection of varieties. While all tests and evaluations have been positive, this is still an experimental variety and Burchell Nursery can not guarantee the results in your orchard based upon the information above that was provided to us by others.

Main Office:
12000 State Highway 120
Oakdale, CA 95361-8887
(800) 828-TREE • (209) 845-8733 • Fax: (209) 847-1972

Fresno Office:
6705 S. Clovis Ave., Fowler, CA 93625
(559) 834-1661 • Fax: (559) 834-1509
Chico Office: (530) 345-0691

Website: www.burchellnursery.com • E-Mail: Info@burchellnursery.com

Supareil From Burchell Nursery

***Supareil in production*▲** ***Supareil in bloom*▲**

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Website: www.burchellnursery.com • E-Mail: Info@burchellnursery.com

Burchell Nursery re-Introduces The Capitola Almond!

(Over 15 years in Evaluation)

It's Only new to You.
Why Switch? US Plant Patent 19369 Capitola is the replacement variety for Monterey.

- Capitola Spur Dynamics is a better pollinator than Monterey.
- Capitola has an earlier harvest date (+8) than Monterey (+30).
- Capitola is larger tree than Monterey.


Capitola

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Fresno Office:
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(559) 834-1661 • Fax: (559) 834-1509
Chico Office: (530) 345-0691

Website: www.burchellnursery.com • E-Mail: Info@burchellnursery.com

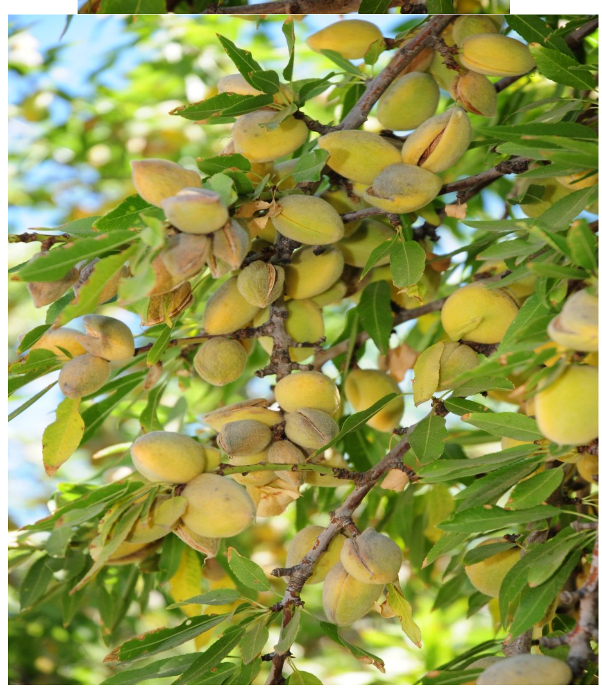
Why Capitola and What is Spur Dynamics?

It will bloom and set on 3 types of wood.

1. On annual lateral shoots.
2. On perennial spurs.
3. On extended perennial spurs.

These additional bearing sites allow for a longer bloom duration, greater pollen volume and greater nut set for itself and for Nonpareil.

This will be a great complement to your Nonpareil!



Capitola Almond Crop 2010

13 Appendix 5 – CITA Rootstocks

HortScience 44(1):196–197. 2009.

'Felinem', 'Garnem', and 'Monegro' Almond × Peach Hybrid Rootstocks

Antonio J. Felipe

Unidad de Fruticultura, Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA), Av. Montañana 930, 50059 Zaragoza, Spain

Additional index words. stone fruits, nematode resistance, *Meloidogyne*, *Prunus*, clonal propagation

***Abstract*. 'Felinem', 'Garnem', and 'Monegro' are three almond × peach hybrid rootstocks released to address the problems of *Prunus* growing in Mediterranean conditions not solved by the presently available rootstocks. These new rootstocks are characterized by red leaves, good vigor, easy clonal propagation, resistance to root-knot nematodes, adaptation to calcareous soils and other Mediterranean agroecological conditions, and graft compatibility with the whole range of peach and almond cultivars as well as some plum and apricot cultivars.**

Stone fruit growing has limitations in the Mediterranean area as a result of the prevalence of calcareous soils, where most rootstocks show lime-induced chlorosis. In addition, the presence of root-knot nematodes (*Meloidogyne* spp.) in many irrigated orchards renders fruit growing extremely difficult, especially after the ban on the use of methyl bromide for soil fumigation. Thus, the need for rootstocks to overcome these shortcomings has become essential for growing stone fruit in many regions, not just the Mediterranean area (Felipe, 1989). 'Felinem', 'Garnem', and 'Monegro' had been released as potential rootstocks for several stone fruit species that are grown in soils having these limitations.

Origin

These three clones were selected among the progeny obtained in the cross between the Spanish almond 'Garfi' [*Prunus amygdalus* Batsch, syn. *P. dulcis* (Mill.) D.A. Webb] as the female parent and the North American peach 'Nemared' [*P. persica* (L.) Batsch] as the pollen donor. 'Garfi' is an open-pollinated seedling of 'Garrigues' almond previously selected because of its good morphological characteristics and ease of clonal propagation (Felipe, 1992; Felipe et al., 1995). 'Nemared' was chosen mainly as a source for root-knot nematode resistance (Ramming and Tanner, 1983). Selection of this progeny was carried out at the then Servicio de Investigación Agraria de la Diputación General de Aragón, now Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA).

Received for publication 29 July 2008. Accepted for publication 23 Sept. 2008.

The development of these rootstocks has involved many research projects from INIA as well as the collaboration of department colleagues, the late Dr. M. Carrera, Dr. J. Gómez Aparisi, and Dr. R. Socias i Company, the nematode resistance evaluation of Dr. J. Pinochet (IRTA, Cabrils), and the technical assistance of J.M. Ansón. I acknowledge the help and comments from Drs. R. Socias i Company, J. Pinochet, M.J. Rubio-Cabetas, and P. Errea.

The contact for reprint requests is Rafael Socias i Company; e-mail rsocias@aragon.es

Description

Unbudded trees of 'Garnem', 'Felinem', and 'Monegro' are vigorous and no differences in size are noticeable between them. The vigor induced in grafted cultivars is comparable to that induced by 'GF-677' or 'Hansen 536' with a similar productivity. Nongrafted plants are vigorous and in the nursery exhibit an erect growth with little or no feathering during the first season (Felipe, 1989). Leaves are red, big, lanceolate, and intermediate in morphology between almond and peach. Active growing shoots exhibit an intense red–purplish color similar to its male parent, 'Nemared'. Because the leaves mature during the growing season, they turn brownish green to green. The first-year shoots are straight with little or no lateral branching. Shoots are green with red areas from which stem color turns to an intense and continuous red–purplish during winter dormancy. Internode length is medium to long (5 to 7 cm).

The three rootstocks bloom early, at the same time as 'Nemared' peach and 'Nonpareil' almond, exhibiting similar low chilling requirements. Flowers are large (3.5 to 4 cm), of the rosaceous type, with large pale pink petals. The flowers have between 30 and 45 stamens and one pistil. Fruits are small (4 to 5 cm in width) and rounded with a pubescent epidermis. Fruits are green with reddish overtones. The mesocarp is thin, nonedible, and has a free stone or endocarp.

Despite their similar morphology and performance, the three clones may be distinguished by molecular markers (Serrano et al., 2002).

Resistances and Susceptibilities

Evaluation was conducted in Zaragoza and under other Mediterranean conditions such in the hotter climate of southern Spain and the mild climate of eastern Spain both in heavy and sandy soils. The three clones were selected because of an important soil chemical limitation that is inherent in Mediterranean environments, which is tolerance to iron chlorosis (De la Guardia et al., 1995; Said et al., 1993) as a result of alkaline soils (pH = 8.0 to 8.5) that contain high levels of active lime (10% to 12%). Their level of tolerance to iron chlorosis is similar to that of 'GF-677' and 'Adafuel' (Felipe, 1989) with 'Felinem' showing the highest tolerance. They also tolerate drought conditions well with a higher resistance to water stress in 'Monegro', mainly selected for almond in nonirrigated conditions. 'Felinem' and 'Garnem' are mostly adapted to irrigated conditions. Adaptation to poor soils is good if the soils are well drained.

Incorporation of root-knot nematode resistance was the primary breeding objective to replace several widespread nematode susceptible almond × peach hybrid rootstocks used for peach production in Spain, especially in replant situations (Pinochet, 1997). All three rootstocks have a high level of resistance to the main root-knot nematode species attacking *Prunus*, including *Meloidogyne arenaria* (Neal) Chitwood, *M. hapla* Chitwood, *M. hispanica* Hirschmann, *M. incognita* (Kofoid and White) Chitwood, and *M. javanica* (Treub) Chitwood (Marull et al., 1991; Pinochet et al., 1996a, 1999). The three rootstocks were evaluated over several years with up to 13 root-knot nematode populations from different geographical areas of the world, showing all rootstocks a broad spectrum of resistance (Esmenjaud et al., 1997; Marull et al., 1994). In addition, 'Felinem' shows a moderate resistance to the root-lesion nematode *Pratylenchus vulnus* (Pinochet et al., 2000). Resistance mechanisms to nematode are determined by hypersensitive reactions (Marull et al., 1994). Partial resistance breaking may occur under extreme heat conditions of mean soil temperature over 35 °C (Esmenjaud et al., 1996; Fernández et al., 1993).

Like most almonds and almond × peach hybrids, they exhibit a low tolerance to root asphyxia caused by waterlogging and are susceptible to crown gall caused by *Agrobacterium tumefaciens* (unpublished data). 'Monegro' and 'Garnem' are also susceptible to the root-lesion nematode *Pratylenchus vulnus* (Pinochet et al., 1996b).

Propagation and Compatibility

'Garnem', 'Felinem', and 'Monegro' propagate well by hardwood and herbaceous cuttings in aerated and well-drained soils (Gómez Aparisi et al., 2002). Best results for hardwood cuttings are obtained in the fall. Cuttings are easily obtained thanks to the low level of shoot branching. They also propagate very well in vitro.

Nursery operations are facilitated by the low presence of feathers and the red leaves as well as by the long vegetative period of the plants, allowing the production of nursery plants in a shorter period. The percentage of bud take is high for all known peach, nectarine, and almond cultivars (personal communication by different nurserymen).

These rootstocks have been selected primarily for almond and peach and have exhibited total graft compatibility with numerous almond, peach, and nectarine cultivars as shown in the almond and peach germplasm collections of the CITA, which maintain the most important Spanish and foreign cultivars (Carrera et al., 2002; Espiau et al., 2002). They are also compatible with some diploid plums (*P. salicina* Lindl. and related plums) such as 'Santa Rosa' and 'Golden Japan'. Compatibility has also been observed with some apricot cultivars belonging to the more compatible apricot group such as 'Paviot' but not with the apricot cultivars of the more exigent group such as 'Moniquí'.

Availability

'Felinem', 'Garnem', and 'Monegro' have been granted European Community Plant Variety Rights numbers 16366, 16363, and 16362, respectively. They are available to nurseries through commercial licenses by Geslive, A.I.E. (C. Juan de Mena 19-3°-D, 28014, Madrid, Spain).

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11 Appendix 2 – Workshop Agenda, Papers and Presentations

ALMOND BOARD OF AUSTRALIA

ADVANCED PRODUCTION SYSTEMS WORKSHOP

Background Papers
17th August 2011

OUR MISSION:

As the Australian almond industry's peak body, the ABA facilitates further growth of the industry, seeks to maximise its profitability and ensure its sustainability, by providing a platform for industry members to collectively respond to industry wide issues, invest in research and marketing, share knowledge,and interact with government and other stakeholders.

AUSTRALIAN ALMONDS
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AL10009

Investigating efficient harvesting systems that improve product safety and quality

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F: 08 8582 3503
E: admin@australianalmonds.com.au
W: www.australianalmonds.com.au

Acknowledgements

This project has been facilitated by HAL in partnership with the Almond Board of Australia (ABA). It has been funded by the Australian almond industry levy. The Australian Government provides matched funding for all HAL's R&D activities.

August 2011

Advanced Production System Workshop 17th August 2011

St Marks College Ballroom 46 Pinnington Terrace North Adelaide

Session	***Welcome***	***Presenter***
8:30am	*Registrations - Tea & Coffee*	
9:00am	Welcoming address	Brendan Sidhu, ABA Chair
9.10am	Introduction and workshop processes	Peter Hayes, Workshop Manager
Session	***Setting the Scene***	***Presenter***
9:15am	Advanced production systems and the need for a holistic approach – the dried grape experience	Ivan Shaw, OAM, Innovator, Dried Grape Grower
9:45am	A future vision to maximise product returns to the Australian almond industry – A sales perspective	Grant Birrell
9.55am	Shake and collect harvesting	Ben Haslett
10.05am	One pass collection - Select Harvests	Tim Millen
10:15pm	*Break*	
10:30pm	Potential technology advances in our products production	John Fielke
10:50am	What is the ideal production system for Australia - Orchard to orifice (takes into account food safety aspect)	Group Discussion
11:50pm	Highlights of US & Spanish study tour	Ben Brown/Ross Skinner/Brendan Sidhu
12:00pm	*Lunch*	
Session	***Identifying the challenges and solutions to achieving the ideal production system***	***Group Facilitator / Reporter***
12:45pm	Four Groups to look at each topic area below with an emphasis on two of them to allocated: Production to the point of harvest; Harvest Equipment; Aeration / Dehydration; Hulling on site; Storage; Processing; and Others identified in earlier process.	TBA
2:15pm	*Break*	
Session	***Presentations by groups***	***Group Facilitator / Reporter***
2:30pm	Each Group to present under a challenge environment, identifying new knowledge, technologies and equipment needed to deliver new systems and the feasibility of success	TBA
Session	***Where to Next***	***Speaker***
3:30pm	R&D priorities & timeframes	Peter Hayes /Ross Skinner/Ben Brown
4.00pm	Closure	Brendan Sidhu

1. Workshop Participants

		Workshop Group
Peter	Hayes	Workshop Manager
Domenic	Cavallaro	Aeration/Dehydration & Hulling Onsite
David	Pocock	Aeration/Dehydration & Hulling Onsite
Troy	Richman	Aeration/Dehydration & Hulling Onsite
Ben	Robinson	Aeration/Dehydration & Hulling Onsite
Brett	Rosenzweig	Aeration/Dehydration & Hulling Onsite
Brendan	Sidhu	Aeration/Dehydration & Hulling Onsite
Leroy	Sims	Aeration/Dehydration & Hulling Onsite
Tim	Vandenburg	Aeration/Dehydration & Hulling Onsite
Brenton	Woolston	Aeration/Dehydration & Hulling Onsite
Neale	Bennett	Harvest & Production
Fei	Tang	Harvest & Production
Troy	Pfeiffer	Harvest & Production
Ben	Haslett	Harvest & Production
Tim	Orr	Harvest & Production
Steve	Paltridge	Harvest & Production
Jason	Robinson	Harvest & Production
Ivan	Shaw	Harvest & Production
Mark	Heyward	Harvest & Production
Ben	Brown	Production & Harvest
Greg	Buchanan	Production & Harvest
Peter	Cavallaro	Production & Harvest
Robert	Gulack	Production & Harvest
John	Kennedy	Production & Harvest
Paul	Martin	Production & Harvest
Tim	Millen	Production & Harvest
Michelle	Wirthensohn	Production & Harvest
Grant	Birrell	Storage, Processing & Sales
Toby	Smith	Storage, Processing & Sales
Nigel	Carey	Storage, Processing & Sales
Tony	Costa	Storage, Processing & Sales
John	Fielke	Storage, Processing & Sales
Tom	Martin	Storage, Processing & Sales
Ross	Skinner	Storage, Processing & Sales

Apologies

Tony	Spiers
Drew	Martin
Peter	Ross
Andrew	Lacey
Daryl	Winter
Graham	Johns
Denis	Dinicola
Damien	Houlahan

2. Mildura Rainfall – Quick Analysis

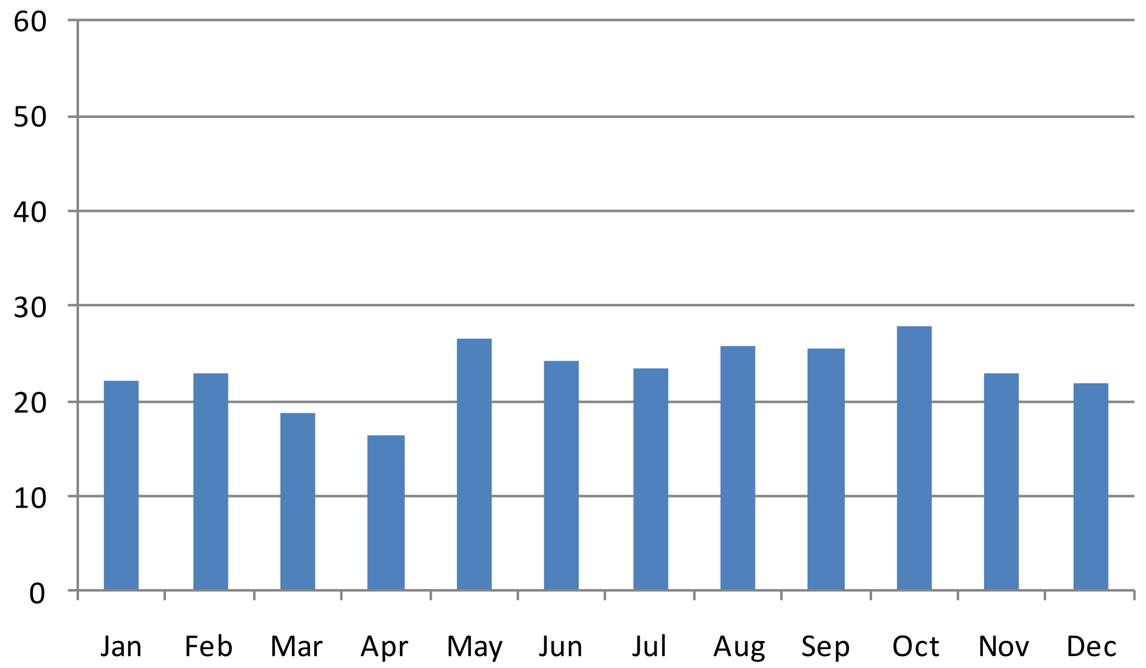
12th August 2011

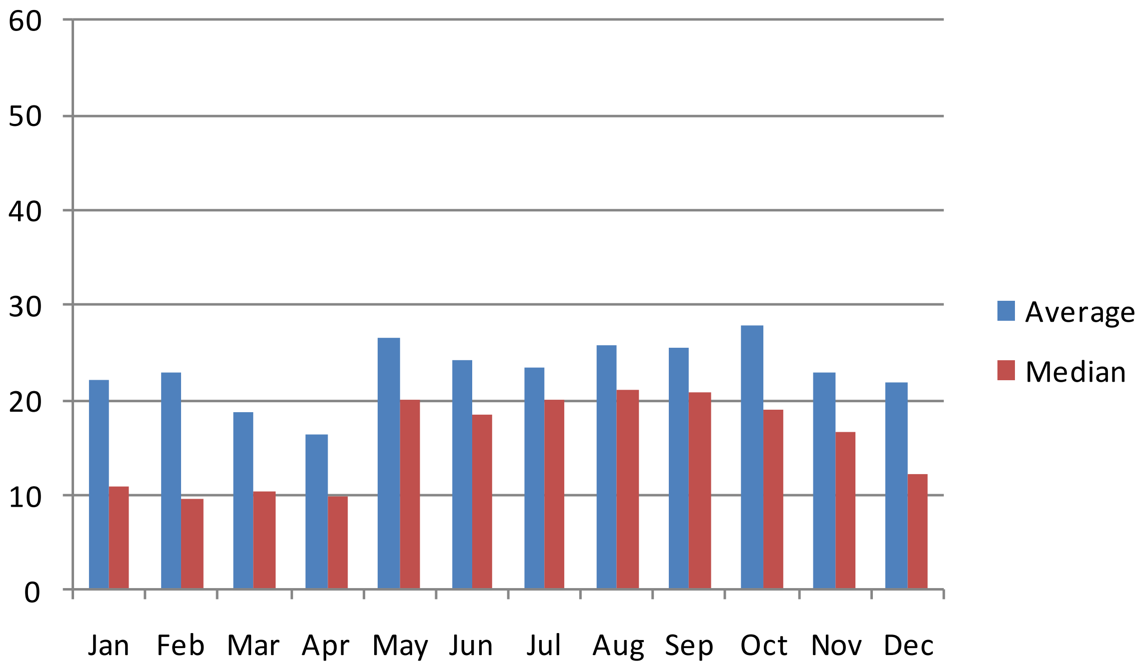
Dr Peter Hayman
Principal Scientist, Climate Applications
South Australian Research and Development Institute SARDI
Waite Research Precinct Bldg 11a
P: 08 83039729, M: 0401 996 448, F: 08 83039717
GPO Box 397, Adelaide, South Australia, 5066

Quick analysis of Mildura rainfall to answer two questions:

1. How do recent seasons compare with historical record?
2. How does monthly rain at Mildura compare with California?

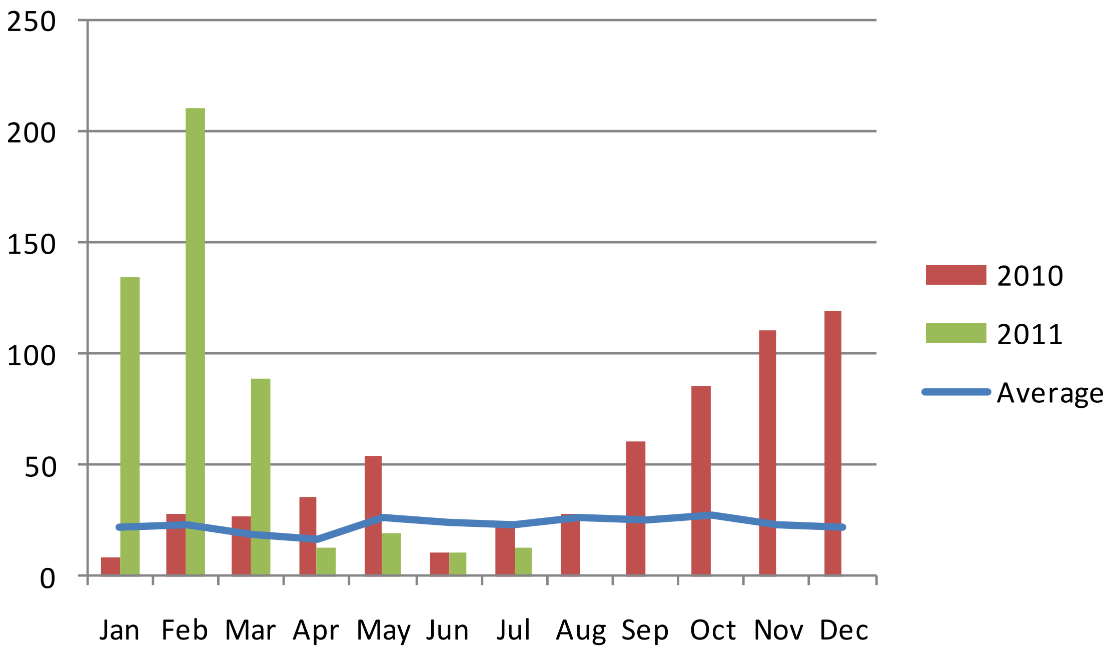
Mildura average monthly Rainfall – very uniform





Mildura average and median monthly rainfall - note the median in summer months is about half the average, this indicates the distribution is very strongly skewed – summers are usually very dry but occasionally wet.

Mildura in 2010 and 2011

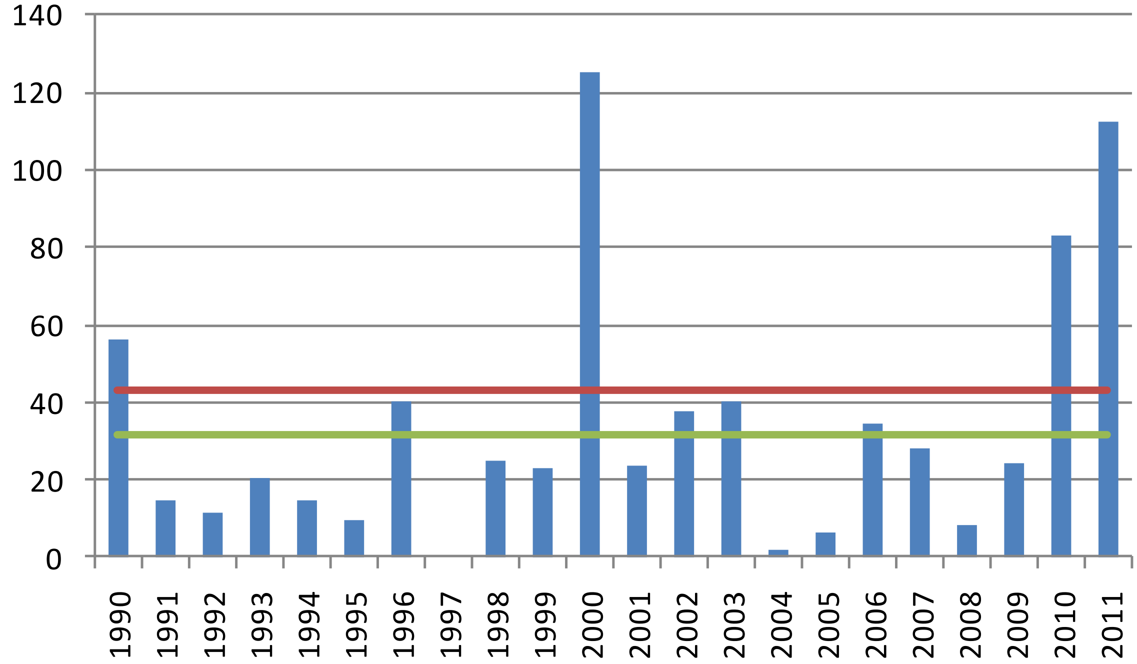


Mildura monthly rainfall showing how the end of 2010 and start of 2011 was extraordinarily wet.

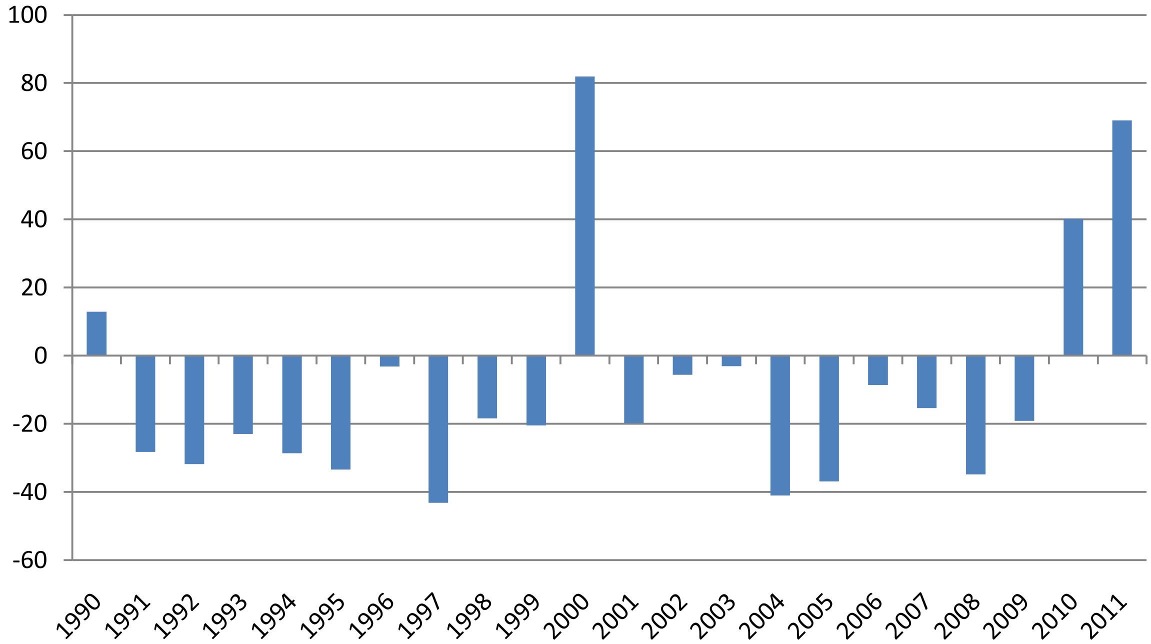
Mildura Rainfall during Almond Harvest – 15th Feb to 15th April

1990 to 2011

Mildura 15 Feb to 15 April rainfall from 1990 to 2011 shows most years in recent memory, prior to 2010 and 2011, have been very dry. The red line is the average (43mm) from 1900 to 2010, the green line is the median. Of the 22 years there have only been 4 above average and 8 above the median. By definition, over historical record half the years will be drier than median and half wetter.

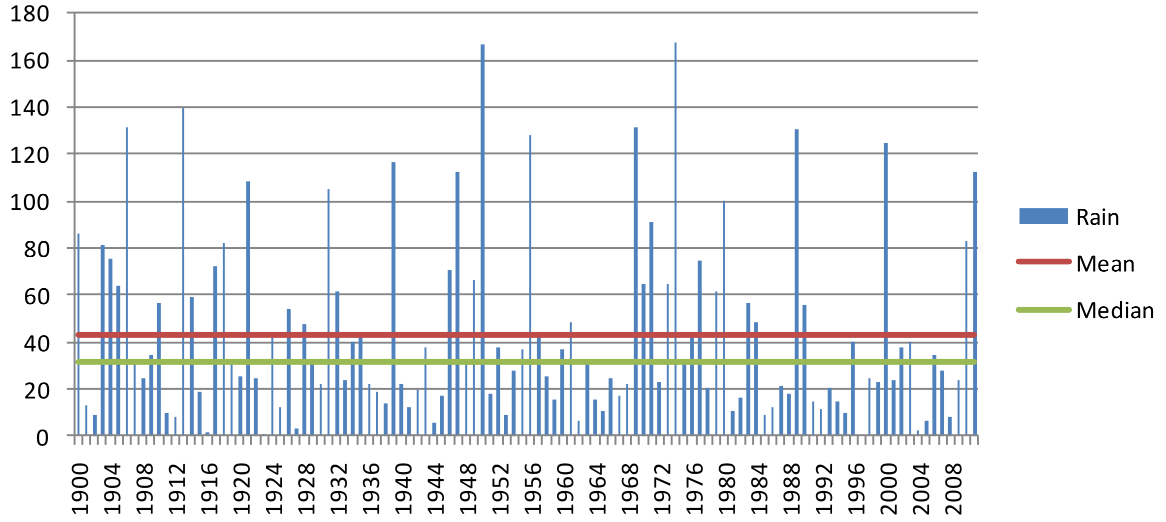


Mildura 15 Feb to 15 April 1990 to 2011 rainfall showing deviations from the long term average of 43mm (same data as above graph).

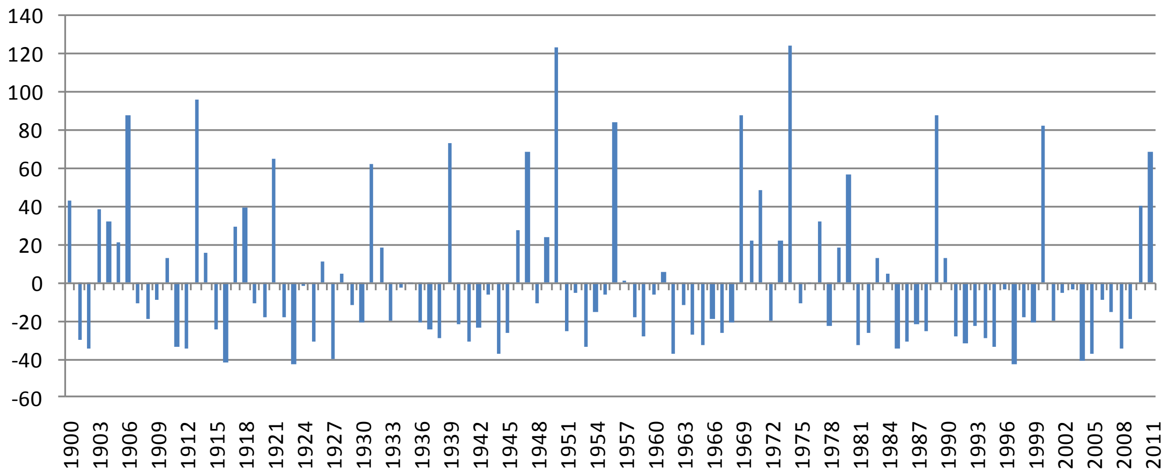


1900 to 2011

Mildura 15 Feb to 15 April rainfall from 1990 to 2011 showing that recent wet autumns are not unusual in historical record.

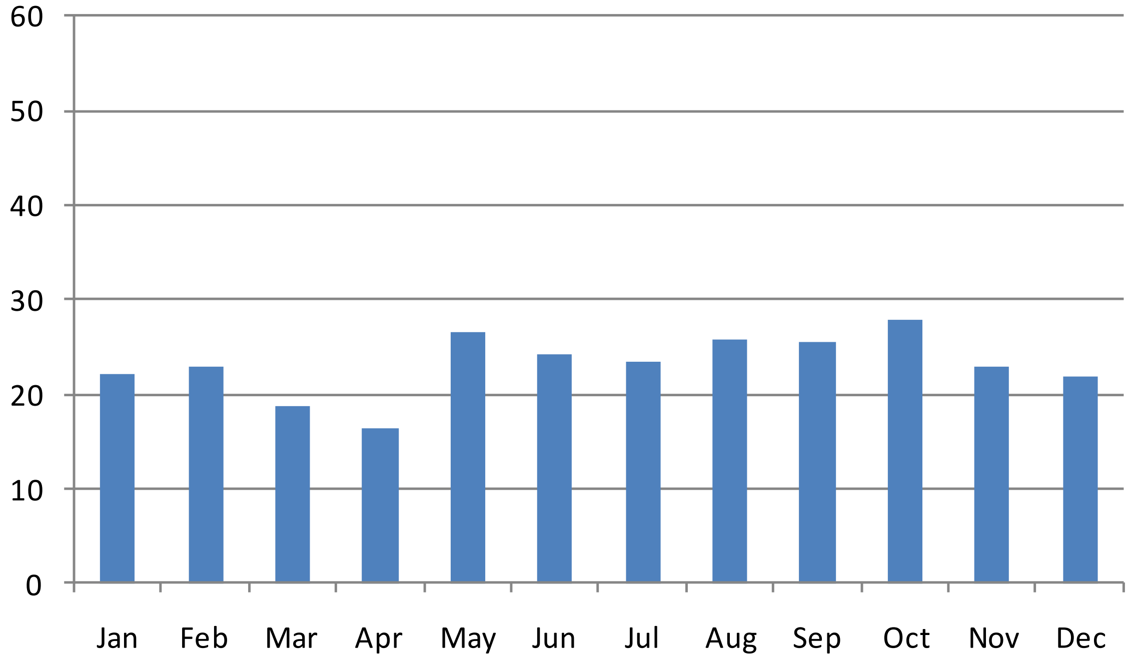


Mildura 15 Feb to 15 April rainfall 1900 to 2011 showing deviations from the long term average of 43 mm (same data as above graph).

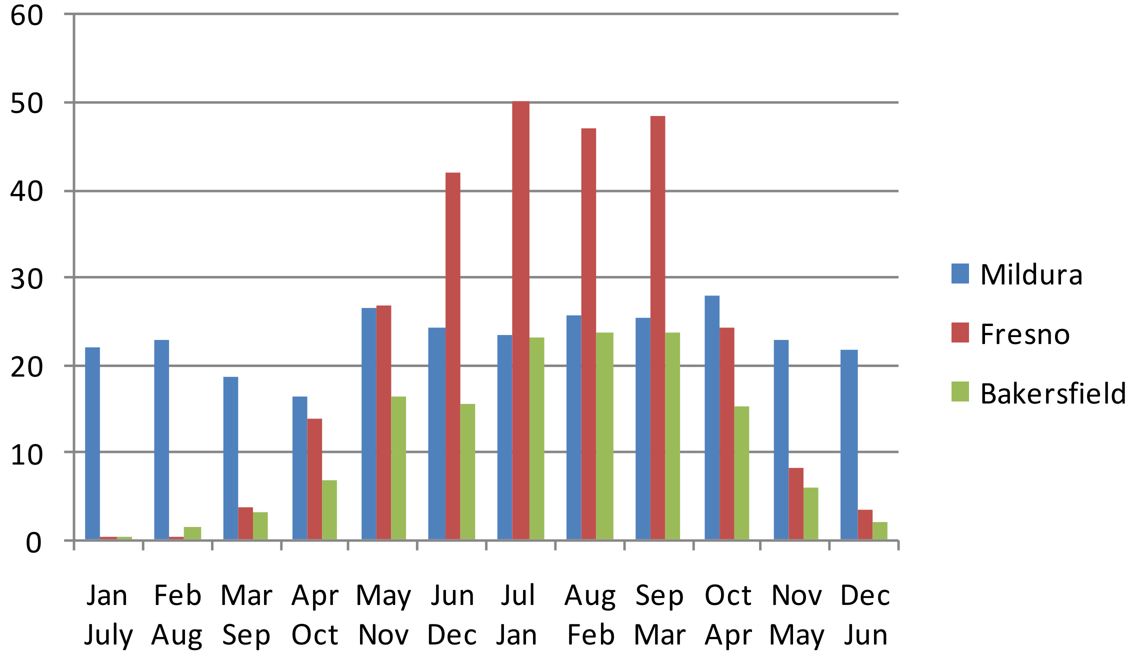


Comparing Mildura with California

Mildura average monthly rainfall – showing Mildura is essentially arid rather than mediterranean – the evaporation is what changes the effectiveness of rainfall.



Comparison of Mildura, Fresno and Bakersfield showing California has a much stronger Mediterranean climate. The summer rainfall in California is extremely low.



Sources:

- Bureau of Meteorology monthly data for Mildura – using Irymple (Arlington)
- Silo Patch Point Data set for daily data for Mildura
- California – The Global Historical Climatology Network
- Fresno air terminal, Fresno county and Bakersfield, Meadows California.

3. Report: Uni of SA Review of Australian Almond Processing Industry

4. R&D Priorities for Further Consideration following John Fielke's (Uni of SA) Report

No.	Processing Concepts	Worthwhile	
		Yes	No
1.	A desktop review of current aeration/dehydration equipment; and current hulling and shelling processes, equipment and technology available from the most common manufacturers.		
2.	Pre-cleaning on farm prior to delivery.		
3.	Storage in controlled environment to manage moisture; biological and physical contamination; shell and kernel damage.		
4.	Aeration / dehydration on farm of whole fruit.		
5.	Aeration / dehydration at huller and sheller of whole fruit.		
6.	Aeration / dehydration at huller and sheller of kernel.		
7.	Hulling on farm, either in the orchard or at the stockpile/storage area.		
8.	A more thorough investigation of a hulling and shelling plant(s) to quantify and develop a better understanding of the sources of chips and scratches, i.e. on arrival (i.e. on farm) and/or at what stage(s) through the processing.		
9.	Early removal of stones and other smaller contaminants prior to hulling and shelling when physical difference in size is greatest.		
10.	Investigate the potential of de-husking (e.g. pin rollers) at the beginning of the lines to optimise in-shell yield and minimise what is being asked of the shear rolls and shear rolls over belts. That is, don't ask shear rolls to hull and shell, maybe use a pin roller for hulling and shear rolls for shelling.		
11.	Techniques and equipment to optimise flow and through put of product between stages.		
12.	Techniques and equipment to size grade in-shell product (i.e. small, medium & large) after the de-husking to enable more accurate setting of the shear roll tolerances. Then run the size grades through specifically set shear rolls.		
13.	Investigate the shear rolls, shear roll over belts and cushioning to examine the cause of the damaged kernel and determine more optimum settings. If settings can be improved investigate more efficient alternatives such as multiple stacks of shear rolls, etc. Early investigation shows damage related to speed of product through the rollers. Concept: more rollers and slower speeds through each roller. If settings can't be improved investigate other alternatives to shell almonds.		
14.	Investigate efficient physical cleaning processes via screening and air separation - after shelling but prior to sizing to remove broken shell, etc. This has a high success rate for cleaning product and can remove 90+% of most physical contaminants. Laser cleaning is not an appropriate sorting procedure here.		
15.	Size graded product (i.e. small, medium & large not full industry sizing at this stage) over gravity tables once passed through the first physical clean.		
16.	Investigate efficient physical cleaning processes via screening, push/pull air separation & gravity tables - after size grading to small medium & large, to remove mouldy kernel, etc. Mostly based on density. This also has a high success rate for cleaning product and can remove 99+% of most physical contaminants. Laser cleaning is not an appropriate sorting procedure here.		
17.	Techniques and equipment to better size product to full range of industry sizes (i.e. 20/22, etc).		
18.	Performance and settings for laser cleaners removing discoloured contaminants from product already sized to full range of industry sizes. This is done prior to secondary processing.		
19.	Performance and settings for repeat laser cleaning to remove chips, scratches, insect and rodent damage from industry sized product, at the packers, based on customer orders and specifications. However; ideally, if you have already: a) identified the causes of the chips and scratches and made machinery modifications to alleviate the issues, and b) laser sorted based on mould, the last laser sort will just be tuned (but highly tuned) to insect and rodent damage. Let packers decide the quality and value of pack but remove them of the pressure to clean contaminated product.		

5. Study Tour: Investigating Efficient Harvesting Systems that Improve Product Safety and Quality

ALMOND BOARD OF AUSTRALIA

Advanced Production Systems Workshop

17th August 2011

Brendan Sidhu
ABA Chairman

AUSTRALIAN ALMONDS

Welcome

- St Mark's College:
  - Adelaide's first university residential college
  - Founded in 1925
  - Accommodates 230 students
- Housekeeping:
  - Toilets next to the Ballroom and on the ground floor.
  - Watch for parking tickets outside, parking inspectors not commonly see but you never know.

Welcome

- ABA Board
- ABA IAC & Sub-committee’s
- Industry Members
- Key Note Presenters
  - Assoc Prof John Fielke
  - Ben Haslett
  - Grant Birrell
  - Ivan Shaw
  - Tim Millen
- Workshop Manager
  - Peter Hayes

Purpose of the Workshop

- Review our current production system to ensure it is the most suitable for us today and into the future

- Originally the workshop was being called a "one pass harvesting system". This has different meanings to different people:
  - To some it meant: One pass pick-up off the ground
  - To others it meant: Shake and Catch

- To provide clarity and to capture a more holistic approach, we decided on the term "Advanced Production Systems"

Advanced Production Systems

- This is deliberately stated:
  - **Advanced**: indicating movement forward
  - **Production**: being all processes contributing to the final product
  - **Systems**: a holistic approach tailored to individual circumstances

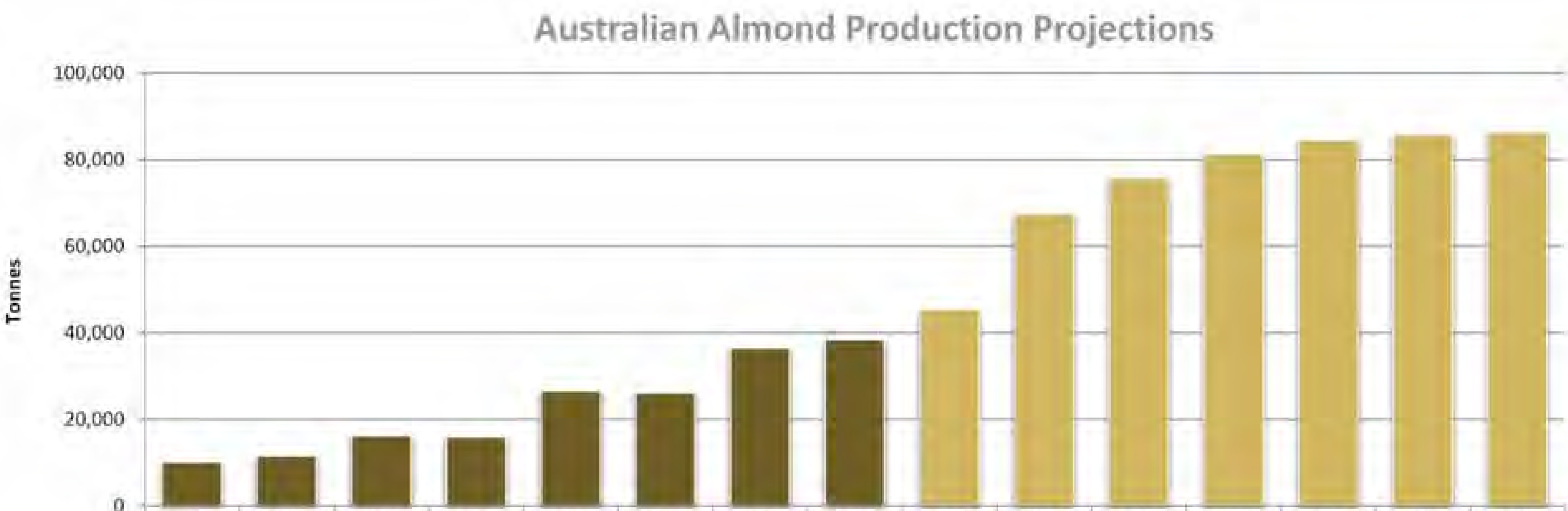
- There is likely to be more than one system required to suit the diversity of growing and processing enterprises in the Australian industry

Why Change?

- In the past decade, the Australian industry has rapidly built on the endeavours of the pioneering Australian almond growers.
- This has predominantly been based on the Californian model of large scale orchards
- This model has served us well enough during the dry years – but has not been as good during the past two wet years where we have issues with:
  - Delayed harvests & crop losses
  - Increased costs of harvest
  - Reduced product quality & value
  - Increased food safety risks
  - Damaged reputation for supply reliability

Why Change?

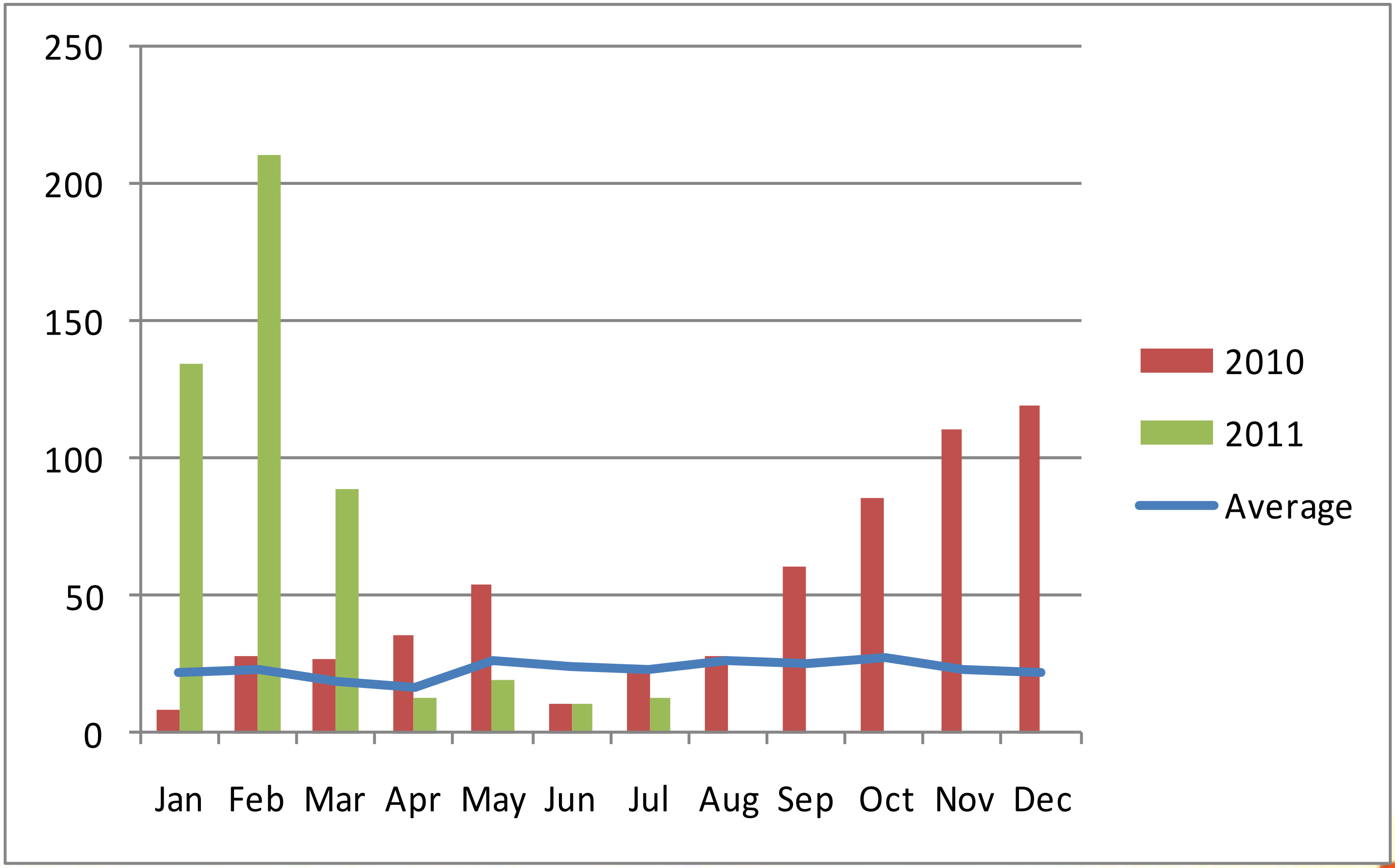
- Supply Increase:



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Tonnage	10,093	11,474	16,178	15,917	26,555	26,060	36,500	38,371	45,400	67,495	75,714	81,329	84,426	85,823	86,257

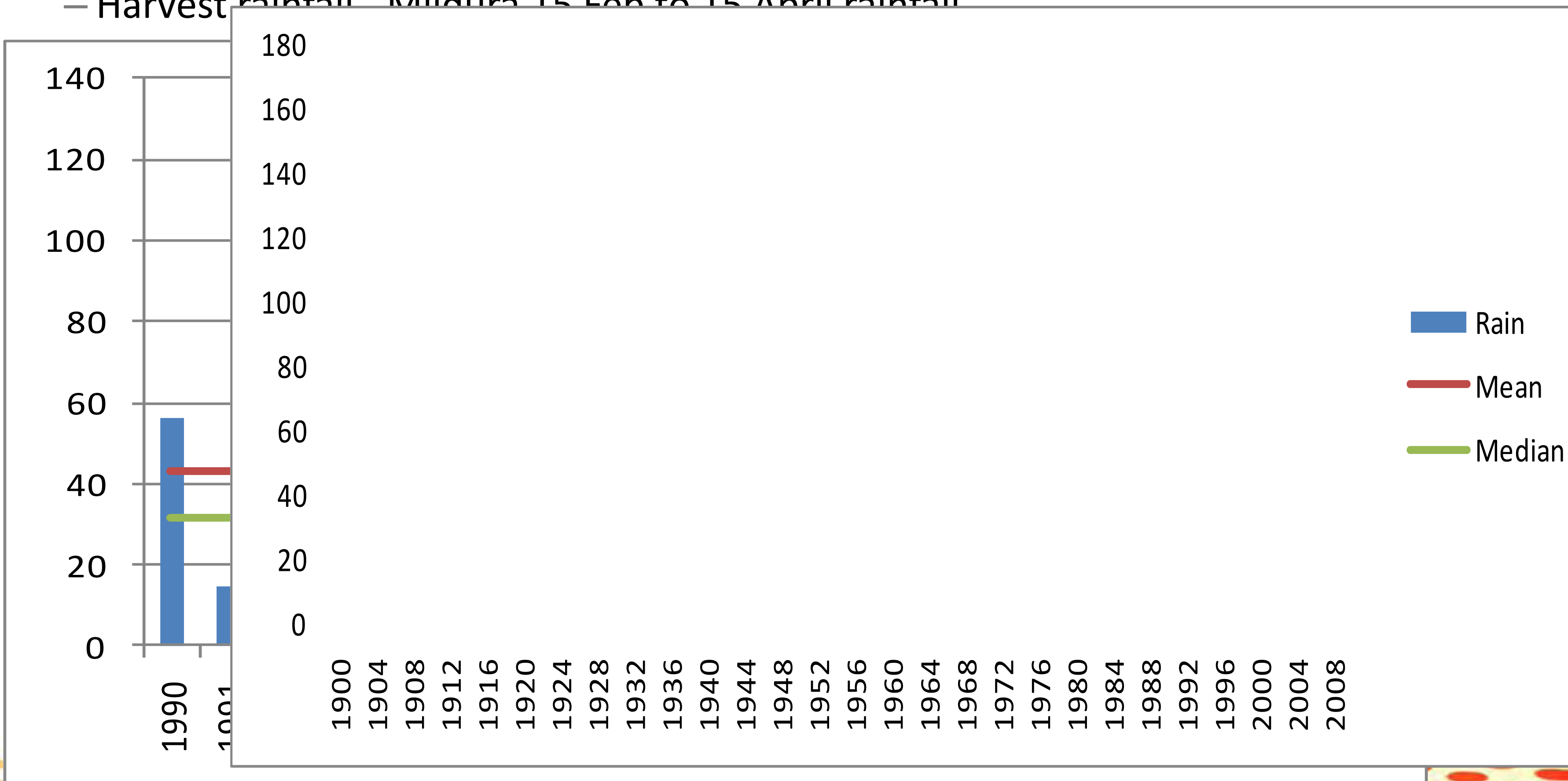
What's a "Normal" Year?

- It wasn't the last two years!



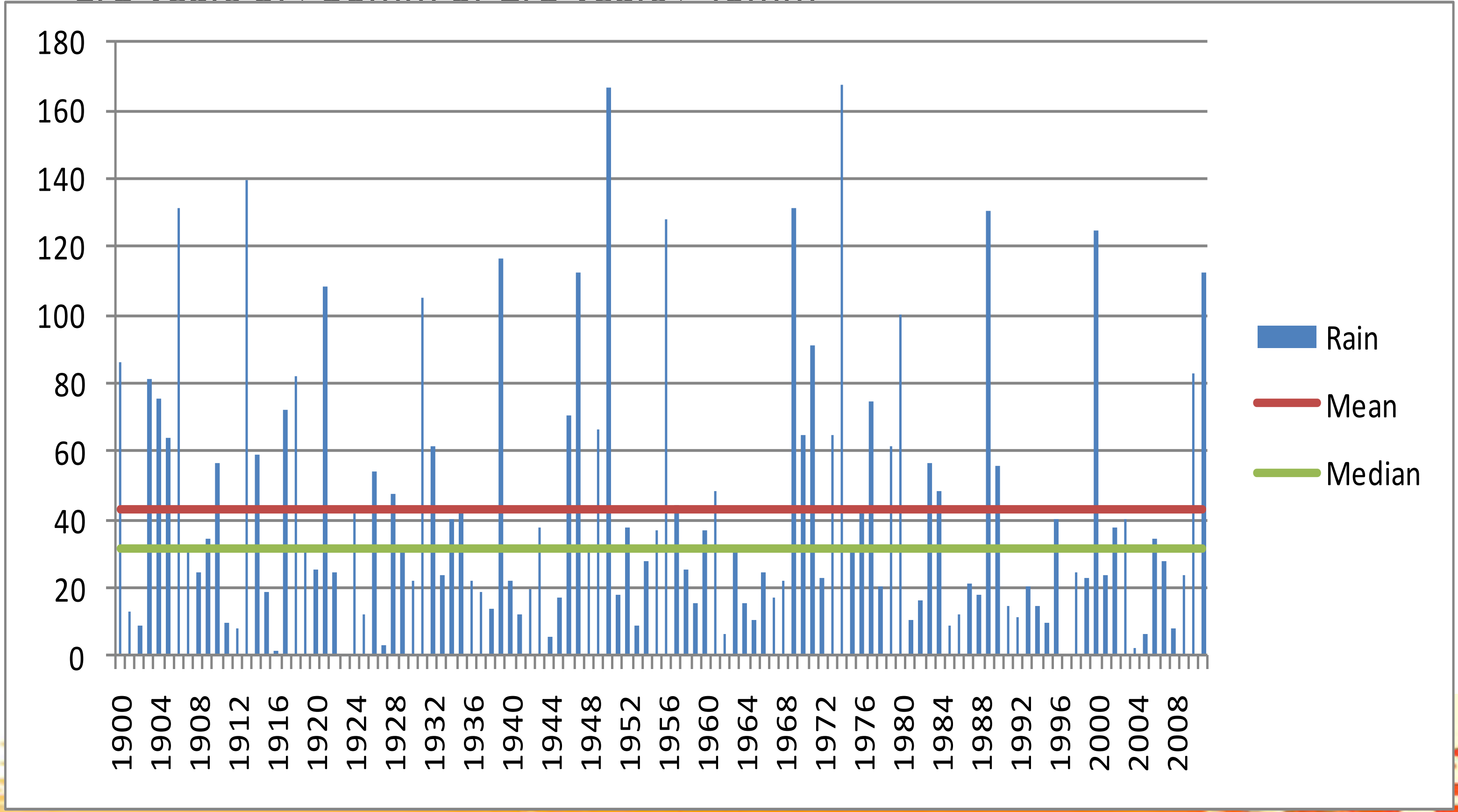
What’s a “Normal” Year?

- It wasn’t the previous 1-2 decades either – mostly very dry
  - Harvest rainfall – Mildura 15 Feb to 15 April rainfall



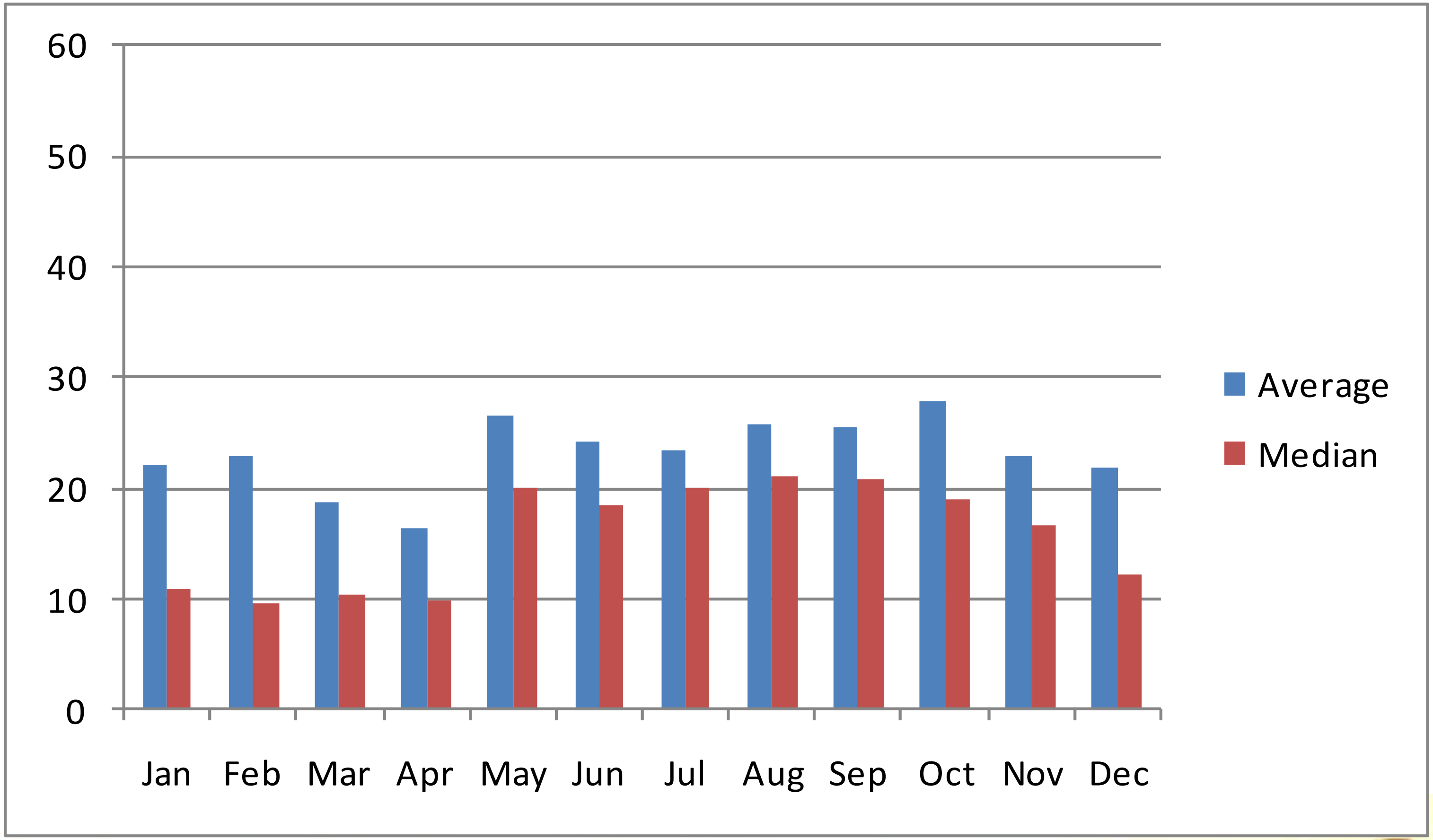
What's a "Normal" Year?

- This is though, harvest rainfall – Mildura, 15 Feb to 15 April:
  - 43 mm average rainfall during harvest!
  - 1/3 years of >50mm or 2/5 years >40mm



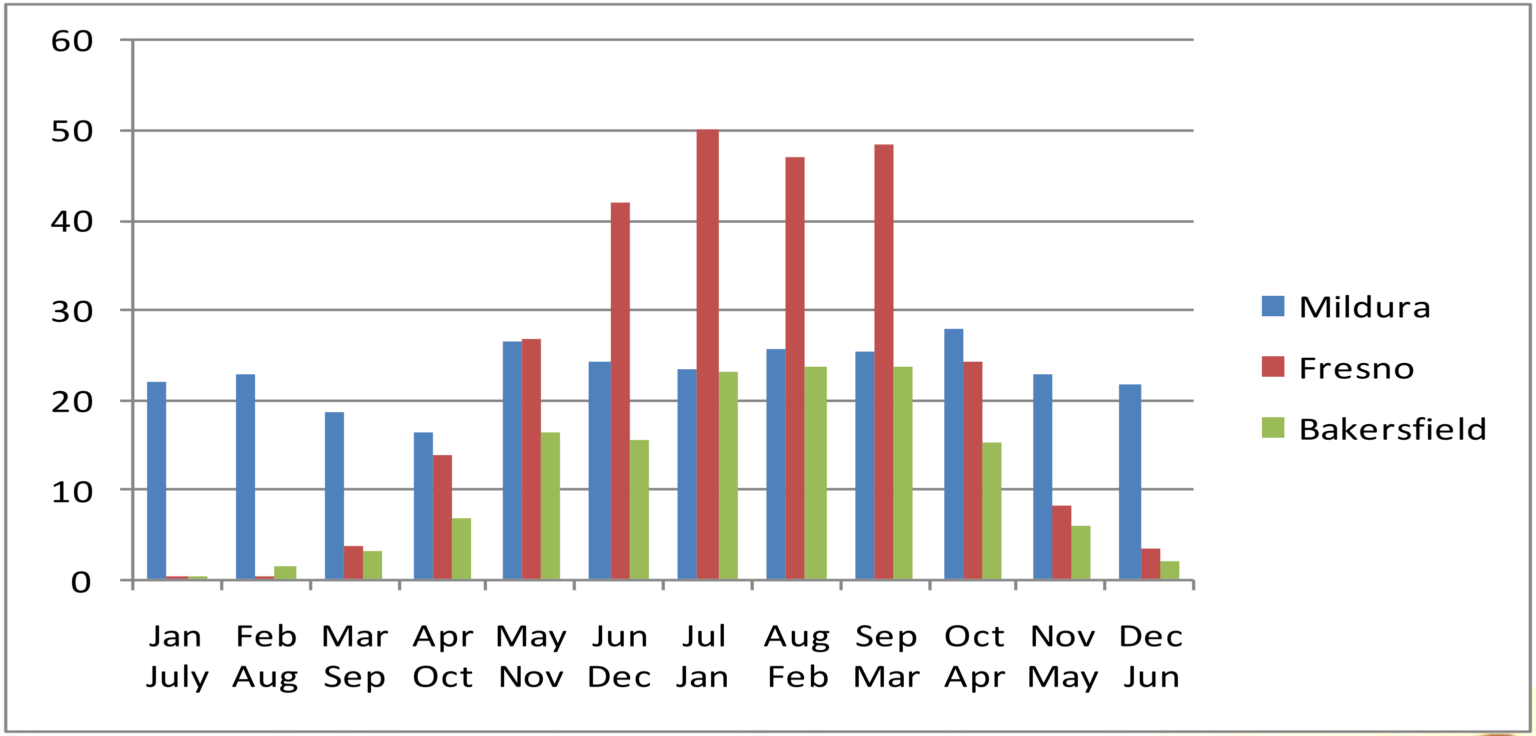
What's a "Normal" Year?

- Mildura Rainfall (mm)



Australia v's California

- We are not California!
  - "Seems it never rains in southern California....." (Albert Hammond, 1972)
  - Average Monthly rainfall (mm)



Workshop Goals

- Develop ideas to:
  - Maintain or improve yield
  - Reduce production inputs (costs)
  - Reduce crop loss
  - Improve product quality
  - Reduce food safety risks

MAXIMISE PROFIT

- We want to identify what is achievable in improving production systems, not only today but also in the future

- The challenge will be taking today's vision for the future and realising it through our R&D investment

Industry Value Chain

- There is a need to have a broad view of our whole value chain:
  - Pre-Farm
  - On-Farm
  - Post Harvest
  - Marketing

Future R&D

- ABA has had discussions with DPI Vic, our lead R&D agency, regarding a funding opportunity worth $4 million over 4 years to establish and operate a "field laboratory" for almond R&D orchard trials.

- The "field laboratory" will be owned by ABA and the proposal includes:
  - Developing improved practices for "traditional orchards"
  - Developing new practices for "future orchards"

Future R&D

- The ABA has formed a sub-committee to progress the concept for an almond centre of excellence which will investigate not only the "field laboratory" but also:
  - Foundation and mother tree repository
  - Small scale nursery for current, and new local and imported rootstocks and varieties for which ABA have propagation rights
  - Industry promotion
  - Office complex
- Any profits will be re-invested back into the industry

Peter Hayes
Workshop Manager

Australian Almonds

Peter Hayes

- Peter Hayes has extensive experience across education and training, R&D investment &management, viticultural operations &government &industry affairs in a 30+ year career in the wine industry.
- Peter initiated development of the CRCV's most successful "Research to Practice" series of professional development activities.
- Career appointments include:
  - Lecturer/Senior Lecturer/Vice Principal, Dookie Agricultural College;
  - State Viticulturist &Statewide Industry Officer (Fruit &Vines), Victoria;
  - Executive Director, GWRDC;
  - Acting CEO, Cooperative Research Centre for Viticulture (CRCV);
  - Director of Viticulture, Rosemount Estates;
  - National Viticulturist &Industry Affairs Manager, Southcorp Wines.

AUSTRALIAN ALMONDS

Peter Hayes

- Career appointments include:
  - Council Member, Australian Wine Research Institute (AWRI);
  - President, Australian Society of Viticulture and Oenology (ASVO);
  - President, (currently Vice-President) of the International Organisation of Vine and Wine (OIV);
  - Chairman, CRC for Irrigation Futures and
  - Board Member, GWRDC amongst many others
- At present he operates as an independent Wine Industry Strategist and Advisor with activity in Australia, India and the UK.

Advanced production systems and the need for a holistic approach – the dried grape experience.

By

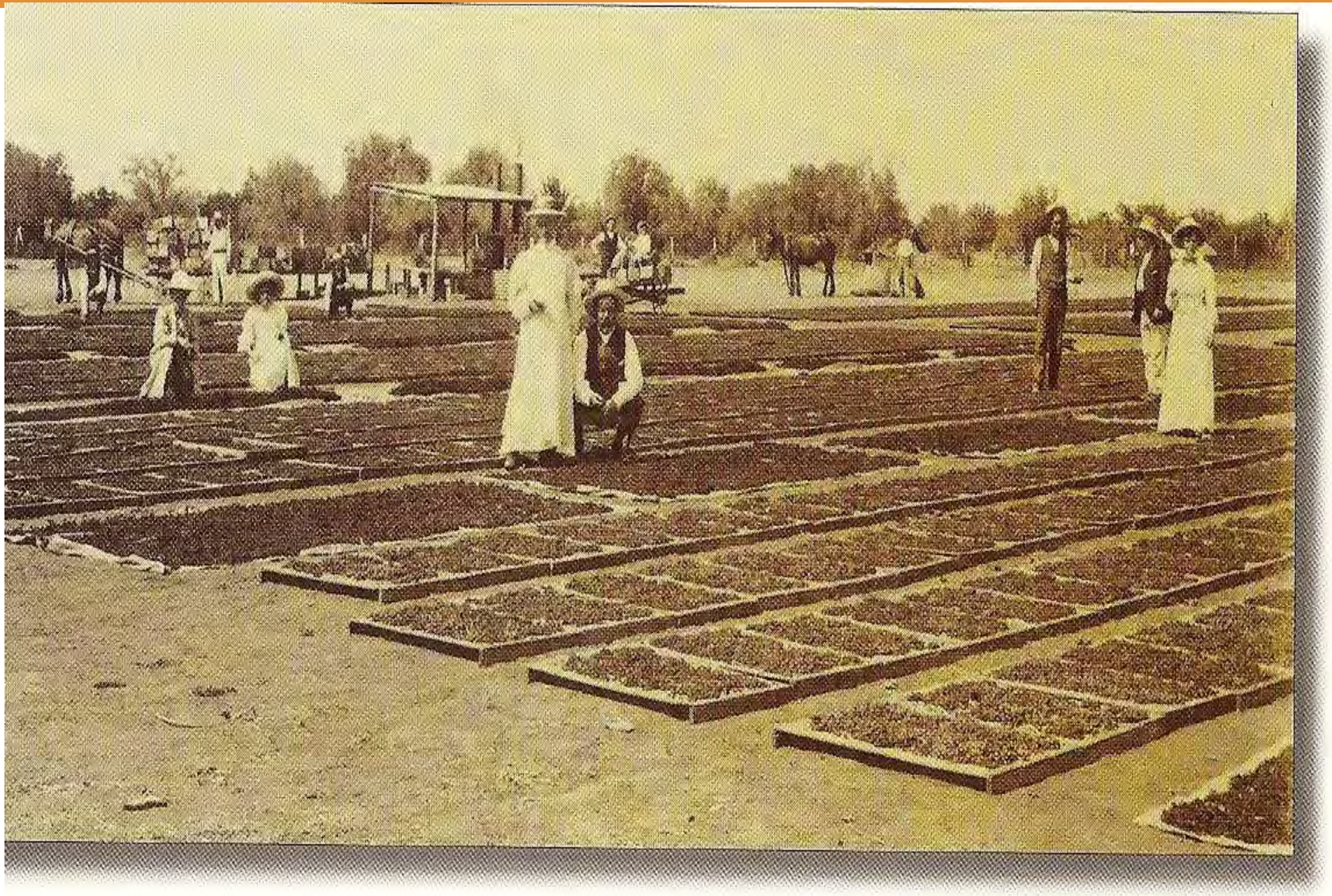
Ivan Shaw

AUSTRALIAN ALMONDS

COMMON AIMS for profitability

- Maximum productivity through optimal physiology of plant and appropriate varieties.
- Minimal inputs (esp labour)
- Capacity for economies of scale.
- Product integrity (quality and no contaminants)
- Risk management – esp weather/contaminants

EARLY DRIED GRAPE PRODUCTION



- Early American influence in Australia led to drying on the ground as is still done in California

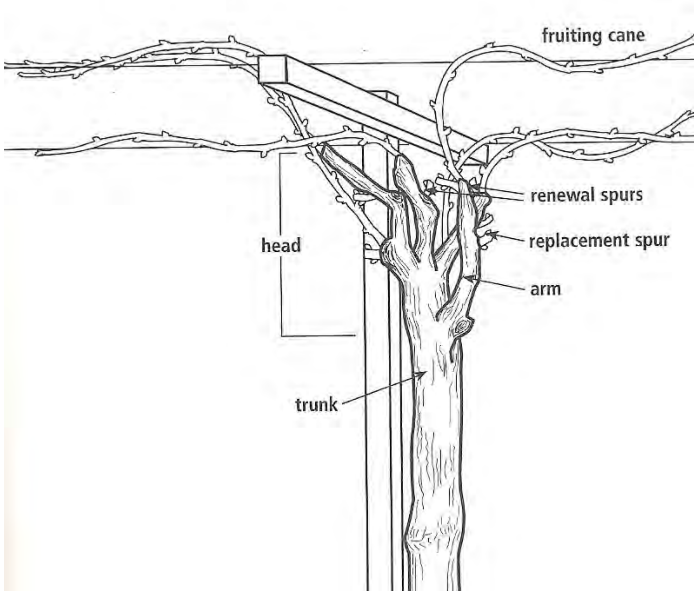
Unpredictable harvest weather soon changed that!

- Dipping in potash and vegetable oil to speed up drying.
- Drying racks were introduced
- Ground drying was only for finish drying

Average Monthly Rainfall for Mildura and Fresno

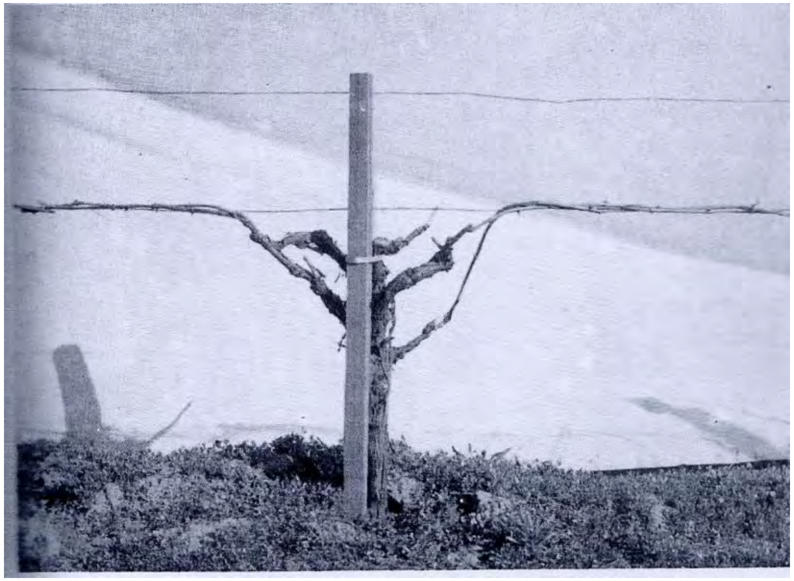
Month	Fresno	Mildura	
Jan	56	26.3	July
Feb	55	26.8	August
March	55	27	September
April	19	29	October
May	10	24	November
June	6	23	December
July	.25	20.7	Jan
August	.25	20	Feb
September	6	17.9	March
October	16	18.3	April
November	27	25.5	May
December	33	22.9	June
Total	283	282.9	

How fruit develops on a grapevine



- A permanent trunk and arms are established.
- Fruit grows on a shoot that developed over the previous spring and summer.
- Sultanas are cane pruned due to unfruitful base buds.

PRODUCTION BASED ON HORSES AND HANDS



-Vine spacing (2.4M)is based on crown width (.6M) plus two cane lengths(1.8M)

-Most vines grown this way till 1990's

-Very labour intensive

Trellis drying was trialled in late 1960s

- Initially used to salvage rain damaged fruit.
- Adopted as production system by small number of growers using "T" trellis

Trellis Drying minimised risk and cost

- Canes had to be hand cut leaving new canes for next season.
- Some “crown” bunches had to be hand removed.
- It could be machine harvested, but new canes and leaves also were also beaten.

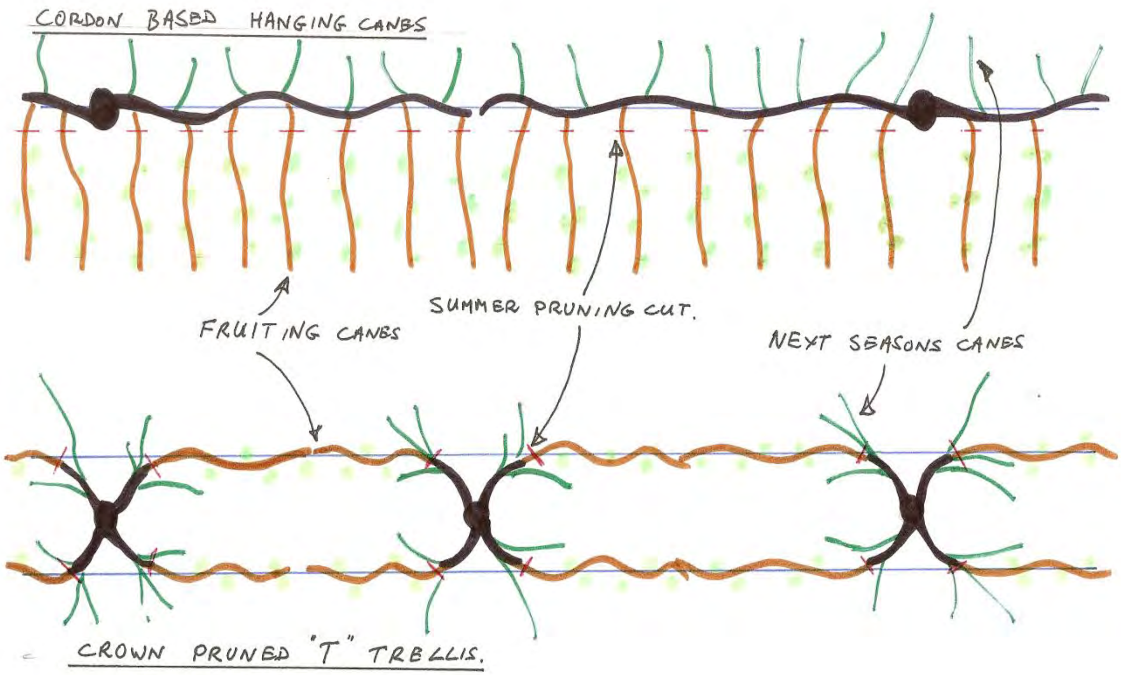
Rate of adoption was slow

- 85% of grapes were still hand picked into buckets up to mid 1990s
- Fear that summer pruning would cripple vines.
- Old , poorly trained vines were not suited.
- Reluctance to trust something new.
- Rush to highly mechanised and profitable wine industry.

Hanging canes from a permanent cordon

- Hanging canes from a permanent cordon was demonstrated in 1980 by CSIRO.
- This was based on the old Sylvoz principle
- Ugly vines, beautiful concept.

Continuous Operations

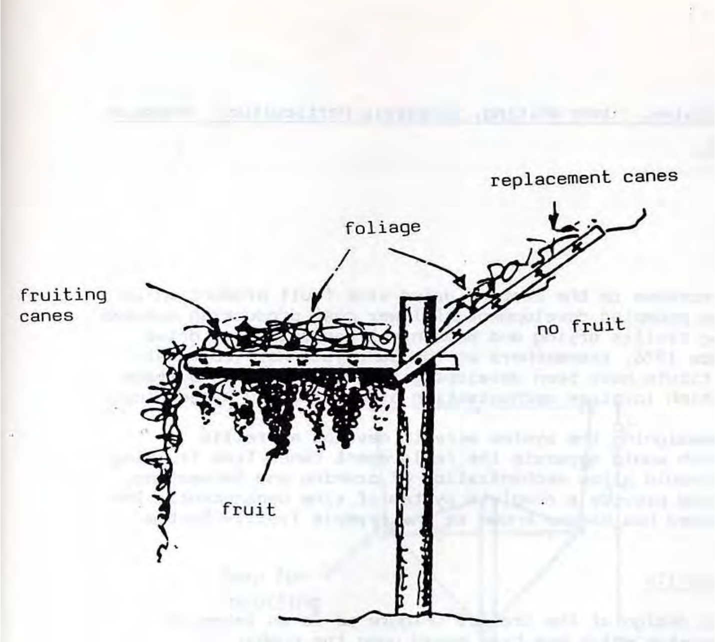


- Conventional crown pruning meant stop /start operations.
- Cordon based systems allowed continuous operations.
- Cordons allowed new and old canes to be separated.
- Vine spacings can be extended to balance vigour.

Mechanisation

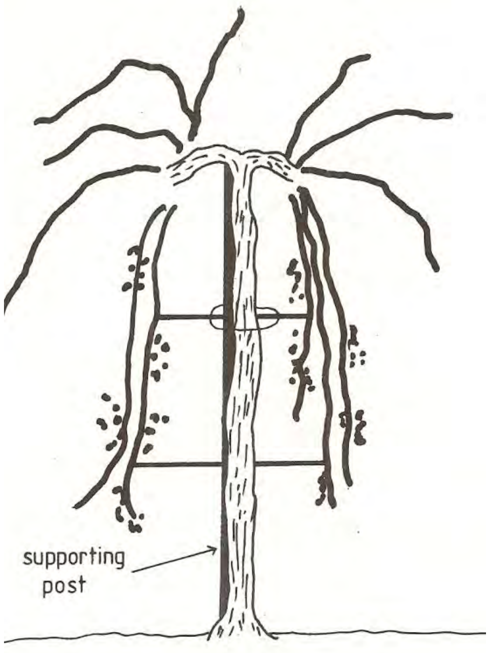
- Deregulation made labour saving and scale a priority.
- Hanging canes allowed separation of fruiting and replacement canes.
- Continuous operations along a row were possible.
- Vine spacing was no longer limited to fruiting cane length.
- This radical change in vine architecture required a fresh start, and new equipment.

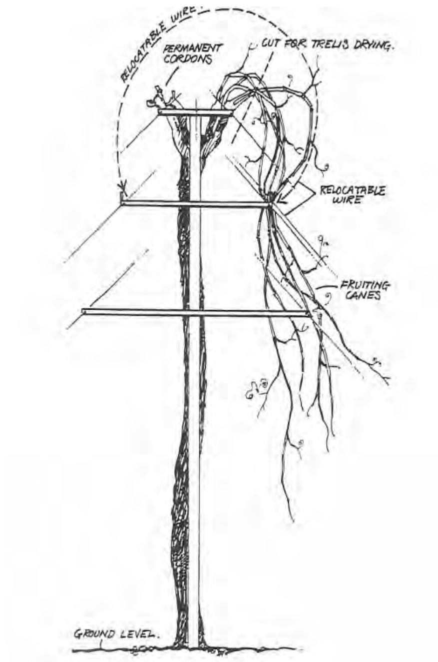
Irymple Swing Trellis-early 80's



- An excellent concept, but unstable and hence impractical.
- It provided optimal fruit distribution and replacement cane exposure to light.
- Seen by industry as not adoptable, and removed.

Efforts were made to simplify the concept.





-Stable trellis but main benefits compromised

-New cane position and micro climate were not ideal.

-Fruiting canes needed to be hand positioned.

-

Simplified Swing Arm Trellis

- Swing-arm maximised new cane exposure to light, fruit distribution, micro climate and mechanisation on a stable trellis.
- The ability to mechanically summer prune is essential for risk management.

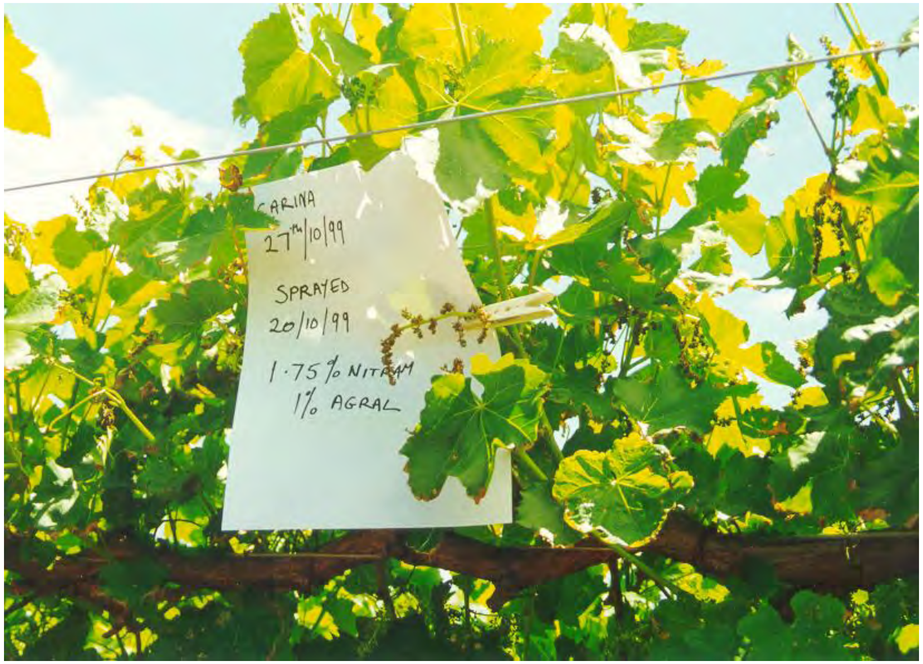
Simplified Swing Arm Trellis

- Swing arm at budburst.
- Fruiting rows face each other to allow two row operations.
- Height of buds from ground minimises frost risk.

Trellis is tipped in Winter.

- Cordons are cleaned up in winter leaving new canes.
- Trellis is tipped 90 degrees in Winter, repositioning fruit canes.
- Most canes are positioned when tipped.

Cordon bunch removal



- Bunches on the cordon can be sprayed out in spring.
- Eliminates 2/3rds harvest costs.
- Essential for an efficient operation.
- Only practical on cordon based systems

SUMMER

- Good fruit distribution.
- Improved micro –climate.
- Replacement canes in optimal position for bud fruitfulness.
- Separation of new and fruiting canes.

HARVEST

- Leaf removal assists spraying and drying.

HARVEST -Cutting

-Mechanical cutting is important for risk management and allows fruit to dry faster.

-Replaces about 8 people, and can also be done at night.

-No cordon bunches remain in harvest zone.

HARVESTING

- Most wine grape harvesters will not fit over the trellis.
- A radial head harvester was specifically developed.
- Replacement canes are untouched.
- No fruit touches the ground - no contaminates.

INTRODUCTION OF NEW VARIETIES

- Industry is still reliant on Sultana which is an inconsistent producer and regularly split by rain at harvest.

- CSIRO varieties are primarily bred or selected for rain tolerance, quality and high production.

- Imported American varieties not checked for rain damage at harvest.

New varieties changing the industry.

- Sunmuscat has proved to be consistent and safe.
- Sunglo should provide a safe substitute for Sultana.
- Carina currants have almost totally replaced the risky Zante variety.

2011- Disastrous season

- Value of new varieties demonstrated.
- Immature Sultanas were cut to salvage crop - poor results.
- Sunglo was able to be left to mature.

DEHYDRATION-FINISH DRYING

- The risk and labour cost of finish drying on ground sheets has been largely replaced by batch drying in bins.
- One large scale producer uses continuous throughput drying.

Californian Trends

- Half the crop is still hand picked onto paper and sun dried.
- About 1/3 crop is hand cut , harvested when stems are brittle, and dropped onto paper sheet to dry.
- Inefficient compared to cordon based systems,including winter pruning.
- Labour cost per hour is 1/3 of Australia and readily available.

Californian Trends

- Tried to replicate hand based principles.
- Quality compromised- damage and grit.
- Guaranteed dry harvest, unlike Australia.

Californian Overhead pergola

- Grown in alternate rows as is Swing Arm.
- Considerable amount of hand labour .
- Micro climate unsuited to Australia.

Harvester for pergola system.

SUMMARY-Vital changes

- Willingness to depart from tradition.
- New rain tolerant varieties
- Adoption of trellis drying.
- Change from crown based to cordon based plantings.
- Use of swing arm to allow optimal physiology and mechanisation.
- Integrated use of the above over entire year.

Conclusion

- Must anticipate the need for change.
- Tradition and existing infrastructure can inhibit essential change.
- New technology can trigger a new direction. (GPS, PLCs, etc)
- Some compromises are inevitable.
- The whole annual cycle must considered.
- While the industry and markets are global, Australian production has its own issues and solutions.
- You never know till you have a go!

Maximising returns with a grower perspective

Grant Birrell
Nut Producers Australia

Australian Almonds

Concepts

- Drive value back to source

- Producer value add

Drive value back to source

- Value can be described as the delivery of benefits relative to cost
- This applies to both receivers AND producers

- Warren Buffet “Price is what you pay, value is what you get”

- Usual view of adding value is the increase of the price of a raw material by adding other less expensive ingredients and packaging to give it consumer appeal

Drive value back to source

- In primary production adding value is often driven in the opposite direction
- Analogy: Capture prawn industry
- In context, doing less downstream by doing more at source presents opportunities to increase value to growers

Drive value back to source

- Considerations
  - Moisture
  - Staining
  - Foreign matter
  - Pests
  - Wind fall nuts
  - Mouldy nuts
  - Insect damage
  - Mixed nuts
  - On farm hulling
  - On farm sizing before hulling and shelling
  - Traceability

Producer value add

- Simple economic equation

- Producer value equals % higher value x price higher value plus % lower value x price lower value less costs

Producer value add

- Producer value is improved by
  - Reduced damage increasing higher value outputs
  - Reduced damage reducing downstream costs
  - Reduced foreign matter reducing downstream costs
  - Increased inshell provides greater market choice
  - Safe food
- Controlling the agenda
- Analogy: tuna farming

Summary

- Drive value improvements closer to source
- Producers can add value themselves by reducing downstream impacts

Shake and Collect Harvesting

Ben Haslett, August 2011

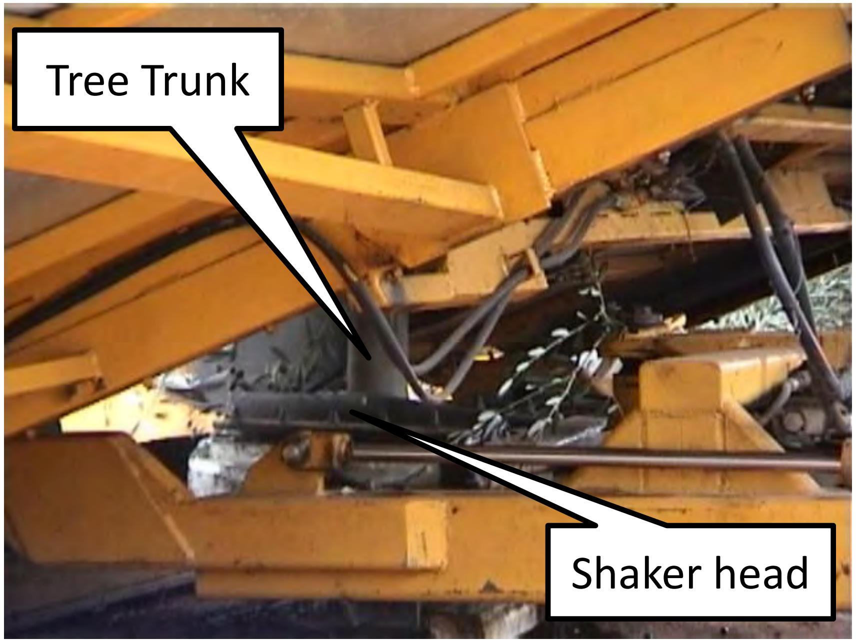
AUSTRALIAN ALMONDS

Overview

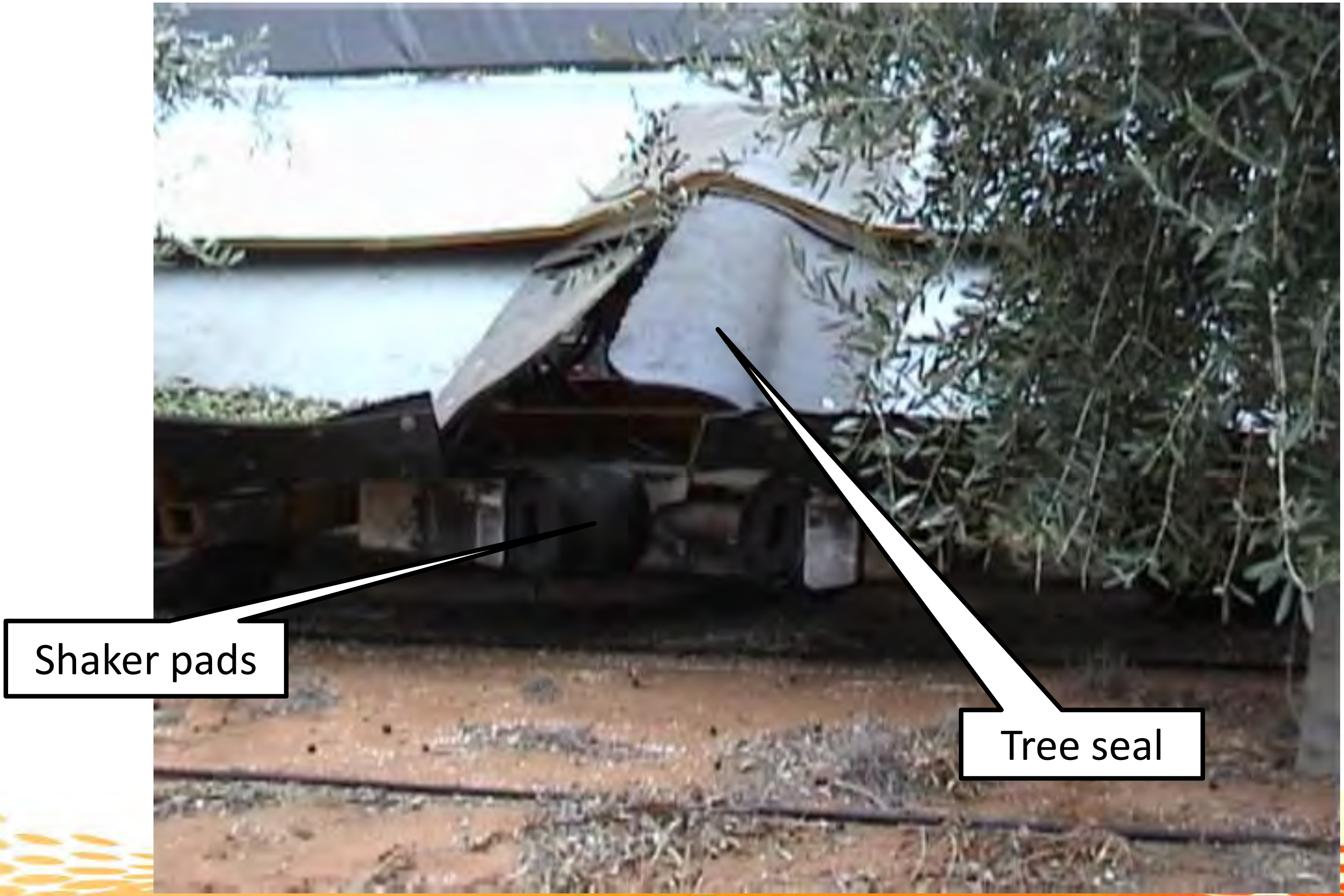
- Introduction / machinery
- Pros
- Cons
- Almond specific / cost
- Summary

Two part shake and catch system

Shaker Side



Shaker side



Receiver side

Receiver

Product collection

Unloading to bankout

Bulk trailer

Product collection

Bulk handling

Bin handling

Pros

- Product doesn't touch ground – this may be a plus for pest, disease and moisture management.
- Product is separated from moist leaves.
- Low dust and orchard erosion.
- Less machine hours per Ha than traditional method (see table).
- Increases chance of harvesting a premium product.
- Less equipment - capital, maintenance, labour units.
- Cheaper on a per tree basis if no windfall retrieval.

Speed comparison

- Assumptions
  - 1 Ha = 285 trees (7m x 5m)
  - 2 part harvester operates at ave. 200 trees per hour so in **10 hou**rs will completely harvest **7Ha per day of Non P = 14Ha of orchard.**
  - Standard side mount shaker operates at 250 trees per hour average **= 8.75Ha per day of Non P = 17.5 Ha of orchard**.
  - Standard sweeper sweep **16 - 20Ha** (40 - 50 acres) per day
  - Standard pick up machine covers **24 - 32 Ha** (60 - 80 acres) per day
  - No extra passes for windfalls with two part harvester.
  - This is machine hours NOT real time to get product up because you can have more than one machine working at the same time.

Machine	Orchard Ha/10 hrs	Time(hrs) per 14Ha
2 part harvester	14	**10.0**
Side mount shaker	17.5	8.0
Sweeper	16 (20)	8.8 (7.0)
Pick up	24 (32)	5.8 (4.4)
Total hrs for ground method		**22.6 (19.4)**

Cons

- Potential to knock off other varieties with machinery depending on row width.
- Windfalls – still need to be ground harvested if significant numbers occur.
- To avoid windfall losses **may** need to harvest when the moisture % is a little higher than traditional.
- Need ability to store and manage moisture levels.
- Less flexibility re shaking angled trunks.
- 1 metre trunk height is preferable (not essential) to facilitate good trunk seal thereby maximising fruit/nut capture.

Almond specific / cost

- Ran machines 20hrs per day, 7 days per week for 5 seasons.
- In practice windfall wasn't a major issue.
- Management of product post harvest needs consideration.
- Tree shape and trunk height is important for maximum nut retrieval.
- Consider tree spacing 7 x 5m or 7 x 4m ideal.
- Some modification of machinery to suit almonds.
- Approx $2.50 per tree versus approx $3.50 - $4.00 (depends on equipment and if contract or owner rate)

Summary

- Two part system works - tree shape, windfall management and storage systems need to be considered.
- Other points:
  - Early season harvest to utilise best weather.
  - Husk removal at in field elevator. Moisture reduction, transport and storage advantages.
  - Harvest hours per day Feb / March.

<u>One Pass Collection</u>

Tim Millen

"The Search Begins"

Introduction

For the Ultimate Nut Harvest – One pass picking up

The goal of Select Harvests(SHV) to " Streamline" the Harvesting process, and we are continually seeking knowledge to improve harvesting of Almonds. In an attempt to achieve this we have been considering ways to combine the operation of sweeping with picking up to remove/limit the need for sweeping as a separate operation.

At present, SHV operate approx 100 sweepers in our Harvest matrix:-

Sweeper matrix

- 100 operators
- 100 machines
- 100 machines that require fuel
- Extra maintenance staff
- Extra spare parts
- Windrows left exposed to the elements
- Extra time needed to complete the process with greater exposure to risk - i.e. rain

Aim

The aim is to purchase/develop a machine that can sweep and pickup in one pass. Many of the major US manufacturers have been contacted regarding a one pass harvester concept over the years

The response from the manufacturers was that they had either :-

- Tried this before and failed
- Not willing to "risk" the cost and time to research and develop

Research

After research SHV came across the "Facma" Company from Italy manufacturing - Nut Harvester; the 380S, which claimed that it could reduce the number of passes required, and used vacuum technology along with counter rotating brushes to sweep and pickup in one pass.

Contact was made with "Facma" and a demonstration was conducted at our Kyndalyn Park Orchard at Lake Powell, Victoria

Demonstration

The self propelled Harvester is equipped with a propulsion system with three wheels, two rear driving and one front steering plus driving on demand. The unit is powered by a VM diesel (80hp) transmitting power via hydraulic

The shaken product on the ground is then windrowed by two front mounted counter rotating brushes (available in varying widths) made from rubber scraper elements and supported by radial oscillating arms.

The head can be move from left to right due to a piston and slide assembly enabling the head to harvest “under tree” and move in and out as it progresses down the tree rows.

The machine is equipped with a lateral blower, which using the aspirator air, blows the almonds from under the tree into the following row.

The product is transferred by the brushes to the vacuum head located centrally on the slide, and the height can be adjusted and regulated.

Once picked up, the product is channelled into a depression chamber where the heavier waste material(sand) is separated.

From here the product pours through a valve onto a conveyor where it is blasted by an air jet generated by a ventilator separating the lighter impurities.

A screw then transports the product into a following trailer.

Summary

Whilst the machine was not quite up to specifications suitable to our requirements, it had many “positive” aspects. The stand out feature being cleanliness of the product picket up.

With further development, this machine has the potential to reduce the number of passes required to pick Almond product up from the Orchard floor once shaken.

The machines limitations were:-

- Sticks block the pickup spout.
- Lack of drive in sandy conditions, particularly on sand hills
- Blowing ability under the trees and through dripper line into the next row
- Lack of protective, air conditioned cabin.
- Overall size

University of South Australia

ALMOND BOARD OF AUSTRALIA

Potential technology advances in our product's production

John Fielke

Associate Professor

Barbara Hardy Institute

School of Advanced Manufacturing and Mechanical Engineering

John Fielke

- BEng (Mechanical), BESc (Ag Eng), PhD (Soil Science)
- CPEng, SMIEAust
- Tillage tool design
- Dried grape processing
- Agricultural equipment design

    Research, Consulting, Expert Witness

- Teaching – CAD/CAM, Mechanical Design

University of
South Australia

Almond Industry Visits

March to June 2011

Supported by Almond Board of Australia

1. Growers

2. Hullers and shellers

3. Packers

Industry Impressions

Growing

- Highly mechanised
- Large scale

Industry Impressions

Hulling and shelling

- Large investments in equipment
- All use same shear rolls and shear roll over belt
- Imported equipment installed in modules
- Product leaving hullers and shellers size graded but not cleaned

University of South Australia

Industry Impressions

Packers

- Responsible to clean product
- Make the best of what they are provided with

University of South Australia

Preliminary Findings

<u>Almond damage (scratched, chipped and broken)</u>

•Negligible damage to kernel while in shell

•Minor damage (scratching) when moving and packing kernels

•Kernel damage is from hulling and shelling process

At what stage of the hulling and shelling is the damage being done?

Can the process be modified or is there a better way?

Potential Advances – On farm

Shaking

(Increase work-rate, leave less nuts on tree, reduce trunk damage)

- Alternative motion for shake
- Controlled time for shake based on almond removal
- Continual vehicle forward travel
- GPS guidance, automation

Better shaking?
Benefits of guidance?
Improved nut removal from tree?

Potential Advances – On farm

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<u>Sweeping</u>

(Less equipment & tree damage, de-skill, improve sweeping efficiency, reduce rain damage)

- Automate avoiding collision with trunk
- GPS guidance (operator only controls sweeping)
- Use of turbulent air to pick up and blow kernels
- Automation of fan directional control
- Integrating sweeping with the pick up

Improved air control?

Integrate with pick up?

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Potential Advances – On farm

Pickup

(increase work-rate, deskill, remove more trash, reduce rain damage, reduce waste to huller and sheller)

•Single pass pick up, sweep and pickup

•Improve stick and stone removal

•De-hull in field by adding thresher

Onboard dehulling?

Single pass?

Trash removal?

Vacuum pick up?

Potential Advances – On farm

<u>Storage</u>
(remove excess moisture)
•Aeration for dehydration of stacks

Dehydration parameters?
Wetting fronts?
Cost effective?

Potential Advances – H & Shelling

(Increase throughput, reduce damage, improve cleaning, moisture control)

New process

Pre-cleaning (remove all stones and trash – recover kernels)

Hulling as a separate process (no damage to kernels)

Size grading before shelling

Shelling with minimal damage

Size grading of kernels (small, medium and large) before cleaning

Efficient cleaning (intermittent jumping screen & push pull air)

Mould removal (gravity table and laser)

Size grading for marketing

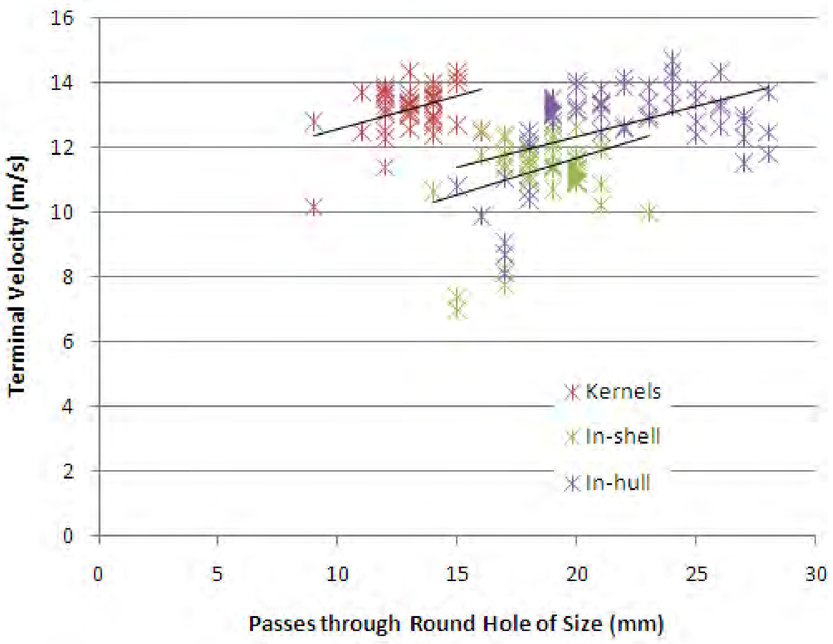
Controlled dehydration (low cost stack drying)

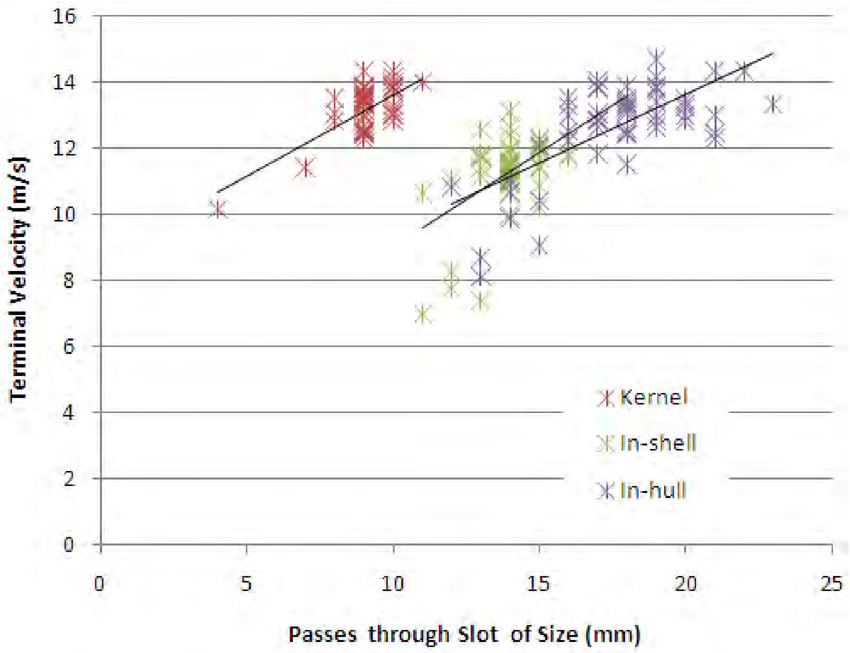
Operating parameters? Benefit of updating? Drying parameters?

Potential Advances – jumping screen

Video

Potential Advances – separation





Sizing using slots (thickness) and then air sorting is best for sorting out kernels

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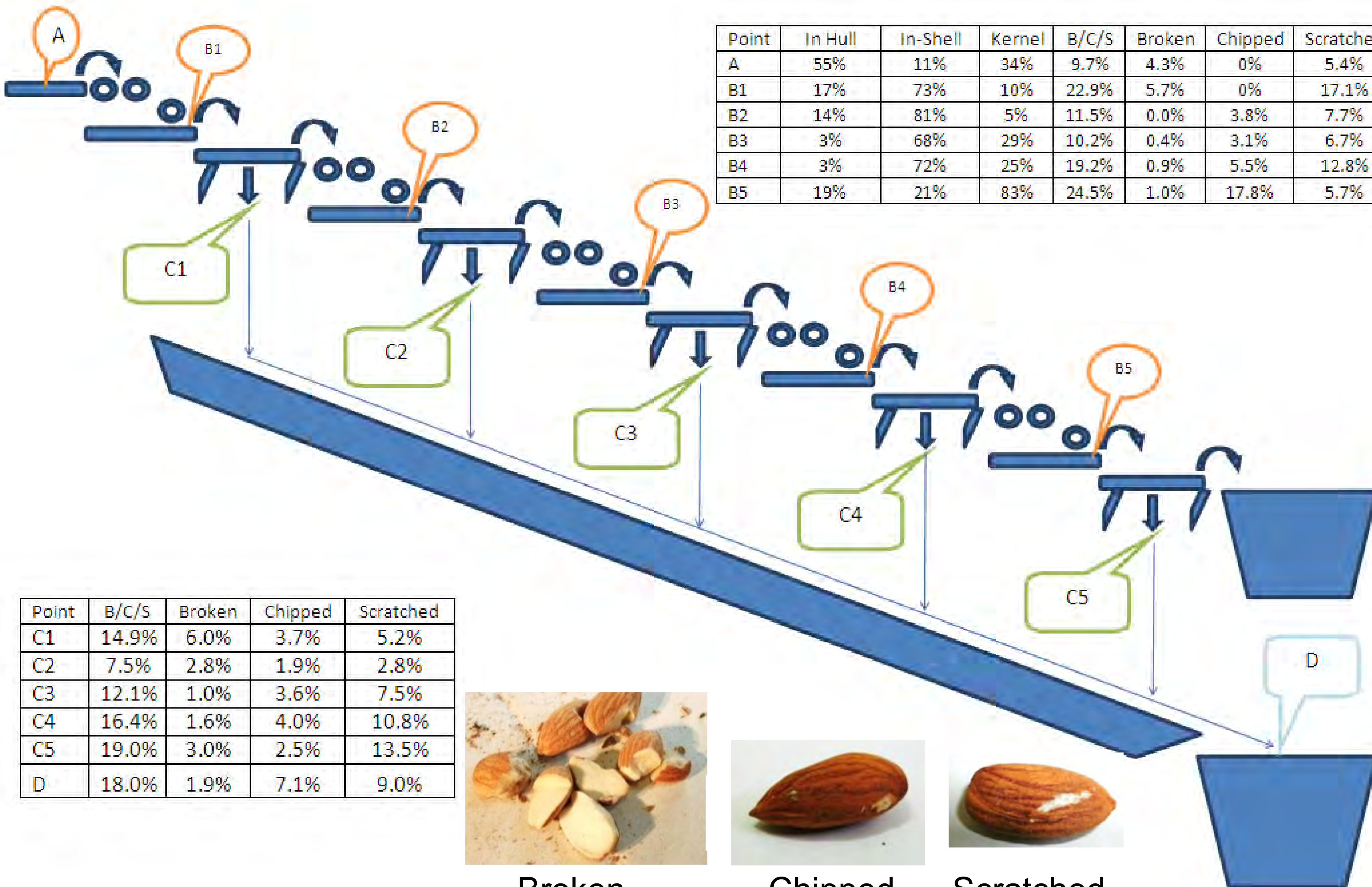
Potential Advances – H & S damage



Point	In Hull	In-Shell	Kernel	B/C/S	Broken	Chipped	Scratched
A	55%	11%	34%	9.7%	4.3%	0%	5.4%
B1	17%	73%	10%	22.9%	5.7%	0%	17.1%
B2	14%	81%	5%	11.5%	0.0%	3.8%	7.7%
B3	3%	68%	29%	10.2%	0.4%	3.1%	6.7%
B4	3%	72%	25%	19.2%	0.9%	5.5%	12.8%
B5	19%	21%	83%	24.5%	1.0%	17.8%	5.7%

Point	B/C/S	Broken	Chipped	Scratched
C1	14.9%	6.0%	3.7%	5.2%
C2	7.5%	2.8%	1.9%	2.8%
C3	12.1%	1.0%	3.6%	7.5%
C4	16.4%	1.6%	4.0%	10.8%
C5	19.0%	3.0%	2.5%	13.5%
D	18.0%	1.9%	7.1%	9.0%

Broken

Chipped

Scratched

Potential Advances - Packing

(Packers provided with cleaned product with minimal mechanical damage)

Efficient electronic sorting

- Insect and rodent damage (now easily detected)
- Sorting of any mixed varieties
- Minimal reworking

Dose not add further mechanical damage
Value adding
Controlled dehydration (low cost stack drying)

Clean product from huller and sheller?
No mechanical damage?
Variety sorting?

Research

1. Provides answers

2. Demonstrates principles

3. Confidence to invest in improvements

It is of benefit to all of industry for the whole value chain to improve all stages of process.

Technology is available NOW

Questions?

Study Tour Highlights

Ben Brown, Ross Skinner & Brendan Sidhu

Study Tour Highlights

Jesse Manufacturing, Chico CA

Stu

Study Tour Highlights

Almont Orchards, Chico CA

- Mark & Fred Montgomerey

AUSTRALIAN ALMONDS


B

Study Tour Highlights





COOLING


WEST COIL
EAST COIL
BLOWER
BLOWER

Study Tour Highlights

UNIQ Food Corporation, Reus Spain


HY-LO

Study Tour Highlights

Study Tour Highlights

The End

12 Appendix 3 – Review of Australian Almond Processing Industry

REPORT: REVIEW OF AUSTRALIAN ALMOND PROCESSING INDUSTRY

Prepared for	Almond Board of Australia 9 William Street, PO Box 2246, BERRI South Australia 5343 ABN 31709079099 Attention: Ben Brown bbrown@australianalmonds.com.au
Prepared by	Associate Professor John Fielke Director, Agricultural Machinery Research and Design Barbara Hardy Institute Mawson Lakes Campus, SA Telephone (61) 8 8302 3119 Email john.fielke@unisa.edu.au Contact details for notices: Mr Sebastien Hebert Business Development Manager Division of Information Technology, Engineering and the Environment University of South Australia 5095, SA Telephone (61) 8302 3973 Email sebastien.hebert@unisa.edu.au
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Important Notice

This report is confidential and was prepared exclusively for the Almond Board of Australia. It is not intended for, nor do we accept any responsibility for its use by any third party.

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1 PROJECT BACKGROUND AND OBJECTIVES

The Almond Board of Australia has recently released their Strategic R&D plan 2011-2106 which has highlighted the following relevant areas:-

- Harvest
  - Harvest systems
  - On-farm product storage
- Primary processing
  - Product storage
  - Hulling &shelling
  - Product sizing
  - Logistics
- Secondary Processing
  - Product classification
  - Product development
  - Product packaging
  - Distribution

The Australian almond industry is preparing itself for:

- A large increase in production from around 35,000 tonnes of kernels in 2010 to over 80,000 tonnes in 2015.
- Ever increasing needs for improved quality.
- Investigating better methods for harvest, dehydration, storage and processing.

The aim of this project was to familiarise Associate Professor John Fielke with the Australian almond industry and to provide some recommendations for further R&D activities to help achieve the above aims.

2

PROJECT VISITS

Date	Visitors	Company
Friday 18 March 2011	John Fielke Andrew Burge Fei Tang (student) Samuel Tok (student) Ben Brown	Jubilee Almonds (grower)
	As above	Almondco (packer)
	As above	Simarloo (huller and sheller)
Monday 11 April 2011	John Fielke Sang-Heon Lee Fei Tang (student) Samuel Tok (student)	Riverland Almonds (packer)
	As above	Laragon Almond Processors (huller and sheller)
Tuesday 12 April 2011	As above	Select Harvests (grower only visited, but they also hull, shell and pack)
	As above	Nut Processors Australia - Pistachio (grower, processor, packer)
Wed 13 April 2011	As above	Mark Stoeckel (grower)
	As above	Omega Orchards (grower)
	As above	Almondco (packer)
Wed 15 June 2011	John Fielke Fei Tang (student) Samuel Tok (student)	Costa Almonds (huller and sheller)

3 INDUSTRY OVERVIEW, IMPRESSIONS AND R&D DIRECTIONS – ON FARM

The almond industry was observed to be highly mechanised and driven by Californian style equipment for both on farm operations and the processing of almonds.

During the visits it was pointed out that the Australian industry is different to California:-

1. Australian trees are unpruned and more compact; hence the equipment does not fit down the row as easily.

2. Australian farmers achieve a higher yield per ha and machines such as sweepers cannot blow the quantities of almonds as well. Sandy textured soils also make sweeping and pick-up operations more difficult

3. Australian trees are mainly drip irrigated with dripper lines generally running on the surface, about 1m out from the trees and consequently interfere with harvesting equipment. California uses micro-sprinkler and flood irrigation which do not interfere with harvesting equipment.

4. The Australian climate is different. Australia has more likelihood of summer rainfall events during harvest and hence orchard operations such as sweeping and pickup need to be responsive to possible rain. This means that Australian growers do not want to sweep large volumes of almonds ahead of the time of pickup. The issues are not wanting swept almonds to become wet as they may spoil and/or require respreading to redry the almonds.

5. Australian growers would like to have the option of being able to pick up almonds at a moisture content greater than final storage moisture content ahead of a rain event and use efficient and cost effective dehydration techniques to dry down the almonds. Some US and Spanish experiences also indicate hulling and shelling efficiencies increase following pre-cleaning and dehydration of all product, regardless of the starting moisture content.

6. The industry desires to eliminate health risks associated with dropping the almonds on the ground. There may become two classes of almond product, those caught from tree shaking and those collected from the ground. In California pasteurising of kernels exists to control health risks. Australia wants to keep its clean-green image and ideally avoid pasteurisation.

7. If product collected from the ground is minimised, opportunities become available to use soil management techniques that improve soil health, increased yields and reduced input costs.

8. Skilled orchard labour is hard to find and retain. The situation would be helped by de-skilling many of the orchard tasks.

In order to achieve the industry aims it was seen that R&D is required to investigate new types of equipment that:-

1. Provides automatic steering down rows (GPS and obstacle avoidance based). This will increase work rates and minimise equipment and tree damage.

2. Improves efficiency of tree shaking – removing more kernels quickly. Thus increasing work rate and eliminating carryover of crop into the next season by remaining on the tree (i.e. mummies) and therefore potentially being collected with the following season's harvest or providing a source of fungal contamination on the tree for the following season's crop. This could include different shaker technologies and the use of a continuously moving shaker vehicle with only the shaker head grabbing onto the tree as the vehicle continually moves along the row. This has been successfully achieved in Spain.

3. Does not need multiple passes of sweeping of kernels and is more tolerant of soil types and ground undulations. This could include integrating the sweeping with the pick-up operating, and using vacuum pickup which could work over dripper lines and small surface undulations. This reduces the number of workers and reduces risk of rain on swept almonds.

4. Better pre-cleans the almonds of sticks and soil at the time of: pickup, placing in the stockpile and loading onto a truck.

5. Dehydrates the almonds when they are in bunker or other storage without darkening the kernel from too high a temperature.

6. Removes the hull on-farm to increase transport/handling efficiency and potentially retain valuable nutrients or alternatively a fueld source for dehydration.

7. Minimises raised dust that carries fungal spores into canopies and almond fruit. In addition, dust can reduce photosynthesis and transpiration capability of the trees.

8. Collect windfalls as they remain a key issue in addressing shake and catch systems, quality deterioration and food safety risks.

4 INDUSTRY OVERVIEW, IMPRESSIONS AND R&D DIRECTIONS – PROCESSING

All processors have invested considerably in their facilities with the various almond processors taking quite different approaches and different set-ups of:

- On site storage of almonds in bunkers versus daily deliveries of almonds for processing.
- Large emphasis on dust extraction versus emphasis on multiple sorting machines.
- Single flow of kernels into processing line versus multiple tanks of almonds that can be blended into the line.
- Use of plastic bins versus use of wooden bins for the shelled kernels.

Of particular note is the large amount of equipment used for conveying around the almonds and the removal and storage of waste (hulls, shells and dust) in comparison to the actual equipment involved in the processing activities.

In the facilities visited, the hulling and shelling was conducted by modules of equipment with much back and forth/up and down movement of the product on a very complex path through the processing line. Also the flow was often one of spreading out, drawing in to load into an elevator and spreading out again.

In all cases the equipment has evolved over the years to quickly process almonds. New customer and food safety demands are requiring the processors to do an ever increasingly better job to; not damage the kernels, remove all contaminants, insect damage, rodent damage and mouldy kernels plus ensure food safety.

5 TOWARDS AN IMPROVED HULLING AND SHELLING PROCESSING LINE

An improved hulling and shelling processing line will be based on the following equipment principles, in the following order:

1. Uniform flow rate of kernels into the line (t/hour).
2. Early removal of sticks.
3. Removal of any metal and large contaminants before entering the processing line and causing damage/inefficiency.
4. Accurate screening with large deck (intermittent jumping screen) to remove all small stones (much smaller than almonds in shell but are of similar size once shelled) prior to hulling and shelling.
5. Hulling and shelling without damage to kernels (repeated multiple times with cleaning).
6. Cushioning of impacts of kernels to eliminate chipping.
7. Size grading of kernels (small, medium and large) and removal of splits using intermittent jumping screens
8. Use of gravity tables to remove stones, shell and shrivelled kernels on size graded product. They will work better with similar size kernels.
9. Final air separation.
10. Final size grading.
11. Laser scanning to remove mouldy kernels (this could be run off line, prior to storage of hulled and shelled product).

Chipped and scratched almonds are an inefficiency of the processing line and these must be minimised or preferably eliminated.

As mouldy kernels can be a large percentage of the crop, these should be removed prior to storage and accumulated for use in alternative products.

Hence, following the hulling and shelling stage there is the opportunity to produce a product that does not contain:-

- Foreign material (stones and other material).
- Chips and scratches as their sources have been eliminated.
- Mouldy, discoloured kernels that have a higher risk of spreading more mould and food safety issues.

This will eliminate the need for the packers to search for and remove contaminants plus mouldy, chipped and scratched almonds and will leave them with a final check and removal of any insect/rodent damage and ensuring food safety.

Intermittent jumping screen

The above mentions an intermittent jumping screen. This is an alternative screening technology developed to improve upon the bouncing ball screen sizing method. The intermittent jumping screen works on the principle of using the optimum screening motion for maximum material passage through the screen and allows a portion of the screen to become blinded by near size material resting in the screen deck holes. After a period of about 10 seconds (up to 20% of screen blinding is allowed to occur) the screen jumps vertically to release any material trapped in the screen deck holes. This provides more accurate and space efficient sizing of product. This technique has been used successfully for sizing products which are easily damaged and hard to screen such as flower bulbs (Israel flower industry) and sunflower seeds (Manoora Seeds, SA) and would be very applicable for almonds. A research screen using this principle is located at the UniSA, Mawson Lakes.

The following R&D is required to achieve the above aims:

1. Develop an understanding of the sources of chipping and scratching of almonds in the hulling and shelling process. As shown in the Appendix, a random sample of product leaving a huller and sheller showed it to contain 32% chipped almonds and 7% scratched kernels.

2. Develop methods to eliminate all chipping and scratching of kernels.

3. Determine the optimum screening parameters with respect to removal of stones and contaminants prior to hulling and shelling and size grading after shelling of:-

    a. screen deck apertures such as round or slot

    b. screen amplitude and direction

    c. screen acceleration (speed)

    d. screen length

4. Demonstration of the improvement in performance of gravity tables and destoners when using size graded product.

5. Integration of the above technologies into a new design of a hulling and shelling processing line which can produce size graded kernels that are free of contaminants.

6 TOWARDS AN IMPROVED PACKING LINE

The packers must be receiving size graded product that is free of contaminants. The packing line will consist of:

1. Multiple laser scanning to find multiple defects.
2. Repeat laser scanning to achieve required quality for specific defects.
3. Only with a low amount of chipped and scratched kernels will laser scanning be able to efficiently find and remove small areas of insect and rodent damage. Both insect and rodent damaged kernels must be totally removed from the final product.
4. Visual inspection for any non-kernel material (not to be used as a contaminant removal stage).
5. Final metal detection to remove any metal present.
6. Packing.

When using electronic sorting it is not good enough to just have one attempt to try and remove all defects. With a large number of defective kernels in the product, multiple attempts of high efficiency equipment will be required to get close to zero defective kernels remaining.

In order to have good detection of insect and rodent damage the kernels need to be free of chipping and scratching which have a similar appearance of the white kernel being exposed through the brown skin. As chips and scratches are avoidable and the elimination of the chips and scratches in the hulling and shelling stage is vital.

<u>The following R&D is required to achieve the above aims</u>

1. Undertake the work listed in the previous section so as to provide packers with a product that is free of contaminants and chipped and scratched kernels.
2. Rate the performance of various electronic sorting devices for both product checking and defect removal.
3. Determination of the number of electronic sorting machines required in series to provide the required level of contaminant removal.

Shaking of almonds (1 pass).

Sweeping of almonds (3 passes are undertaken).

The sweepers both comb the almonds to the centre of the row (front of machine) and blow almonds near the drip line and along the row of tree trunks into the next row (rear of machine).

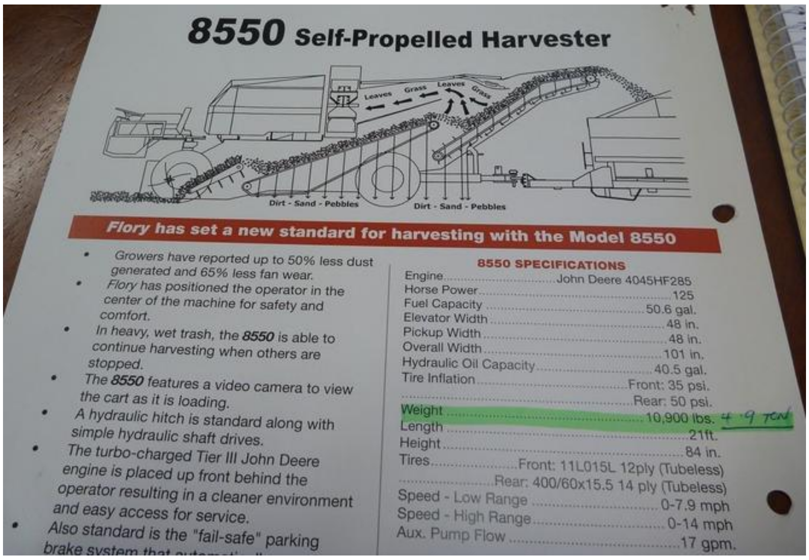
Final pass of sweeping (ready for pickup).

Note drip lines about 1m from the tree trunk.

A new style (Exact) sweeper has an additional rotary brush to help gather kernels. One of the 2 brushes was removed as it was too difficult for the operator to control.

Pick up of almonds (1 pass). Machines can have a stick remover fitted.

The pick up uses a rotating flap to lift the almonds onto a cleaning and transfer chain.



8550 Self-Propelled Harvester

Flory has set a new standard for harvesting with the Model 8550

- *Growers have reported up to 50% less dust generated and 65% less fan wear.*
- *Flory has positioned the operator in the center of the machine for safety and comfort.*
- *In heavy, wet trash, the **8550** is able to continue harvesting when others are stopped.*
- *The **8550** features a video camera to view the cart as it is loading.*
- *A hydraulic hitch is standard along with simple hydraulic shaft drives.*
- *The turbo-charged Tier III John Deere engine is placed up front behind the operator resulting in a cleaner environment and easy access for service.*
- *Also standard is the "fail-safe" parking brake system that ...*

8550 SPECIFICATIONS

Engine	John Deere 4045HF285
Horse Power	125
Fuel Capacity	50.6 gal.
Elevator Width	48 in.
Pickup Width	48 in.
Overall Width	101 in.
Hydraulic Oil Capacity	40.5 gal.
Tire Inflation	Front: 35 psi.
	Rear: 50 psi.
Weight	10,900 lbs. 4.9 TON
Length	21ft.
Height	84 in.
Tires	Front: 11L015L 12ply (Tubeless)
	Rear: 400/60x15.5 14 ply (Tubeless)
Speed - Low Range	0-7.9 mph
Speed - High Range	0-14 mph
Aux. Pump Flow	17 gpm.

Specification for pick up.

Haul out of almonds (note rear bumper which pushes against a lever on pickup to start transfer of almonds into the haul out vehicle).

Extra operation (i.e. Prepa-Jack) to lift almonds above swept row (undertaken following rain on swept row) plus undertakes removal of sticks.

Bunkers for storage of almonds awaiting dispatch to huller and sheller. Bunkers are generally within 2km of almond harvest.

Elevators can have a stick remover fitted and thus sticks are removed at the point of transfer to the bunker.

Almonds stored in sheds save the labour to place and remove large tarpaulins and eliminates sweating under the tarpaulin if the almonds are too wet.

APPENDIX – ALMOND PROCESSING

Almonds are brought to huller and shellers by trucks and emptied onto concrete pads or into an underground hopper.

Almonds are precleaned and placed in a silo prior to hulling.

The flow from the silo is regulated by the gate height.

Hulling and shelling is undertaken using shear rollers (upper) and a shear roller running over a belt (lower).

Following shelling, screening is used to remove the kernels with uncracked almonds being returned for shelling on a machine with a smaller clearance.

Air separation is used to remove pieces of broken hull and shell.

Destoners are used to separate stones from kernels. Air is blow up through a vibrating screen with the lower mass kernels moving down the screen and the heavier stones being lifted by friction up and over the top of the screen.

Gravity tables are used to separate various mass and density particles. Each chute represents a slightly different physical property.

Kernels are size graded and placed in plastic bags in a bin.

The final size graded product is not free of contaminants. Note mouldy kernels (dark) and small melons remaining.

Dehydration of almonds with excess moisture content is undertaken using:-

- Bins with a mesh floor with heated air blown up through the bin, or
- Placed in a heated tunnel previously used for prunes, or
- A wrapped vertical stack of four bins with a suction fan fitted on top that pulls ambient air through the base of the bottom bin (as used in garlic industry).

Both plastic and wooden bins are used for storage of shelled almonds.

Dust extraction and air cleaning forms a major part of process.

The hulls and shells are placed in stockpiles for later sale (primarily as a stock feed).

Fumigation of almonds on receival.

Fumigation in boxes is also undertaken with spear going into the sealed plastic liner.

A pre-cleaning line to remove foreign material using a laser scanner.

Colour sorters are used to remove chipped (light patches) and mouldy (dark) kernels. The settings determine the size detected and hence the number removed. Good kernels are ejected alongside each reject removed. These lane based machines use a portion of the lanes to rework the discharged material.

Kernels rejected by a colour sorter.

Cascades to reduce damage to falling almonds.

Typical contaminants delivered with kernels from huller and sheller (mainly stones that are smaller than the almond in a shell).

Hand sorting is still used but plays only a checking role.

The electronic sorting machines are not removing all of the defects.

Many of the chips are caused by impacts with other almonds.

Automatic sample collection is used.

Processing is undertaken up high and needs many elevators and platforms.

APPENDIX – ALMOND DAMAGE/ SORTING EFFICIENCY – BACK OF THE ENVELOPE REVIEW

During the visits a sample of almonds was collected at the start and end of a packing line.

Analysis of the sample of almonds, as delivered from the huller and sheller showed:-

	Number	%
Good kernels	455	58.1%
Scratched kernels	34	7.5%
Chipped	253	32.0%
Insect	36	4.6%
Deformed	5	0.6%
Total	783	

Following the final sorting and being ready to pack, a sample of the same batch of almonds showed:-

	Number	%
Good kernels	588	70.3%
Scratched kernels	52	8.8%
Chipped	193	23.1%
Insect	3	0.4%
Deformed	0	0.0%
Total	836	

Knowing that the total number of undamaged kernels cannot increase from processing (only defective almonds are removed but there is a possibility that more chipped and damaged kernels can be created) a trial and error analysis showed that the samples could be balanced if the following sorting efficiencies occurred:-

	Efficiency	% kernels in starting sample	No. removed from a batch size of 100 kernels	% kernels in end sample
Removal of good kernels	0%	58.1%	0	69%
Increase in scratched kernels	0.8%	7.5%	0.8	9%
Removal of chipped kernels	45%	32.0%	14.4	21%
Removal of insect damaged kernels	94%	4.6%	4.3	0.4%
Removal of deformed kernels	100%	0.6%	0.6	0.0%
Total			20.1	

The method of collecting samples and analysing them was crude as an accurate test needs to examine the finished product and the contaminants removed for a more precise result.

Despite this the results indicate the following:-

1. Nearly one third of the kernels were chipped and 7.5% were scratched.

2. A small number of kernels had insect damage.

3. The cleaning process at the packer had many product movements and resulted in just less than 1% of kernels being scratched.

4. Approximately 45% of the chipped kernels were removed (this was evidenced by the large number of chipped kernels removed by the hand sorters).

5. There was a very large percentage of the kernels that were removed and downgraded in the final cleaning process.

6. There was a high level of efficiency (94%) for removing insect damaged kernels. However many insect damaged kernels remain. (4 in every 1000 kernels still had insect damage).

The implication from these results are:-

1. The source of the high number of chipped kernels needs to be identified and eliminated. This will give a higher quality product, reduce downgrading/segregation and increase yield as the chipped pieces are not lost from the product.

2. The sources of the scratched kernels must also be identified and eliminated.

3. By reducing the white portions of kernels from chips and scratches the electronic sorters (colour and laser) will be able to be more finely tuned to detect and eject the kernels with insect damage.

4. If the sorting of insect damage can be repeated from 94% ejection to 94% x 94% this will then result in a change :-

   from 460 insect damaged kernels/10,000 kernels

   to 27 insect damaged kernels /10,000 kernels (94% removal)

   to 1.7 insect damaged kernels /10,000 kernels (94% x 94% removal)

13 Appendix 4 – Student Thesis, *Identifying sources of mechanical damage in almond processing*

UNIVERSITY OF SOUTH AUSTRALIA

School of Advanced Manufacturing and Mechanical Engineering

Bachelor of Engineering

in

Mechanical Engineering

Identifying sources of mechanical damage in almond processing

By Samuel Kwang Ming Tok

2011

ABSTRACT

Almonds that are damaged or blemished fetch a lower price on the commodities market. A significant portion of the damage that is inflicted on the almonds may be caused by processing. This is an area of concern for the Almond Board of Australia as the processing of the almonds may be destroying some of the value of the crop. This study aims to identify the sources of mechanical damage in almond processing.

A series of site visits were carried out in order to understand the whole process flow of almonds from harvest to the final packaging. The probable sources of mechanical damage identified were the primary processing and secondary processing facilities. It was found that there was negligible damage whilst the kernel remained in the shell. A sampling study and data analysis further narrowed down the source to the primary processers.

The primary process of removing almond hulls and shells known as hulling and shelling was studied in detail in order to understand the mechanical processing involved. Samples were taken from each stage of the hulling and shelling process and examined to identify and quantify the mechanical damage present in the almonds. The data was then studied and analysed to find the forms of damage and the percentage of the almonds that are damaged at each stage. Machine settings data such as roller and belt speeds and diameters were obtained and used to extimate the velocities that the almonds are subject to when going through the machines.

The study also measured the thickness and width of the in-husk almonds, in-shell almonds and kernels to obtain size distribution data. It was found that the size of the in-shell almonds and its kernel did not increase in thickness or depth proportionally with the thickness and depth of the whole in-husk almond. As the thickness and depth of the in-husk almond increased, the thickness and depth of the in-shell almonds increased at a reduced rate and the thickness and depth of the kernels stayed within a narrow range.

The study determined the impact energy and velocity required to cause mechanical damage in almonds.

The almond kernels were subjected to impact tests from a pendulum impact tester. Almond kernels were impacted with a steel anvil, with the pointed end of another almond and with the pointed end of another almond with the targeted almond at an offset in order to produce a glancing impact affecting mainly the surface of the almond. The tests showed that impacting the almonds with an almond point required less energy to produce damage and even less energy with higher incidences of damage when the impact was offset. The energy levels required to produce damage by anvil, almond point and almond point with offset were 46.7mJ, 11.5mJ and 7.1mJ, respectively. The 46.7mJ required to produce damage in almond kernels using the anvil corresponds to dropping an almond kernel from a height of 3.9 m.

The almond kernels were then subjected to impact tests using a rotary arm impact tester. The study found that an impact velocity of 5.5 m/s will damage 1 in 10 kernels and at 19 m/s all of the tested almond kernels were damaged.

The study has produced results that identify the shear rollers and belts of the hulling and shelling machines to be a significant source of mechanical damage to the almonds. It has also identified energy levels and velocities that damage almonds and information on the anatomy of almonds. The study also found that the almond kernels are mechanically damaged after removal from its shell by the hulling and shelling process.

The results of this study imply that the almond kernels should be kept inside of their shells until ready for the hulling and shelling process in order to prevent damaging them. The shear rollers and belts of the hulling and shelling machines are causing damage to the almond kernels and further studies should be carried out to improve the hulling and shelling process in order to reduce mechanical damage to the kernels.

DECLARATION

I declare that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text.

22 November 2011

Samuel Kwang Ming Tok

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I thank Mr. Tony Costa of Costa Almonds who was most helpful during my site visits, process and sampling study. The involvement of Costa Almonds in this study was crucial to its success and is most appreciated.

Most of all, I would like to thank my family who have always stood by me and for their support especially during this period. I thank my wonderful wife Karine who literally handled most of our family's affairs so that I could complete my studies. I thank my sons, Shann and Cornelius for understanding that their Papa was working during the times that I was glued to my laptop analyzing data or writing my thesis.

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1. Introduction

1.1 Health benefits of consuming almonds

Almonds have been consumed since ancient biblical times. They were a valuable commodity transported from Asia into the Mediterranean, into Greece, Turkey and the middle east on the Silk Road (Almond Board of Australia, 2009). Since ancient times, many have believed that consuming almonds are beneficial to them. This has been endorsed by the National Heart Foundation of Australia as almonds and other nuts are listed on their Healthy Tick list of foods (National Heart Foundation of Australia, 2011). They are a natural source of healthy unsaturated fats. It has also been concluded that the consumption of almonds lowers LDL cholesterol (Abbey et al., 1994; Kris-Etherton et al., 2009). Obesity and Diabetes Week (NewsRx, 2003) reports on a study that proves almonds can help individuals to achieve weight loss goals. Another study conducted by the Institute of Food Research (IFR) has found that finely ground almonds are a potential prebiotic (Nutraceutical Business & Technology, 2009).

1.2 The Australian market share of almonds

The top three almond producers in the world are California, Spain and Australia. The market share of these three producers are 82% for California, 8% for Spain and 3% for Australia (Almond Board of Australia, 2010). In 2010, Australia produced an estimated 45,400 tonnes of almonds (Fell et al., 2011) compared with California's production of 748,427 tonnes (Western Farm Press, 2010). The total estimated amount of Australian almond plantings have increased by 5% from 2009 to 2010 and as these plantings mature, it is forecasted that Australia will overtake Spain to be the second largest producer of Almonds within the decade (Almond Board of Australia, 2010).

The Australian Nut Industry Council president, Brenton Woolston told the Advertiser in March 2008 (Austin, 2008), that the almond industry will grow to produce 77,000 tonnes in 2015. The Almond Board of Australia (2009) provided an updated forecast of 80,000 tonnes of almond production by 2015. This appears to be a valid prediction as three quarters of the Australian almond plantings have yet to reach full maturity (Almond Board of Australia, 2010; Almond Board of Australia, 2011).

1.3 The Australian almond industry

Australia does enjoy some advantages compared to the Californian almond industry. For a start, Australia produces a higher almond yield per hectare than USA (Almond Board of Australia, 2009; Olam, 2009). The Australian almonds also fetch a premium of about 7% more than the USA almonds due to better process management (Olam, 2009). However, the rainy season in Australia coincides with the harvesting of almonds. This presents some challenges for the industry as the rain will interfere with the harvesting process and exposes the almonds to increased moisture levels and the risk of mold growth (Brown, 2011).

As the production quantities are forecasted to increase, the Almond Board of Australia is also increasing its investment in research and development. It is especially important to consider if the industry has the technology and facilities to cope with the anticipated quantities that will pass through the processing plants.

The Almond Board of Australia has initiated this project by requesting the University of South Australia to assist in industry improvements. The main concern is the efficiency, capacity and ability of existing facilities to process the almonds. As the production quantities increase up to 2015, the processing capacity has to be increased to cope with the future growth.

The Almond Board of Australia would like to see research and developments in several areas. These can be broadly classified into the areas of harvesting, dehydration techniques, damage prevention and secondary processing improvements (Brown, 2011).

In order to understand the almond industry, a number of visits to almond orchards and processors were conducted with the support of the Almond Board of Australia. The information that follows was gathered from these visits to AlmondCo, Jubilee Almonds, Laragon, Riverland Almonds, Select Harvests, Simerloo and Costa Almonds.

1.3.1 Growing and harvesting almonds

The almonds are a tree nut and grown in an orchard. When it is time to harvest the nuts, the nuts are shaken off the trees, collected and stored awaiting delivery to the primary processing facilities.

1.3.2 Primary processing of almonds

The primary processing of almonds is known in industry as hulling and shelling. This is the process of removing the hulls and shells of the almond so that only the edible kernel remains. The kernels are size graded at this stage before being sent to the secondary processors.

1.3.3 Secondary processing – sorting and packing almonds

The secondary processing of almonds involves sorting and grading the almonds. The process uses machine vision systems. The almond kernels go through the sorting machines that pick out the bad or lower quality almonds from the good ones. The kernels which have color differences, chips, scratches, mold or insect damage are removed from the good ones by air ejectors.

1.4 Objectives and scope of project

The removal of the hull and shell of the almonds is a necessary process and without doubt adds value to the product. The general public is used to buying almonds that have been shelled and are ready to eat (or used in recipes). Therefore, the process of removing the hulls and shells makes the almonds marketable.

Since visual presentation plays a part in the price of almonds, it is important to prevent damage to the almond kernel. Mechanical damage in the form of chips or scratches to the kernel will obviously be recognized as defects. Excessive mechanical damage would cause the price of the almonds to be downgraded. This is highly undesirable and mechanical damage has become a necessary evil that reduces some of the product's value.

The scope of this project is to find the sources of mechanical damage and to develop ways to minimize them in order to retain the product value.

1.4.1 Identify and rank sources of mechanical damage

The process from harvest to packing uses a variety of machinery which is possibly inflicting mechanical damage to the almond kernels. In order to reduce mechanical damage as much as possible, the first part of this project aims to find the sources of mechanical damage to almonds. After ascertaining the sources of mechanical damage, future studies can be carried out based on the results of this study to intervene and find solutions to minimize the damage.

In order to identify the source of mechanical damage, product samples were collected at in-puts and outputs of all primary and secondary stages of processing. The almonds from each stage were then examined for mechanical damage, in order to narrow down the sources of mechanical damage.

1.4.2 Finding out the dimensional characteristics of almonds

The next step of the project was to measure and record the dimensions of the almonds. The information obtained will be useful for understanding the anatomy of almonds and proposing future machine settings.

In order to do this, a random sample of almonds was taken from the orchard for data collection. Data was collected on the dimensions of in-husk almonds, in-shell almonds and almond kernels.

The information was sorted, to provide the size distribution and range of in-husk almonds, in-shell almonds and almond kernels. This information will provide important information in determining the suitability of existing equipment and for further studies in improving the equipment and processes.

1.4.3 Rate current sorting capability

The almond kernels are sent to the secondary processors after they have been shelled. This stage of processing concentrates on removing foreign objects such as sticks and stones as well as blemished almonds. Almonds that are blemished are rejected from the lot.

There are two issues to be considered in this area. The first issue is that there is anticipated growth in the industry. The equipment in use has to be able to cope with the demands of the industry growth. The almonds being processed have to be sorted quickly and efficiently in a single pass if possible. If multiple passes are required, the equipment would be tied up with sorting the same batch of almonds multiple times. This means that the plant will not be able to operate effectively. Time will be wasted sorting the same almonds over and over again.

The second area of concern is that the standards required by the customers are getting more stringent. The customers are expecting almost zero defects in the delivered products. This has proved to be a challenge with the present equipment. In order to satisfy customer demands, the equipment has to be capable of sorting to a standard that is acceptable to the customer.

The objective of the second part of the project is to study the efficiency of the present machines. There are various machines using different sorting techniques available.

The main principle is that the machines will analyze light that is reflected off the product to determine color conformity to specifications (Antosh, 1985). Every machine will have its strengths or weaknesses.

The existing machines can be rated by taking product samples from both the “accept” and “reject” streams of the machines. The samples can then be inspected for the quantity of blemished almonds in the accepted stream and the quantity of good almonds in the reject stream. This will provide data on the accuracy of the machines.

The project findings on the accuracy of the machines can then be presented to the Australian almond industry for further review. It is anticipated that the findings will aid the Australian almond industry to better understand the capabilities of the machines. This will also help the industry to determine if further studies will be required with regards to future plant equipment upgrades.

2. Literature review

2.1 Anatomy of almonds

The fruit of the almond tree consists of a kernel encased by a shell and a hull (Esfahlan et al., 2010). When the fruit is dry enough, the hull splits open to reveal the shell as shown in Figure 2.1. The almond has to have the hull removed and the shell cracked in order to get to the edible kernel.

Figure 2.1 Almond in split hull, in shell and kernel.

Almonds can also be catagorized into hard shelled and soft shelled varieties. In today's market, the soft shelled varieties are more valuable with the Nonpareil variety fetching the highest prices (Western Farm Press, 2009).

2.2 Mechanical properties of almonds

Hard and soft shelled varieties of almonds possess different mechancial properties. A comparison study was done on the mechanical properties of Gulcan and Nonpareil almonds. Gulcan is a hard shelled variety and Nonpareil is a soft shelled variety which has a shell that is soft enough to be broken by hand. The study found that there are very big differences in the force required to crack open hard or soft shell varieties of almonds (Aktas et al., 2007).

Their study was focussed on the Southeast Anatolia region in Turkey. In this region, the almonds are cracked when they are fresh, dried or after being stored according to the market conditions. Thus, the study conducted experiments at three different moisture levels of 7.2%, 22.9% and 33.6% of in-shell moisture level. In order to attain the exact moisture levels required for the experiment, the almonds were dried or had distilled water added to them in a sealed glass jar. The almonds were then left for storage at 5°C in the sealed glass jar and thoroughly mixed at regular intervals to ensure equilibration.

The dimensions and weight of the Gulcan cultivar was compared to the Nonpareil cultivar before the almonds were cracked. The Gulcan cultivar was found to be bigger and heavier than the Nonpareil. Increasing the moisture level also caused a significant increase in the length and sphericity of the almond dimensions for both cultivars.

The moisture level also caused significant variation in the force required to crack the almond shells. It was found that increasing the moisture content of the in-shell almonds reduced the force required to crack open the shells of both varieties. This was supposedly because the shell becomes soft and weak when it has absorbed water. The results of Aktas et al's (2007) study was in agreement with the results of another study carried out by Aydin (2003) which came to the conclusion that increased moisture levels decreased the compressive force required to rupture almond nuts and kernels.

Aktas et al's (2007) study found during experiments that the shell had to be compressed and deformed by 2mm to 3mm before the maximum rupture force was reached. The amout of compressive force required to rupture the in-shell almonds was minimum along the x-axis and maximum along the y-axis as defined in Figure 2.2. The amount of force required to rupture the in-shell almonds was also substantially lower for the Nonpareil cultivar compared to the Gulcan cultivar. The maximum and minimum energy absorbed by the in-shell Gulcan cultivar before rupture was 831.57mJ along the y-axis at 7.2% moisture level and 190.40mJ along the x-axis at 33.6% moisture level respectively. The Nonpareil cultivar's maximum and minimum energy absorbed along the same loading axes and moisture levels were significantly smaller at 79.86mJ and 11.21mJ.

The energy absorbed by the in-shell Gulcan cultivar along the z-axis before rupture was 755.28mJ at 7.2% moisture level, 466.19mJ at 22.9% moisture level and 221.02mJ at 33.6% moisture level respectively. The energy absorbed by the in-shell Nonpareil cultivar along the z-axis before rupture was 75.62mJ at 7.2% moisture level, 57.57mJ at 22.9% moisture level and 24.26mJ at 33.6% moisture level respectively.

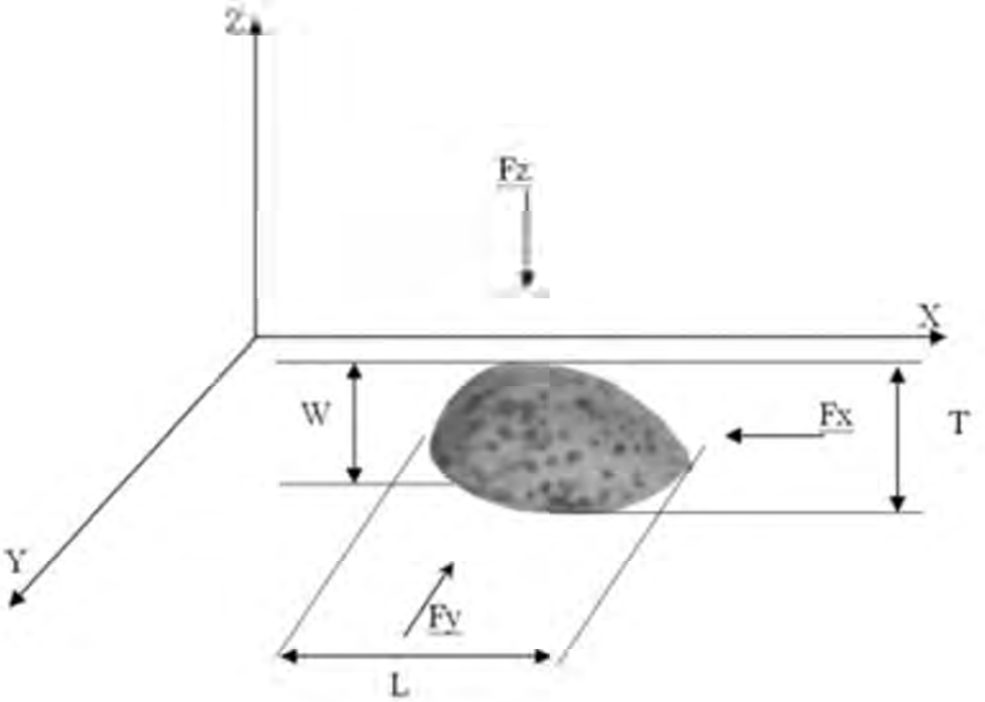


Figure 2.2 Definitions of axis used by Aktas' study (Aktas et al., 2007).

2.2.1 Mechanical properties of other nuts

Studies on other nuts was used to compare the results obtained by Aktas et al's (2007) study.

A study on the fracture resistance of pine nuts under compression determined that increased moisture levels resulted in a reduction in the compressive force required to fracture the pine nuts (Vursavus and Özgüven, 2005). The study also found that the pine nut shells required the lowest rupture force, deformation and required power when the compressive load is in the vertical orientation as shown in Figure 2.3. When the shape profile of the pine nut is compared with the almond, compression force in the vertical orientation of the pine nut corresponds to compression in the x-axis of Aktas's almond.

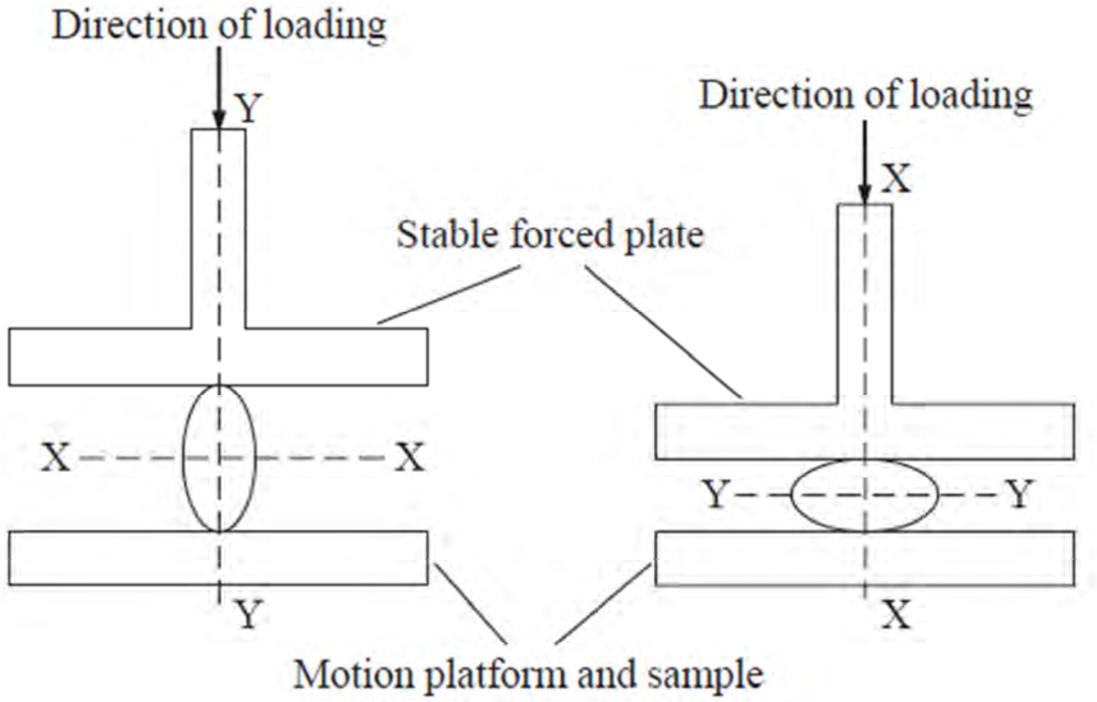


Figure 2.3 Pine nut compression load in vertical orientation (left) and horizontal direction (right) (Vursavus and Özgüven, 2005).

A study on the cracking characteristics of walnuts concluded that the least amount of force is required to crack the walnut along its length as defined in Figure 2.4 (Koyuncu et al., 2004). When the shape profile of the walnut is compared with the almond, applying a compression force along the length of the walnut corresponds closely to compression in the x-axis of Aktas's almond.

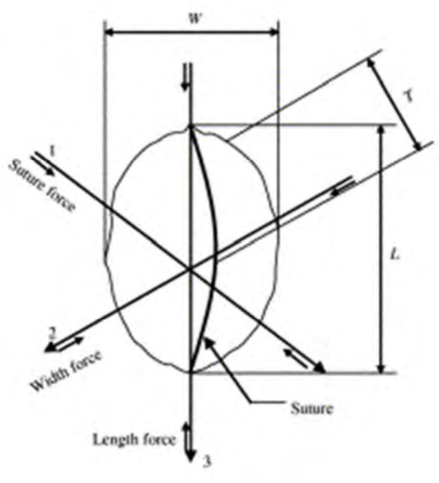


Figure 2.4 Definitions of walnut length, width and suture (Koyuncu et al., 2004).

A study on the behavior of pistachio nuts under compression loading also found that increasing the moisture level in the nuts resulted in reduction in the force required for rupture. However, the study found that the highest level of energy was required when attempting to rupture the pistachio along the x-axis as shown in Figure 2.5 (Galedar et al., 2009).

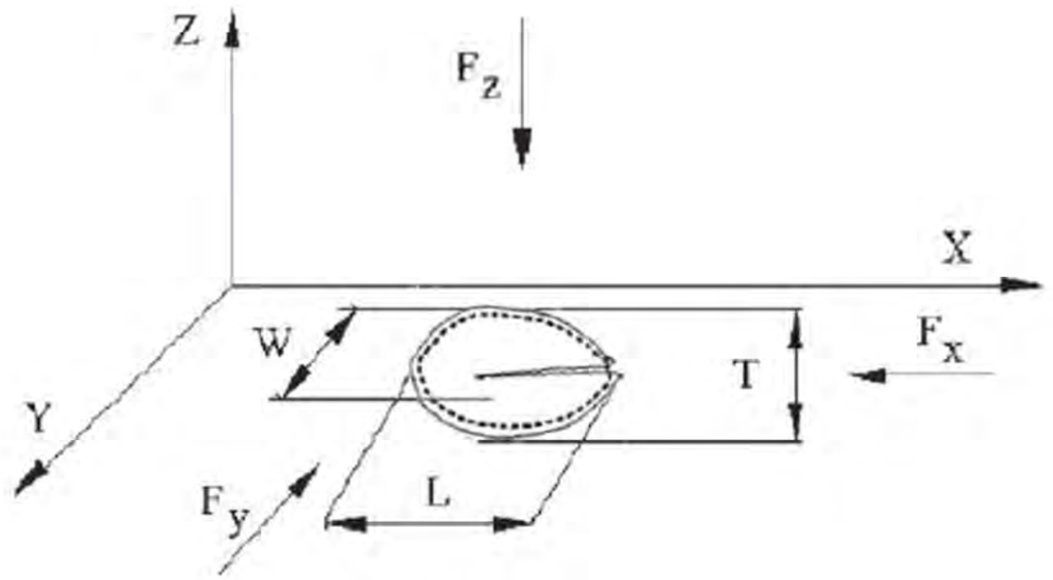


Figure 2.5 Definitions of pistachio nut axis by Galedar et al (2009).

2.2 Almond growing and harvesting

Almonds are grown in an orchard and harvested using a variety of machines. A visit to Jubilee Almonds' Orchard organized by the Almond Board of Australia was pivotal to understanding the growing and harvesting processes as described here.

2.2.1 Pollination of almond trees

Almond trees are not self-pollinating by nature. Several varieties need to be planted in close proximity of each other in order for the almond flowers to be pollinated by bees so that the trees can bear fruit (The Fresno Bee, 1995; Cline, 2010). The growers will hire bees from beekeepers during the pollination period so that the bees can pollinate the almond flowers (Goddard, 2007; Western Farm Press, 2010).

2.2.2 Almond varieties

The major varieties presently grown in Australia according to a 2010 survey are Nonpareil (50%), Carmel (32%) and Price (12%) plus others such as Fritz and Mission (Almond Board of Australia, 2010). Figure 2.6 shows these almond varieties and the differences in the kernel appearance.

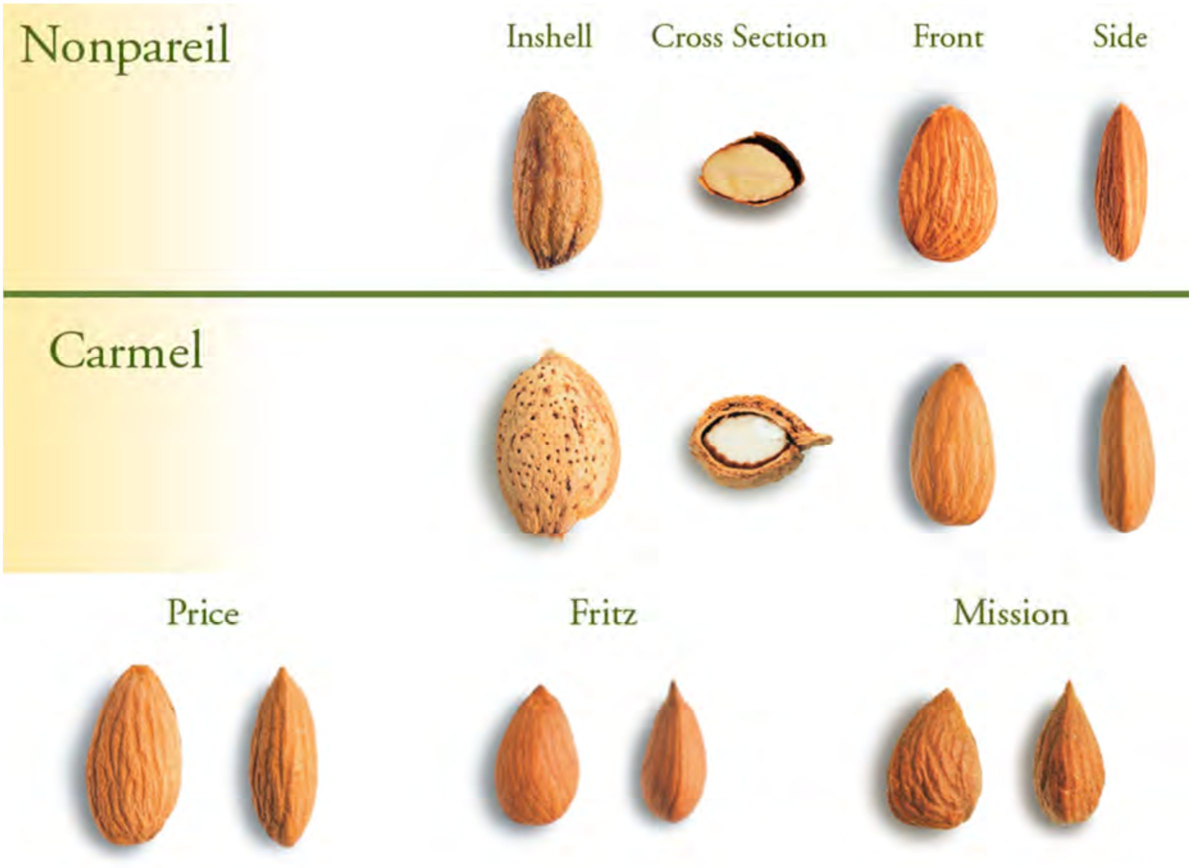


Figure 2.6 Almond varieties grown in Australia (Almond Board of Australia, 2009).

2.2.3 Segregation of almond varieties in the orchard

The need for different varieties to be planted in the same orchard poses a problem for the growers. Almond varieties fetch different market prices and mixed varieties of nuts are sold at marked down prices. This means that the growers have to maintain segregation of the harvested nuts in order to fetch the highest possible prices for their produce.

Segregation of variety is achieved firstly by planting each almond tree variety in a row as shown in Figure 2.8. Each row is dedicated to that one particular variety. The most valuable variety is the Nonpareil (Western Farm Press, 2009); thus the Australian growers usually have this variety on every other row. The rows of trees are also spaced far enough to avoid mixing of any fruit that falls onto the ground.

2.2.4 Almond harvesting process

Almonds are harvested using a mechanical shaker (The Fresno Bee, 1995). The almonds have to be dry enough in order to be harvested. If the almonds are too green, the shaker will not be able to shake them off the tree. The shaker is driven up to the tree and padded hydraulic clamps clamp onto the tree trunk. The tree is then shaken and the almonds, leaves and sticks fall to the ground as shown in Figure 2.7.

Figure 2.7 Almonds being harvested with a mechanical shaker.

After drying, the almonds are swept into windrows with a sweeper machine. Once the almonds (and leaves) are in windrows, they are left on the ground to further dry out. Figure 2.8 shows the almonds in a windrow.

Figure 2.8 Almond trees planted in rows and an almond windrow in the middle .

The almonds are then picked up with another machine called a 'pickup'. The pickup has an integrated desticker to remove sticks from the almonds. The desticker is effective only for the larger sticks and smaller sticks and twigs are still present in the harvested almonds. Figure 2.9 shows the pickup in operation.

Figure 2.9 A pickup with an optional integrated desticker in operation.

The almonds collected by the pickup are transferred into a bankout which transports the almonds to the storage facilities. This allows the pickup to keep doing its job of collecting almonds off the ground. The bankout’s tray can be tipped to the side to unload the almonds into the tray of the elevator. Figure 2.10 shows a bankout and the elevator into which it unloads the almonds. The elevator hooks the sticks off from the main conveyer with a desticker and deposits them onto a different conveyer. The main conveyer deposits the almonds into the bunker and the sticks are deposited into the bin on the left.

Figure 2.10 Picture of a bankout and elevator.

The harvested almonds are then stored until the primary processors are ready to receive them for processing.

2.2.5 Post harvest almond storage

In the Australian almond industry, the growers have to store the almonds until the hullers and shellers are ready to receive them for processing. Most Australian hullers and shellers do not have storage facilities for the almonds. Therefore, if the processing capacity of the hullers and shellers does not keep up with the increased quantities produced by the orchards, the almonds will have to be stored for longer periods of time before the hullers and shellers and packers are ready to receive them.

While some growers may have purpose built sheds, most of the almond growers store their almonds in tarpaulin covered bunkers. Figure 2.11 shows an almond storage shed and bunker. The storage bunker presents a cost effective solution as it is simply an open concrete enclosure to contain the almonds in the area. The almonds are covered by a tarpaulin to protect them from the rain. The tarpaulin affords protection from the rain, but has the problem that almonds ‘sweat’ under it as the moisture is trapped. The shed does not have the problem of trapped moisture under a tarpaulin but requires a higher investment.

Figure 2.11 Storage shed for almonds (top) and storage bunker (bottom).

2.3 Primary processing – hulling and shelling of almonds

The primary processing of almonds involves the removal of its husk and shell. This process is accomplished by shearing the almonds between a pair of rollers and then between a roller and belt that rotate with a speed differential. The shearing effect breaks the hulls and shells from the kernel. The almonds are then passed over a screen to remove the loose kernels before repeating the process on the next stage. The space between each subsequent stage of rollers is reduced to hull and shell increasingly smaller almonds. Throughout each stage, the kernels are separated from the hull and shell remnants using gravity tables or vibrating screens as seen in Figure 2.12. The final step of the process is to grade the almonds by size through a series of sizing screens as seen in Figure 2.13.

Figure 2.12 Vibrating screens with round holes separate kernels from husk and shell remnants

Figure 2.13 Overhead vibrating screens size grade and drop kernels into the respective bins below.

2.3.1 Patents related to hulling and shelling

The technique of using rollers to shear off the husk and break the shells of almonds has existed since 1917 when an inventor patented a machine that hulled almonds and cracked their shells by shearing them between a roller and a stationary bow shaped member, then separated the loose kernels with reciprocating screens (Vaughn, 1917). Figure 2.14 shows part of a drawing of the invention with the roller labeled item 26 and the bow shaped member labeled item 28, items 14 and 17 are the reciprocating screens.

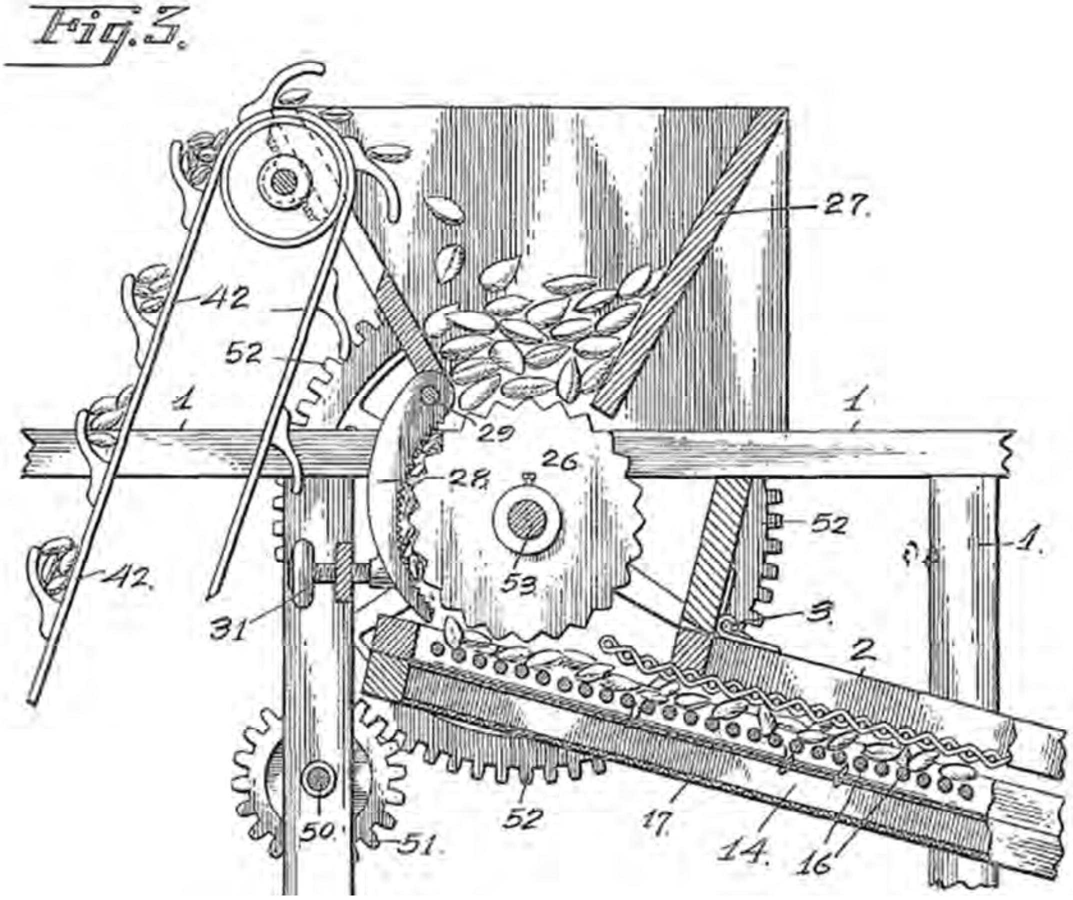


Figure 2.14 Machine patented in 1917 for hulling and cracking almonds (Vaughn, 1917).

The same inventor also patented an improved machine based on his previous patent with improved screens and a vacuum device to separate the unwanted husk and shell remnants from the kernels (Vaughan, 1925). Figure 2.15 shows the patented invention with the screens labeled as items 76 and 82.

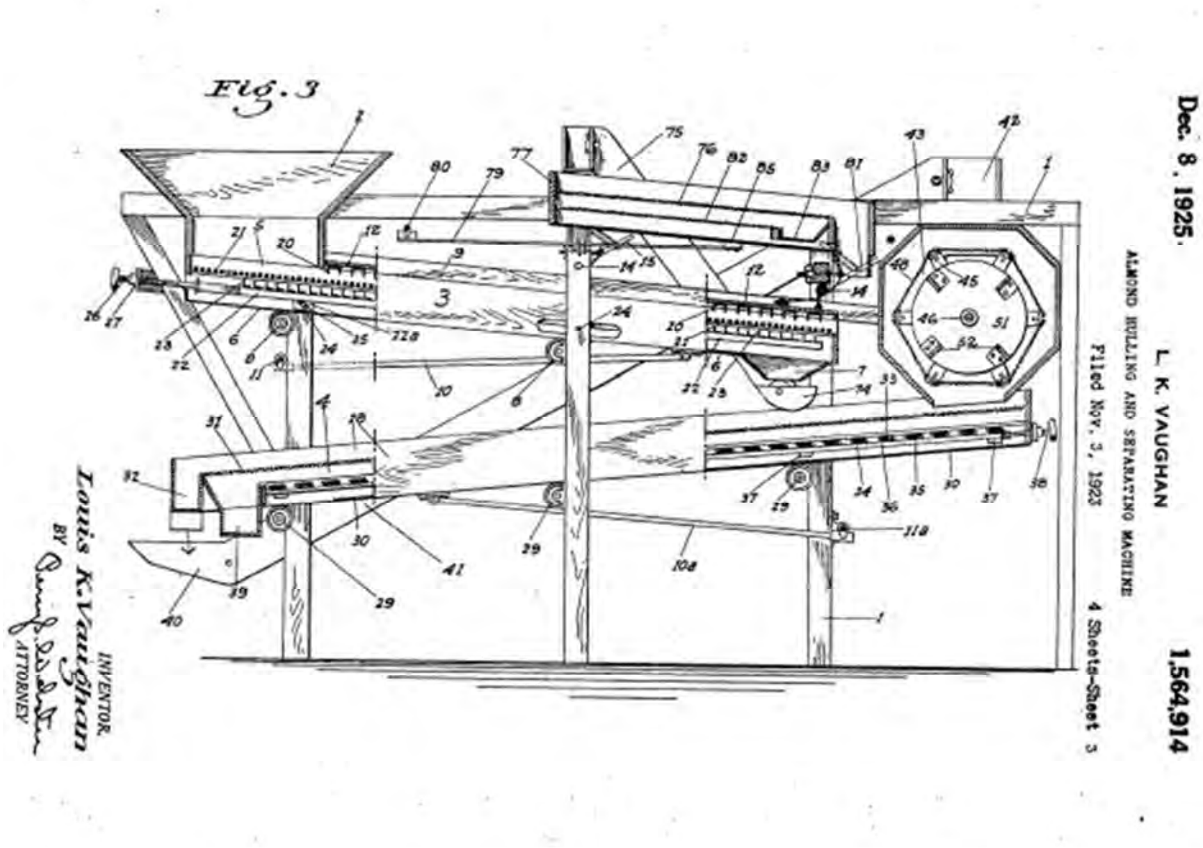


Figure 2.15 Vaughan's patented machine with screens (items 76 and 82) for separating husk and shell remnents (Vaughan, 1925).

An invention for hulling pistachio nuts as shown in Figure 2.16 was patented in 1981 (Volk, 1981). This invention uses a roller with projections and a stationary member with slots in order to hull the pistachio nuts. The design is similar to Vaughn's 1917 invention which uses a roller and stationary member to hull and shell almonds. The method of hulling in both inventions essentially uses the same means of imposing a shear force on the nuts.

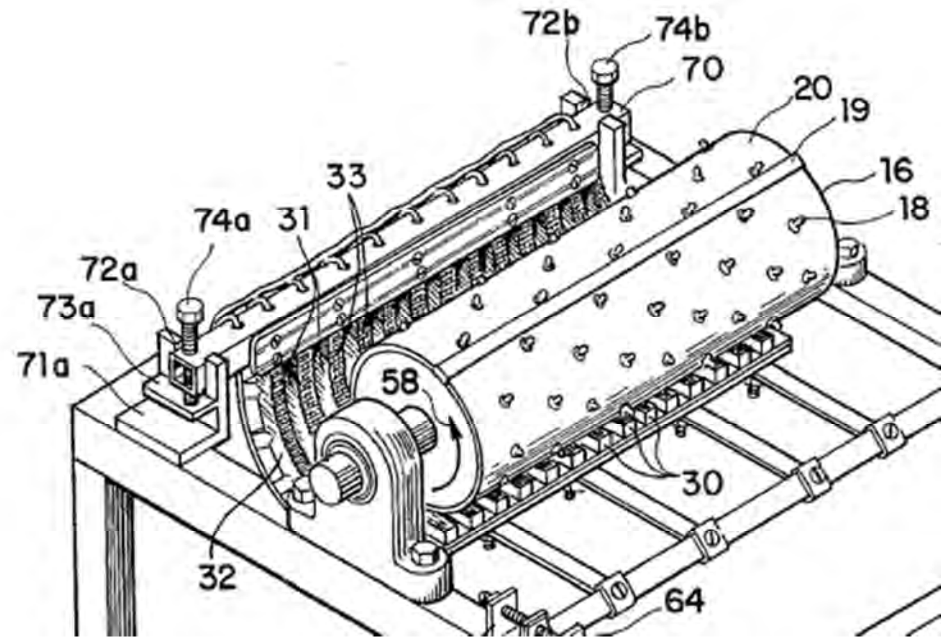


Figure 2.16 Patent for pistachio nut huller (Volk, 1981).

2.3.2 Moisture level parameters of almonds for efficient hulling and shelling

The moisture content of the almonds is important for efficient hulling and shelling. According to Don McKinney, Chairman of the Central California Almond Growers Association, the almond kernels should not have more than 5% moisture content (Cline, 2006). High moisture content not only promotes mold growth but also causes the hull to be rubbery. The almond would not be hulled effectively with a rubbery hull as the hull will compress rather than split under the rollers. The Australian industry guideline for almond kernel moisture content is 6% moisture content and 15% moisture content for the hull (Brown, 2011). If the moisture content is significantly above these values, the delivery of the almonds will be rejected by the primary processor (Stoeckel, 2011).

2.3.3 Size grades of almond kernels

The final part of the hulling and shelling process is to size grade the almond kernels.The USDA (1997) standards of specifying the range in number of whole almond kernels per ounce is an internationally recognized method. The USDA count range per ounce standards is:

- 16 to 18, inclusive.
- 18 to 20, inclusive.
- 20 to 22, inclusive.
- 22 to 24, inclusive.
- 23 to 25, inclusive.
- 24 to 26, inclusive.
- 26 to 28, inclusive.
- 27 to 30, inclusive.
- 30 to 34, inclusive.
- 34 to 40, inclusive.
- 40 to 50, inclusive.
- 50 and smaller.

There is no tolerance allowed when a range is specified. Therefore, if the range specified is 16/18, there has to be no less than 16 and no more than 18 kernels in an ounce.

The Australian almonds are sized graded as per international and USDA standards (Almond Board of Australia, 2010).

2.4 Secondary processing – colour sorting and packing almonds

The secondary processing of almonds subjects the almonds to a colour sorting process before packing them.

As with most other products, almonds are sorted and graded by its quality and appeal. The fewer defects the product has, the higher the price it can fetch on the market. As with any agricultural product, it is to be expected that there will be some variation in the product quality, appearance and size.

Almonds are graded according to standards established by a recognized authority such as the United States Department of Agriculture (USDA) or the Almond Board of Australia. A third party or independent authority is required as the third party will not be deemed as having a direct interest in the selling price of the product. Buyers are able to refer to the standard and know what to expect for the price that they are paying.

2.4.1 Almond grade categories

The USDA has defect tolerances for each almond grade. The USDA standard categorizes almonds into seven grades. The grades in descending order of value are U.S. Fancy, U.S. Extra No. 1, U.S. No. 1, U.S. Select Sheller Run, U.S. Standard Sheller Run, U.S. No. 1 Whole and Broken and U.S. No. 1 Pieces (USDA, 1997).

The Almond Board of Australia uses slightly different terms to grade the almonds. The Almond Board of Australia categorizes almonds into grades known as Fancy, Extra Supreme, Supreme and Manufacturing (Almond Board of Australia, 2010).

The defect categories for almonds are: dissimilar varieties, doubles, foreign material, kernels damaged by chipping or scratching, particles and dust, split and broken kernels, bitter almonds, serious damage and other defects (USDA, 1997).

2.4.1.1 Almond pricing by grade

Almonds are graded according to their size and visual presentation (Axelrod, 2011). The best grades are called 'fancy' grade. Naturally, there is a small percentage of defects allowed, beyond which the almonds will be downgraded to a lower grade (USDA, 1997). Lower grading means that a lower price would be paid for the almonds. Typically, the wholesale price of almonds starts from $5 a kilogram and drops by about 50 cents per kilogram for each grade that it is lowered.

2.4.2 The food safety standpoint for colour sorting

It is important for almonds to be of high quality and safe for consumption. There have been two separate incidences of salmonella contamination of almonds from California (Gary Gentile, 2004; The Cornucopia Institute, 2007). The two incidences were serious enough for the US government to legislate the pasteurization of almonds (Raine, 2007). There was also an Australian almond product recall in April 2011 due to the possible presence of salmonella (FSANZ, 2011).

In order to prevent food contamination, the Central California Almond Growers Association recommend proper rodent control and non-usage of manure or compost as fertilizer (Cline, 2006). This is because salmonella contamination usually occurs from contact with fecal matter, poor employee hygiene or sanitization practices (The Cornucopia Institute, 2007).

A study was done to find out if there is a correlation between aflatoxin contamination and the USDA grade of shelled almonds. The study found that high quality almonds only accounted for 3.2% of the aflatoxin mass while damaged grades of almonds accounted for 96.8% of the aflatoxin mass (Whitaker et al., 2010). The study concluded that the use of sorting techniques have the potential to effectively remove aflatoxin-contaminated kernels thereby reducing overall aflatoxin content of the lot to acceptable levels.

There have been other similar studies carried out. A study on brazil nuts found that sorting by size, density difference and Near Infra Red spectrophotometry resulted in selected nuts with no aflatoxin detected (Scussel and Mello, 2009).

Another study claims that the removal of discolored peanuts by color sorting removes most aflatoxin-contaminated peanuts as the discoloration in peanuts is primarily due to mould growth (Hocking and Pitt, 2006).

2.4.3 Colour sorting for removal of foreign matter found in almonds

There is a variety of foreign matter found in the almonds and these will all have to be removed from the final product. These include sticks, stones, dried peaches and even tiny melons that are picked off the ground of the orchard during harvesting as shown in Figure 2.17.

The harvesting process uses a mechanical shaker to shake the almonds off the tree. This process will also shake off any weak bits on the tree such as leaves and sticks. When the almonds are collected off the ground by the machines, sticks and other foreign material will also be picked up in the process. The pickup machines have destickers and screens to separate foreign matter from the almonds. Some orchards have another desticker to remove sticks before the almonds are stored in the bunkers or sheds. Despite all of these efforts, foreign matter still gets through. These are often small sticks that are too small to be picked up by the destickers or stones or melons that are about the same size as an almond.

Most hullers and shellers may have a destoner machine as part of their process. However, the destoner only removes dense material and not all of it. Some small stones may be getting through the process as they may be light in weight.

Dried peaches as shown in Figure 2.17 are another form of foreign matter in almonds. Almond trees can be grafted onto a variety of rootstocks such as peach, plum, peach/almond, and plum almond hybrids (Western Farm Press, 2011). Peach rootstock is very common and has been used for decades (Ledbetter and Sisterson, 2008). If the almond plant does not strike and the tree produces peaches or a combination of peaches and almonds, the dried peaches become a foreign material to the process.

Figure 2.17 Foreign matter removed by a laser sorter at the packers (top left); stones removed by a destoner machine at Costa Almonds (top right); tiny green melons in the product from the hullers and shellers (bottom left); dried peaches removed from almonds at hulling and shelling stage (bottom right).

2.4.3 Machine vision systems for food sorting

Food sorting can be carried out using machine vision systems. Machine vision systems are better than human inspections in terms of speed, accuracy, consistency and efficiency of food sorting (Narendra and Hareesh, 2010). It has been found statistically that machine vision measurements are more consistent than human measurement (Churchill et al., 1992; Verma, 2010). Machine vision systems have proven to be especially useful where manual sorting and evaluation of products such as raisins are costly and unreliable due to their subjective nature (Abbasgolipour et al., 2010).

Machine vision sorting has proved to be successful for objective assessment of food products such as bakery products, meat, fish, vegetables, fruit, prepared consumer foods and grain (Brosnan and Sun, 2004).

However, the variety of shapes, colours and textures of foodstuffs present a challenge for machine sorting (Sun, 2000; Connolly, 2005).

Machine vision systems were in use in all of the secondary processing facilities visited for this project. An argument for the use of such systems is that the sorting of almonds by human inspectors is unreliable as the inspector is only able to view the side of the kernel that is facing upwards (Page, 2011). Nonetheless, human inspectors were also a part of the process in all of the secondary processing facilities visited for this project. Figure 2.18 shows the use of human inspectors after the almond kernels have been through the colour sorting process. The kernels are moved past the inspectors on the green conveyor belts and the inspectors pick out any out of specification kernels before the kernels are packed.

Figure 2.18 Human inspectors at the secondary processors.

2.4.3.1 Difference between Mono, Bi and Tri chromatic systems

The main difference between mono-chromatic, bi-chromatic and tri-chromatic systems are the number of colour hues differentiated by the machine.

Mono-chromatic systems only differentiate between light and dark contrasts (Elexso, 2005). This system is unable to differentiate between a blue object and a red object if the colour shades are similar as the image is captured by the machine in gray scale (Gunasekaran, 1996).

Bi-chromatic systems are able to differentiate in the green and red spectrum of colours while Tri-chromatic systems are able to differentiate across the full colour spectrum to detect colour variations (Elexso, 2005).

2.4.3.2 Laser sorters

Laser sorters are sorting machines that use lasers as their light source. A variety of lighting sources can be used including incandescent, fluorescent, lasers, X-ray tubes and infrared lamps (Brosnan and Sun, 2004). The Elexso colour sorters use halogen lamps as a light source (Elexso, 2005).

2.4.3.2.1 Laser sorting efficiencies

A laser sorting system was developed to separate almonds having embedded shells from normal kernels. The study used near infrared lasers and line scan cameras to inspect both sides of the kernels simultaneously. This method of sorting resulted in 88.5% of normal almonds and 82% of almonds with embedded shell being correctly identified in a single pass (Pearson and Young, 2002). When a two-pass test was carried out on almonds with 0.1% embedded shell content, it resulted in 0.025% of embedded shell almonds in the accept stream with 6.2% of normal almonds in the reject stream. Therefore, multiple passes or machines may be required to attain high sorting efficiencies.

2.5 Project plan

This project requires a number of site visits for sample collection, sorting and process studies. The visits that have already been conducted to the orchards, primary and secondary processors provided important information on the process flow of the almonds from harvest to packaging.

A few more visits will be carried out in order to understand the primary and secondary processes and to collect samples.

In order to find the sources of mechanical damage in almonds, the following tasks will be completed:

- Analyze processes of primary and secondary processors.
- Carry out sampling at primary and secondary processor to gather data on kernel damage.
- Measure almond dimensions to find the size distribution of almonds.
- Carry out pendulum impact tests to find the effect of impact energy on almond kernels.
- Carry out velocity tests to find the effect of velocity on almond kernels.
- Carry out shear rolls test to find the effect of roller clearances on almonds.

A Gantt chart scheduling all of these tasks is shown in Figure 2.19.

2.5.1 Sampling and analysis for mechanical damage

In order to identify the source of mechanical damage, the process flow of all primary and secondary stages of processing will be studied. This requires prior coordination and agreement with the primary and secondary processors. To ensure that the study is conducted in a safe manner, all OHS requirements of the site being visited will be complied with.

After understanding the process, the sampling points in each process can be determined. Samples will be taken at the sampling points and inspected for mechanical damage. The data will then be analyzed and the sources of mechanical damage identified.

Samples will be requested from each processor being studied. As the study is being carried out in conjunction with the Almond Board of Australia, it is anticipated that there will not be a cost imposed for the samples taken.

2.5.2 Determining size distribution of almonds

A sample lot of almonds will be measured in order to find the size distribution of almonds while in-hull, in-shell and kernel. This information can be used in further studies to minimize damage in almond processing.

2.5.3 Finding the effects of impact energy, velocity and shear rolls on almond damage

The effects of impact energy, velocity and shear rolls on almond damage can be found out by carrying out the relevant tests. All of these tests will be carried out subject to the availability of the testing equipment.

The impact testing will be carried out on a pendulum impact tester, the velocity testing will be carried out on a rotary arm velocity tester and the shear rolls testing will be carried out on a shear rolls tester. All of the machines are available at the University of South Australia's Mawson Lakes campus.

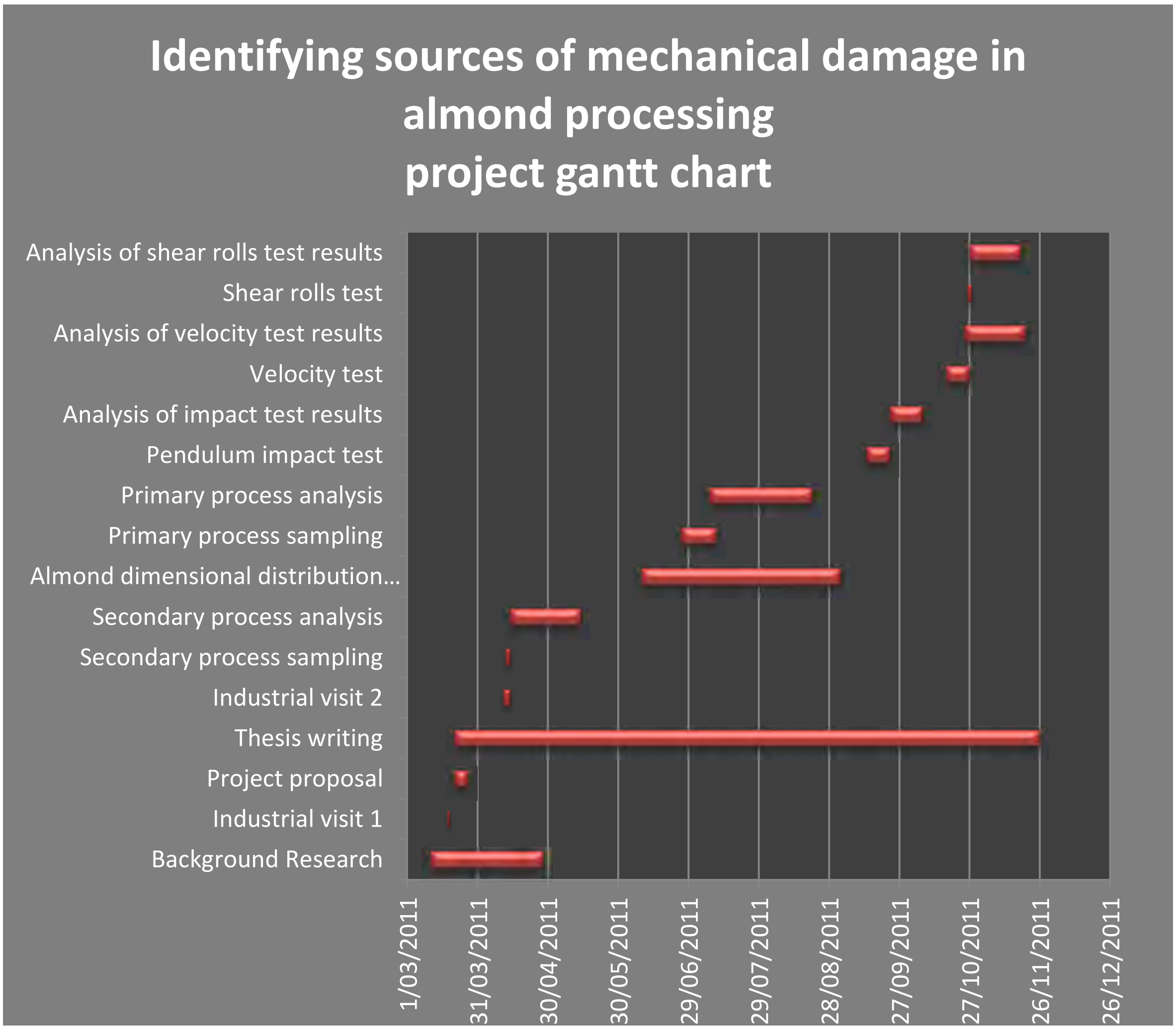


Figure 2.19 Gantt chart for project plan.

3. Determination of damage by processors

A number of site visits were conducted to understand the primary process of hulling and shelling and the secondary process of sorting and packing. Samples were taken in order to study the damage being inflicted on the almonds at each processor.

Samples were taken from the packer, Riverland Almonds before and after the almonds were sorted. Samples were then taken from Costa Almonds at various stages of the hulling and shelling process to study the damage from hulling and shelling machines.

3.1 Determination of damage at secondary processor

3.1.1 Sorting process of Riverland Almonds

The Riverland Almonds process begins with the receipt of the almonds. The almonds are brought from the hullers and shellers in wooden crates lined with large plastic bags as shown in Figure 3.1. The large plastic bags protect the almonds and prevent foreign material from getting mixed into the kernels.

Figure 3.1 Wooden crates for almonds (left). Almonds in large plastic bags (right).

The almond kernels then go through a fumigation process with a food grade fumigant in order to kill any insects, eggs or larvae.

The first stage of Riverland Almonds' process is the removal of foreign matter from the almond kernels using a laser sorter. This process is new to Riverland Almonds and is a dedicated laser sorter used solely for the removal of foreign matter.

The next stage of the process uses a series of color sorters to reject out of specification kernels and foreign material. The color sorters reject kernels that have white on them or are of a darker or lighter shade of color. The kernels that are chipped, scratched or broken will have white spots where the brown skin is damaged to reveal the white almond meat inside. The kernels that are of a different shade of color may be from another variety or have mold growth. Any foreign material that is not the exact same color as the almond kernel will also be picked out.

The almond kernels are flung off a belt through the air for the cameras to capture the color of the kernels. When cameras of the color sorters pick out an out of specification almond, a jet of air knocks the kernel out in mid-stream into the reject stream. The remaining kernels then repeat the process at the next stage until the last machine. There is some wastage generated as good almonds that are beside the bad ones will sometimes get knocked out by the air burst, therefore, any increase in the rejection rate will also result in an increase in good almonds in the waste stream (Antosh, 1985).

The kernels are sent through a final stage of visual inspection before being packed into bulk bags or carton boxes as shown in Figure 3.2.

Figure 3.2 The almond kernels go through a final visual inspection (left). Almonds packed into bulk bags (right foreground) or carton boxes (right background).

3.1.2 Foreign material removal by laser sorter

Riverland Almonds find a lot of foreign material mixed in with the almond kernels and implemented a laser sorting stage to remove foreign material before the colour sorting process. The foreign materials removed by the laser sorter were mainly small stones as seen in Figure 3.3 that were smaller than an almond in a shell. Although the laser sorter is able to remove the foreign material, it would be better if the foreign matter is removed earlier at the hullers and shellers before being sent to the packers.

A customized solution to remove foreign matter could be implemented. This could be accomplished by a screen allowing small particles to pass through but sending the almonds to the next stage of processing.

Figure 3.3 Riverland Almonds' laser sorter (left) removes foreign material (right).

3.1.3 Color sorting to remove out of specification almond kernels

The almond kernels are loaded into the color sorters through a large hopper. The hopper is located up high as shown in Figure 3.4 and is loaded by a forklift. There was a hypothesis by Riverland Almonds that the dropping of the almonds through the large hoppers of the sorting machines were causing impact damage in the form of chips or scratches to the almonds. This has prompted Riverland Almonds to implement a number of cascades as shown in Figure 3.4 to prevent damage to the falling almonds.

Figure 3.4 Hopper for loading almond kernels into the color sorters (left). Cascades at Riverland Almonds (right).

3.1.4 Results from sampling for mechanical damage at packers

A sample of almond kernels was taken from Riverland Almonds before the color sorting process and after the color sorting process. These kernels were visually inspected and sorted to quantify the defects in the sample.

3.1.4.1 Analysis of secondary processing mechanical damage to kernels

Samples were taken for data collection and hand sorted into the following categories: good, chipped, scratched, insect/rodent damage and doubles.

The results obtained from the sample of almonds from Riverland Almonds are as indicated in Table 3.1. The doubles were then omitted from the final tally as they are not categorized as damaged almonds.

Table 3.1 Results of Riverland Almond's sampling

	Before		After	
	Quantity	%	Quantity	%
Good	455	58.5	588	70.33
Chipped	253	33	193	23.9
Scratched	34	7.5	52	8.84
Insect/Rodent Damaged	36	4.6	3	0.36
Doubles	5		0	

From Table 3.1, it is evident that 45.1% of the almonds arrive at the packers with some form of damage already inflicted. Collectively, 40.5% of the almonds are chipped or scratched before the product arrives at the packers. This leads to the conclusion that 40.5% of the almonds have been mechanically damaged at the hullers and shellers, during harvest or during transportation.

Figures 3.5 to 3.8 defines the defects found in the almond kernels.

Figure 3.5 Example of a 'double'. Two mating almonds (twins) in the same shell.

Figure 3.6 Examples of chipped almonds

Figure 3.7 Example of a scratched almond

Figure 3.8 Examples of insect or rodent damaged almonds

3.1.4.2 Calculating efficiency of sorting machines in removing defective almonds

After analyzing the data to quantify the mechanical damage in the sample, the data was used to work out the sorting efficiency of the process. This study was done in order to better understand the process and obtain some useful information that could be used in future studies.

The following method was used:

The quantities of almonds were balanced to account for the difference in the sample quantities taken before and after the process. In order to do this, the assumption is made that all of the good kernels passed through without being air ejected. Since the number of good kernels cannot be increased through processing, the number of good kernels in the 'after' sample was multiplied by a factor to bring it down to the exact same quantity as in the 'before' sample. The rest of the quantities were subsequently multiplied by the same factor to produce the results in Table 3.2. The sorting efficiency was worked out with formula 3.1.

$$Sorting\ Efficiency = [1 - \left(\frac{Number\ of\ defect\ remaining\ after\ sorting}{Number\ of\ defect\ before\ sorting}\right)] \times 100\% \quad \textbf{(3.1)}$$

Table 3.2 Efficiency of machines in removing defective almonds

	Before		After		Efficiency in removing defects
	Quantity	%	Quantity	%	%
Good	455	58.5	455	70.4	N/A
Chipped	253	33	149	23.1	41.1%
Scratched	34	7.5	40	6.19	-17.6%
Insect/Rodent Damaged	36	4.6	2	0.31	94.4%
Doubles	5		0	0	100%

The negative percentage for removal of scratched almonds implies that there is additional scratching caused by the sorting process itself with 6 out of 646 kernels being scratched during the process.

The sorting process is quite efficient at removing deformed and insect/rodent damaged almonds, but some still remained in the final sample. It is desirable to remove as many if not all of the insect/rodent damaged almonds as it may constitute a food safety concern. Based on the calculated rate of 94.4% efficiency of insect/rodent damaged kernels, a second pass will remove a further 94.4 % of the defect left in the lot. Taking the representative sample of 4.6% insect/rodent damage and projecting it in terms of a 10,000 kernels lot size a starting figure of 460 insect/rodent damaged kernels per 10,000 kernels is obtained. After the first pass, 94.4% of insect/rodent damaged kernels will be removed leaving 26 insect/rodent damaged kernels in the lot. After the second pass, only 1 insect/rodent damaged kernel will remain in the lot. Thus, if it is desired to eliminate insect/rodent damaged kernels as much as possible, a second pass or machine will have to be implemented. Alternatively, the sensitivity of the sorting machine could be increased. However, increasing the sensitivity of the sorting machine will also result in an increase in rejections of good almonds.

3.2 Determination of damage by secondary processor

3.2.1 Hulling and shelling process of Costa Almonds

In order to find the source of the mechanical damage, the hulling and shelling process used by Costa Almonds was studied. From the visits to facilities operated by Simerloo, Costa Almonds and Laragon, it was found that the hulling and shelling equipment is similar at all of the companies. There were differences observed in the number of stages, the adjusted gap between the rollers and the belts as well as the layout of the machinery. Overall, the machinery used by all of the companies use the same principle of shear rollers, shear roller and belt and screens with bouncing balls. Therefore, the study of Costa Almonds will provide an indication of where the mechanical damage is occurring in the hulling and shelling process.

The hulling and shelling process facility can be used for both hard and soft shell varieties of almonds. However, the machine settings have to be modified by varieties. The almond’s shell strength varies greatly among different varieties and using a hard shell setting on a soft shell variety would cause significant damage to the almond kernels (Ledbetter, 2008).

The process begins with the receival of almonds by the primary processor. The almonds are transported by trucks from the orchard to the primary processor as shown in Figure 3.9.

Figure 3.9 The truck tips its tray to pour the almonds out (right).

Costa Almonds stores the received almonds in a shed as shown in Figure 3.10. The shed has limited storage space and is meant only to provide some protection to the almonds that are being immediately processed.

Figure 3.10 Shed for temporary almond storage at Costa Almonds.

After the primary processor receives the almonds the hulling and shelling process begins with the almonds being loaded into the machines as shown in Figure 3.11. The pre-cleaning machines are shown in Figure 3.12.

Figure 3.11 Front end loader collects almonds from shed and loads them in the hopper.

Figure 3.12 Almond pre-cleaning machines at Costa Almonds.

The first stage of the process is a pre-cleaning stage where sticks and stones are removed from the almonds. The waste streams from the precleaning stages are shown in Figure 3.13.

Figure 3.13 Desticker and destoner removes sticks and stones in the pre-cleaning process.

The hulling and shelling process used by Costa Almonds is a five stage process. At each stage of the hulling and shelling process, the almonds go through a set of rollers, followed by a roller and belt, and finally through a vibrating screen. The pair of rollers runs at a speed differential in order to shear the husks off the almonds. The roller and belt are also rotating at different speeds to exert a shear force to crack the shells of the almonds. These rollers and belts work in tandem to hull and shell the almonds.

The screens are vibrating screens with bouncing balls inside to clear them. Any object (almonds, hulls, shells or foreign) that gets lodged in the screen will be hit by the bouncing ball, thereby dislodging it and clearing the screen. The screen vibrates and ‘throws’ the almonds in a forward direction. Any kernel that is small enough will pass through the screen onto a conveyor and transferred to the end of the processing. The rest of the almonds go to the next stage of the hulling and shelling process where the process is repeated.

3.2.2 Sampling for mechanical damage caused by the hulling and shelling process

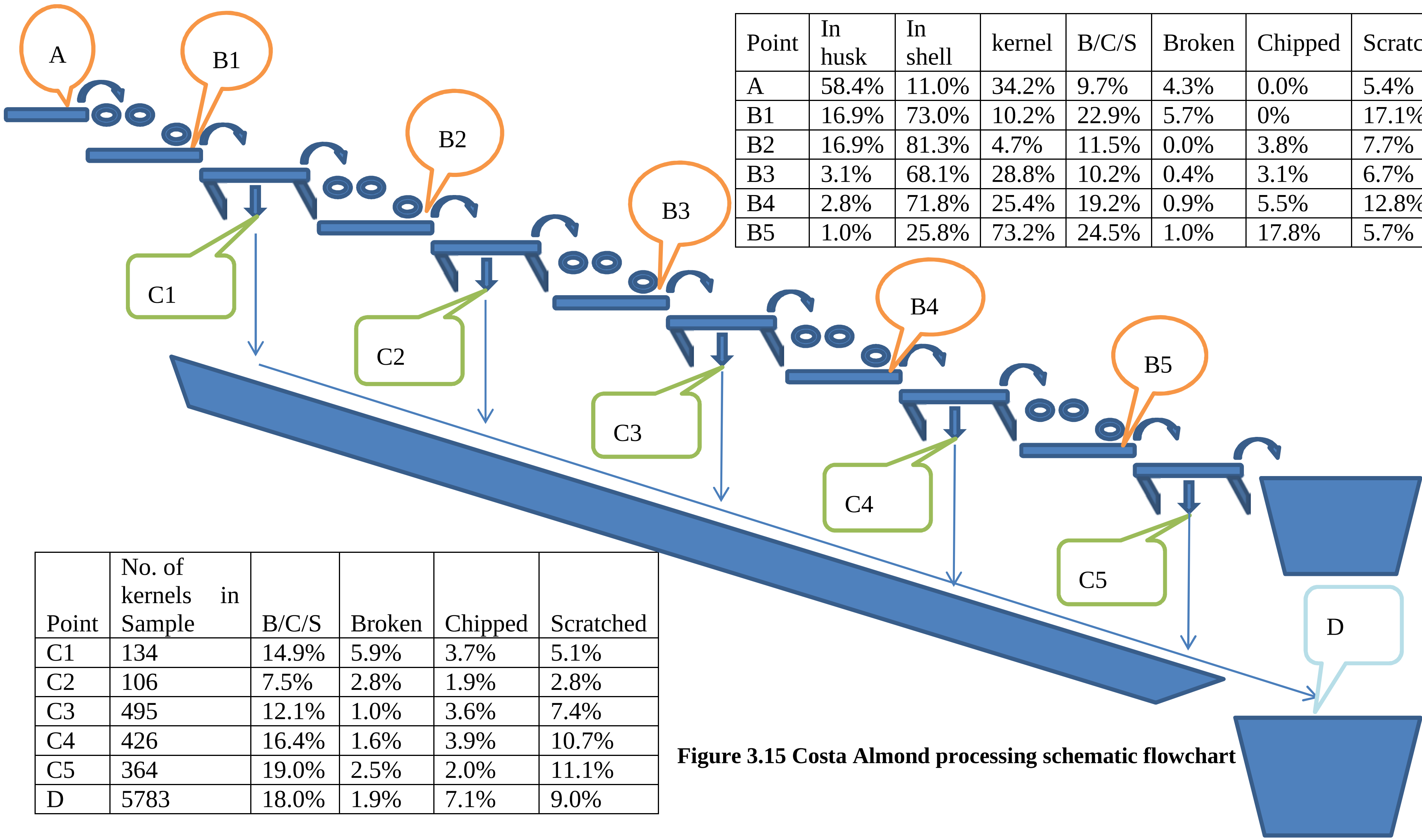
In order to determine the mechanical damage of almonds from the hulling and shelling process, samples were taken and examined at every feasible point. The samples were sorted into lots of in-husk almonds, in-shell almonds and kernels as shown in Figure 3.14 before being checked for signs of mechanical damage.

Figure 3.14 Samples segregated by in-husk, in-shell and kernels.

A schematic flowchart of Costa Almond’s hulling and shelling process is shown in Figure 3.15; it shows the five stages and labels the points where samples were taken.

Point A is the end of the pre-cleaning process where sticks, stones as well as foreign objects are removed before the hulling and shelling process. Points B1 to B5 are at the end of the respective stage of processing after the almonds have gone through the rollers and belt. Points C1 to C5 are the respective stages of screening, thus the sample taken consists of the kernels that have passed through the screen. Point D is the end of the process where the almond kernels are collected.

Samples were taken from the stockpile before processing, at the end of pre-cleaning (point A), at all five stages of the process (points B1-B5 and points C1-C5), and at the end of the process (point D). The samples were checked for signs of mechanical damage and the results recorded. The sample numbers for in-hull and in-shell almonds as well as kernels were recorded and the results analyzed to work out the hulling and shelling efficiency of the processing plant.



Point	In husk	In shell	kernel	B/C/S	Broken	Chipped	Scratched
A	58.4%	11.0%	34.2%	9.7%	4.3%	0.0%	5.4%
B1	16.9%	73.0%	10.2%	22.9%	5.7%	0%	17.1%
B2	16.9%	81.3%	4.7%	11.5%	0.0%	3.8%	7.7%
B3	3.1%	68.1%	28.8%	10.2%	0.4%	3.1%	6.7%
B4	2.8%	71.8%	25.4%	19.2%	0.9%	5.5%	12.8%
B5	1.0%	25.8%	73.2%	24.5%	1.0%	17.8%	5.7%

Point	No. of kernels in Sample	B/C/S	Broken	Chipped	Scratched
C1	134	14.9%	5.9%	3.7%	5.1%
C2	106	7.5%	2.8%	1.9%	2.8%
C3	495	12.1%	1.0%	3.6%	7.4%
C4	426	16.4%	1.6%	3.9%	10.7%
C5	364	19.0%	2.5%	2.0%	11.1%
D	5783	18.0%	1.9%	7.1%	9.0%

Figure 3.15 Costa Almond processing schematic flowchart

3.2.3 Results of sampling for mechanical damage caused by the hulling and shelling process

The samples were checked for signs of mechanical damage and the results recorded. The sample numbers for in-hull and in-shell almonds as well as kernels were recorded and the results analyzed to work out the mechanical damage caused at each stage as well as the hulling and shelling efficiency of the processing plant. The results of these findings are summarized in Table 3.3.

Table 3.3 Percentage of mechanical damage caused by each point in the hulling and shelling process and the hulling and shelling efficiency of the machines.

Point	In husk	In shell	kernel	B/C/S	Broken	Chipped	Scratched
A	54.8%	11%	34%	9.7%	4.3%	0.0%	5.4%
B1	16.9%	73.0%	10.2%	22.9%	5.7%	0%	17.1%
B2	16.9%	81.3%	4.7%	11.5%	0.0%	3.8%	7.7%
B3	3.1%	68.1%	28.8%	10.2%	0.4%	3.1%	6.7%
B4	2.8%	71.8%	25.4%	19.2%	0.9%	5.5%	12.8%
B5	1.0%	25.8%	73.2%	24.5%	1.0%	17.8%	5.7%
	Remaining Kernels	Kernels Removed	No. of kernels in sample	B/C/S	Broken	Chipped	Scratched
C1	89.8%	10.2%	134	14.9%	5.9%	3.7%	5.1%
C2	85.6%	4.2%	106	7.5%	2.8%	1.9%	2.8%
C3	60.9%	24.7%	495	12.1%	1.0%	3.6%	7.4%
C4	45.4%	15.5%	426	16.4%	1.6%	3.9%	10.7%
C5	12.2%	33.3%	364	19.0%	2.5%	2.0%	11.1%
D	N/A	N/A	5783	18.0%	1.9%	7.1%	9.0%

The results have been expressed as percentages of kernel to ensure that the information is uniform. For example, Table 3.3 shows that 10.2% of the kernels at point B3 have some form of mechanical damage, and this can be further broken down into 0.4% broken, 3.1% chipped and 6.7% scratched almonds.

Figure 3.16 shows mechanically damaged samples from the study that has been defined as scratched, chipped and broken.

Figure 3.16 Clockwise from top: Scratched, chipped and broken almonds from the Costa Almonds hulling and shelling process.

3.2.3.1 Mechanical damage as a percentage of kernel content in sample

There is a possibility that the almonds may be damaged by the rollers and belts while they were still in their husks and shells. The compressive forces could possibly crush the kernels while they are still in their husks.

In order to determine if the damage was done to the kernels before or after they were removed from their husk and shells, almonds that were still in their husks or shells were carefully removed and examined for signs of mechanical damage.

The study found that the kernels that were removed from their husks and shells by hand had no signs of mechanical damage at all. This leads to the conclusion that the almonds do not get damaged mechanically by the Hulling and Shelling machines if they are still in their husk or shell. Only the loose kernels in the sample bore signs of mechanical damage.

The amount of mechanical damage percentage increases with the kernel content percentage in the sample as shown in Figure 3.17.

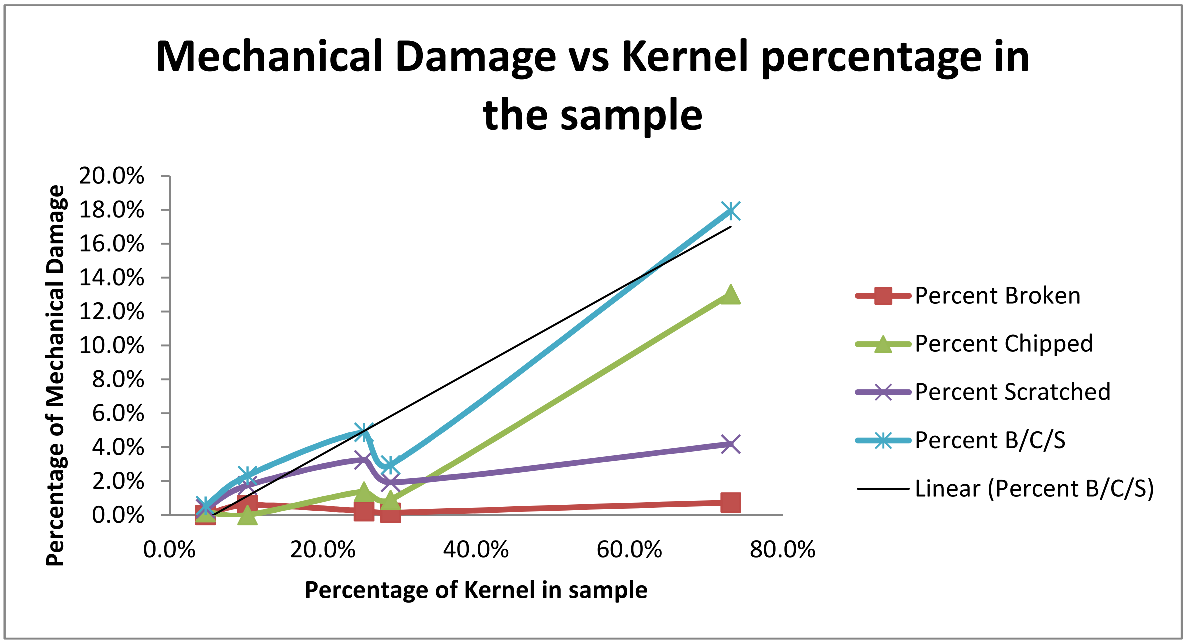


Figure 3.17 The relationship between kernel content in the sample and mechanical damage.

3.2.3.2 Results of study of secondary processing

When the kernels were removed from their husks and shells by hand, no sign of mechanical damage was found. This leads to the conclusion that the almond kernels are being damaged by the hulling and shelling process.

The result shown in Table 3.3 indicates that the amount of mechanical damage varies at each stage of the hulling and shelling process. The difference in the amount of damage at each stage is possibly due to the different almond sizes and machine settings at each stage of the process.

4. Determine the size distribution of almonds

A sample batch of in-husk almonds were obtained from Mark Stoeckel's almond orchard. These almond samples were used for data and statistical collection.

In order to find the range of the almond sizes, two measurement templates shown in Figure 4.1 were designed and fabricated. The templates were made from a perspex sheet and had round holes and slots cut into them. These templates were used to size the almonds. The round hole template sizes the width of the almonds and the slotted template sizes the thickness of the almond.

The almond industry currently uses screens with round holes to separate the almond kernels from the husk and shell. Various other agricultural industries may also use slotted screens in their machinery.

Figure 4.1 Round hole template (left) and slotted template (right)

4.1 Size distribution for width and thickness of in-husk almonds

An initial sample of 377 in-husk almonds were randomly selected using a sample divider. These in-husk almonds were then measured and sorted using the templates.

An in-husk almond that can fit through a 15 mm diameter hole but not through a 14 mm diameter hole is catagorized as a 15 mm wide almond. Similarly, an in-husk almond that fits through a 15 mm slot but not a 14 mm slot is catagorized as a 15 mm thick almond. This method of measuring the almonds was carried out for the whole measuring process. The almonds were maneuvered into positions that allowed them to drop through the templates without being forced. Figure 4.2 and 4.3 show the size grading process.

Figure 4.2 Top row, grading the in-husk almonds width. Middle row, grading the in-shell almonds width. Bottom row, grading the kernels width.

Figure 4.3 Top row, grading the in husk almonds by thickness. Middle row, grading the in-shell almonds by thickness. Bottom row, grading the kernels by thickness.

The in-husk almond samples were measured and Figure 4.4 shows the size distribution of the width of the almonds. The resulting distribution shows a bell shaped distribution curve. The highest percentile of the in-husk almonds had a width of 21 mm. The in-husk almonds ranged in width from 15 mm to 28 mm diameter. 92.3% of the sample had a width between 19 mm to 25 mm.

Since the distribution of in-husk almonds begins from a minimum width of 15 mm, a pre-cleaning process can be used to remove stones or other foreign matter under the size of 15 mm. Any existing loose kernels and shelled almonds under 15 mm width will also be removed in the pre-cleaning process and will have to be reclaimed.

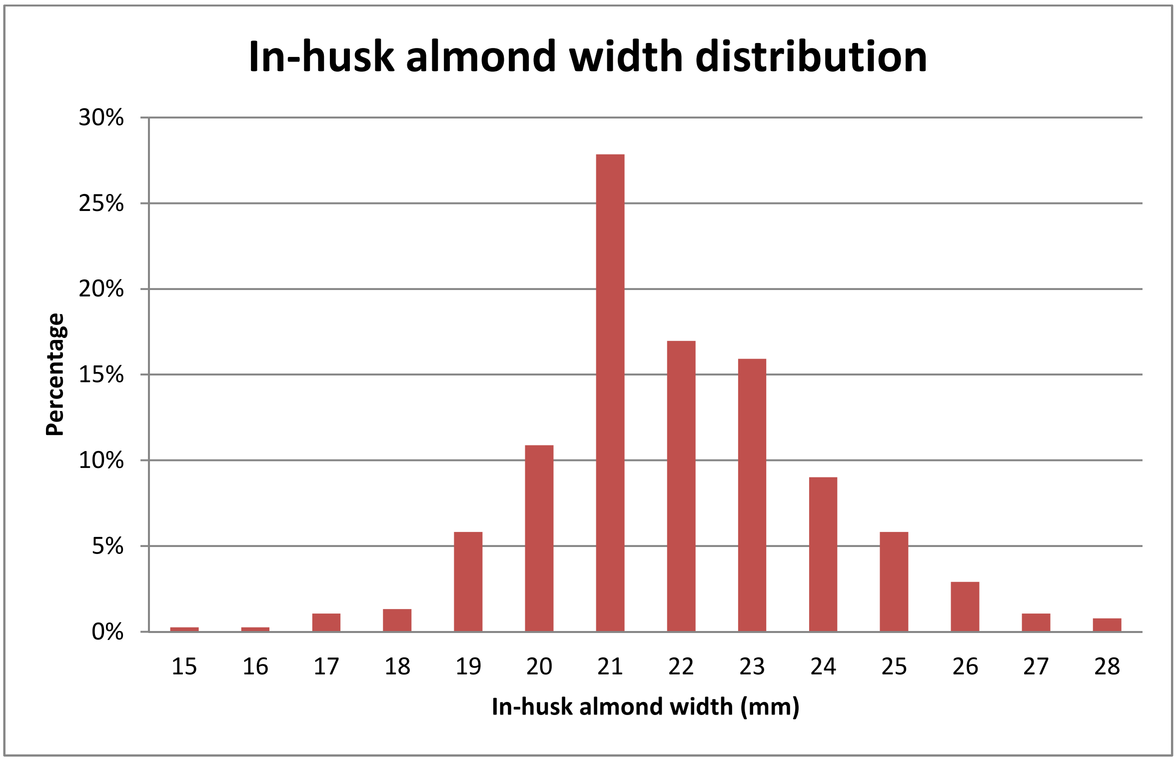


Figure 4.4 In-husk almond width size distribution

The in-husk almonds were then measured using the slotted template. The resulting bell shaped distribution curve is shown in Figure 4.5. The highest percentile of the in-husk almonds would fit through an 18 mm slot. The almonds ranged from a thickness of 12 mm to 23 mm. 95.7% of in-husk almonds were in the range of 15 mm to 21 mm thickness.

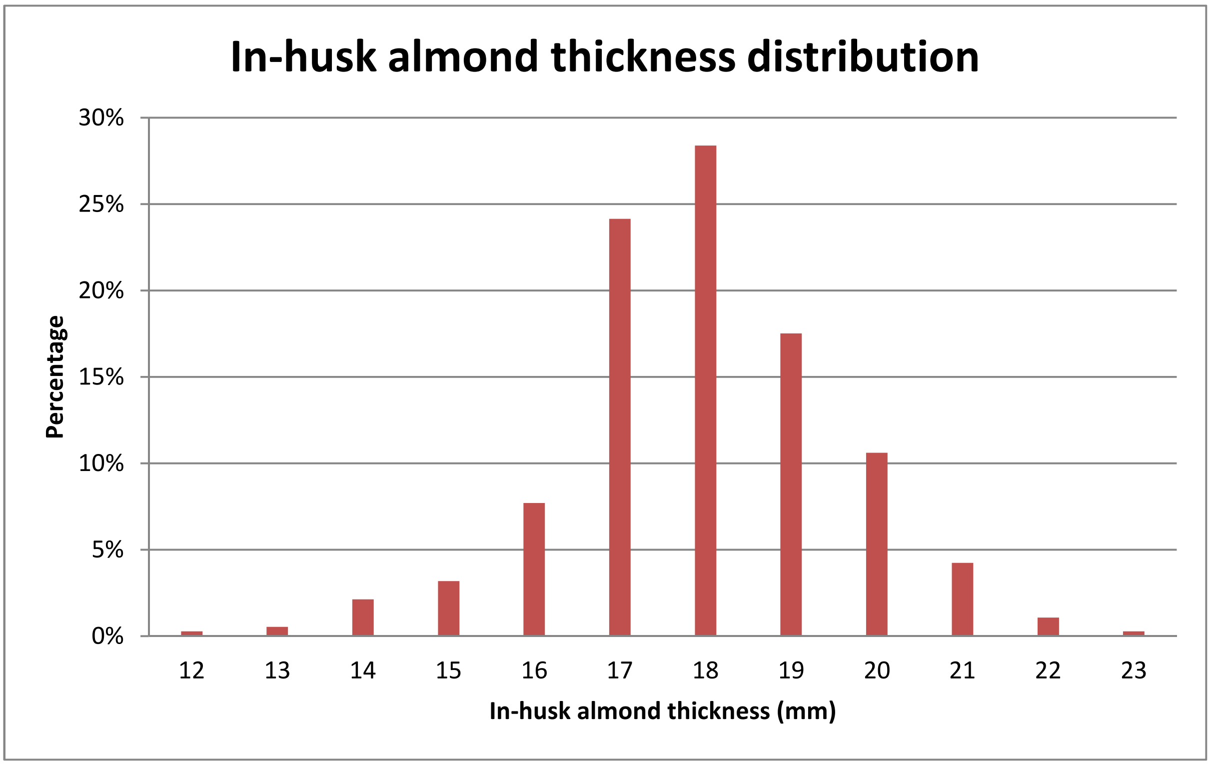


Figure 4.5 In-husk almond thickness size distribution

4.2 Relationship between the mass and width of the almonds

The in-husk almonds were weighed and the mass averaged out in order to find the average mass of almonds in comparison with their width. There was a linear relationship between the width of the almond and the mass of the almond as shown in figure 4.6.

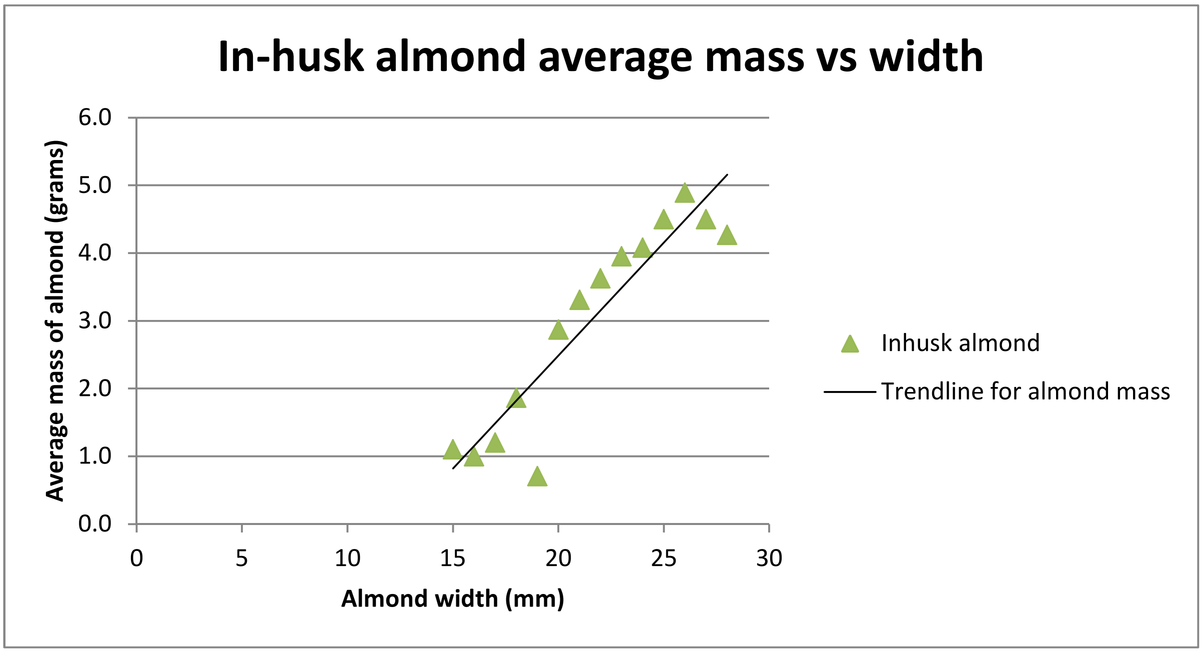


Figure 4.6 Averaged mass of in-husk almonds plotted against width.

4.3 Size distribution for width and thickness of in-shell almonds

After the in-husk almonds were measured and sorted, the almonds were carefully removed from their husks and the in-shell almonds were measured and sorted.

The round holed and slotted templates were used to measure the in-shell almonds. The same method was used whereby an in-shell almond that can fit through a 15 mm diameter hole but not through a 14 mm diameter hole is catagorized as a 15 mm wide almond and likewise for the slots. As before, the almonds were moved into a position so that they could drop through without being forced through.

Figure 4.7 shows the resulting bell shaped width distribution of in-shell almonds. The largest percentile of in-shell almonds had a width of 18 mm. The in-shell almond widths ranged from 14 mm to 23 mm. 97.3% of the in-shell almonds were in the range of 16mm to 21 mm width.

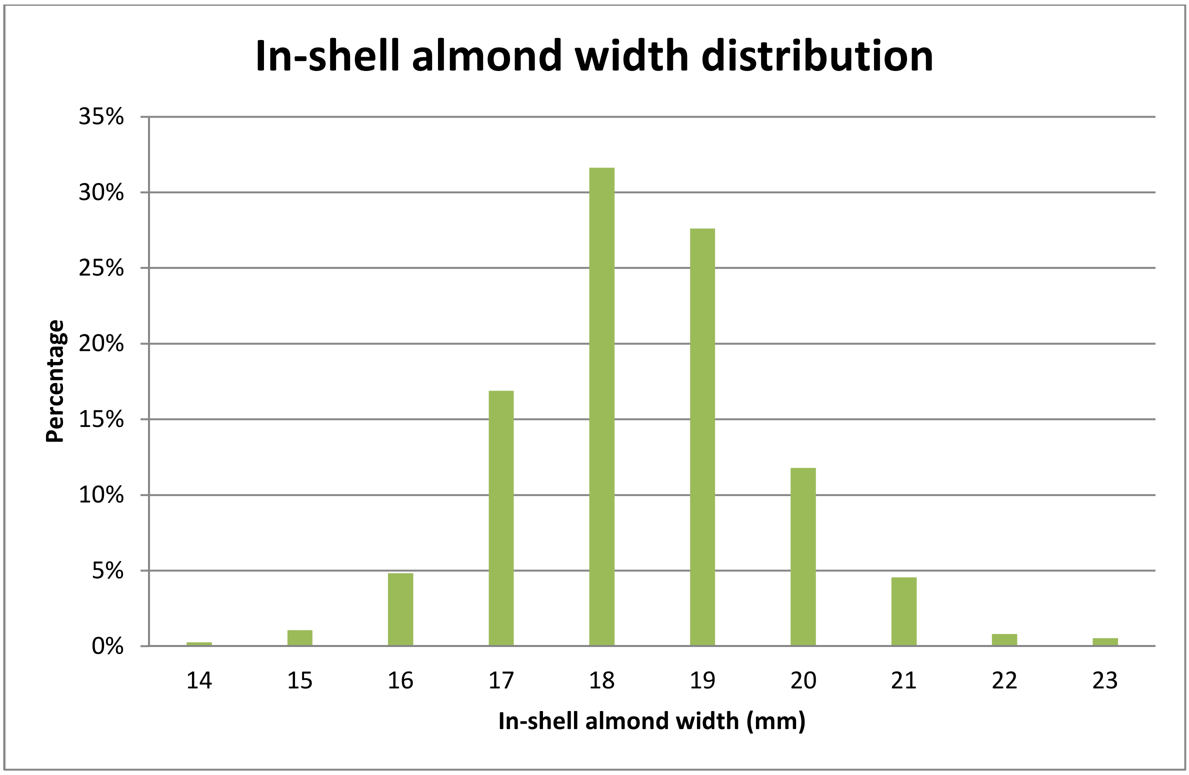


Figure 4.7 Width distribution of in-shell almonds.

The in-shell almonds were then measured using the slotted template and the resulting bell shaped distribution curve is shown in Figure 4.8. The highest percentile of the in-shell almonds would fit through a 14 mm slot. The almonds ranged from a slot width of 11 mm to 19 mm. 97.8% of in-shell almonds were in the range of 12 mm to 16 mm thickness.

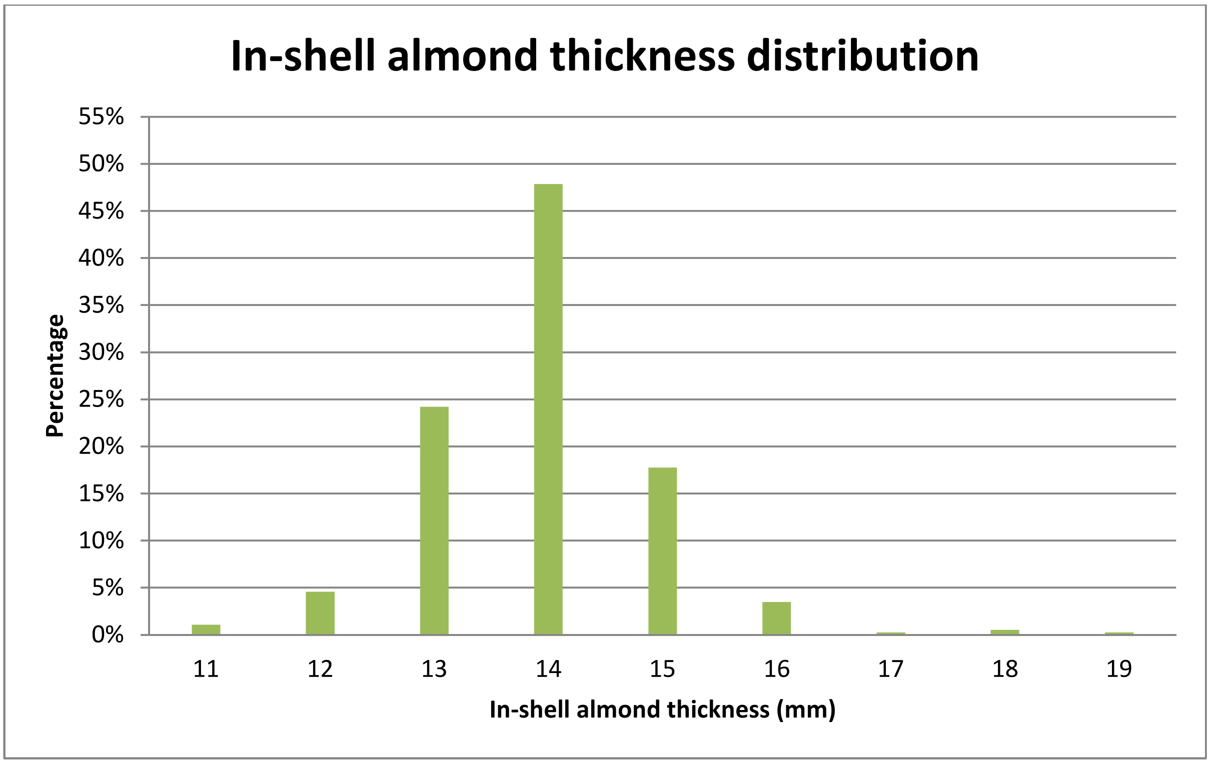


Figure 4.8 Thickness distribution of in-shell almonds.

4.4 Size distribution for width and thickness of almond kernels

The final part this exercise was to measure and sort the almond kernels. The almond kernels were carefully removed from their shells and the kernels were then measured and sorted.

The same method was used with the templates as in the previous two exercises with the in-hull and in-shell almonds. As before, the kernels were moved into a position so that they could drop through without being forced.

The resulting normal bell shaped distribution is presented in Figure 4.9. The largest percentile of kernels in the sample had widths of 13 mm. The almond widths ranged from 9 mm to 16 mm. 98.3% of the kernels were in the range of 11 mm to 15 mm width.

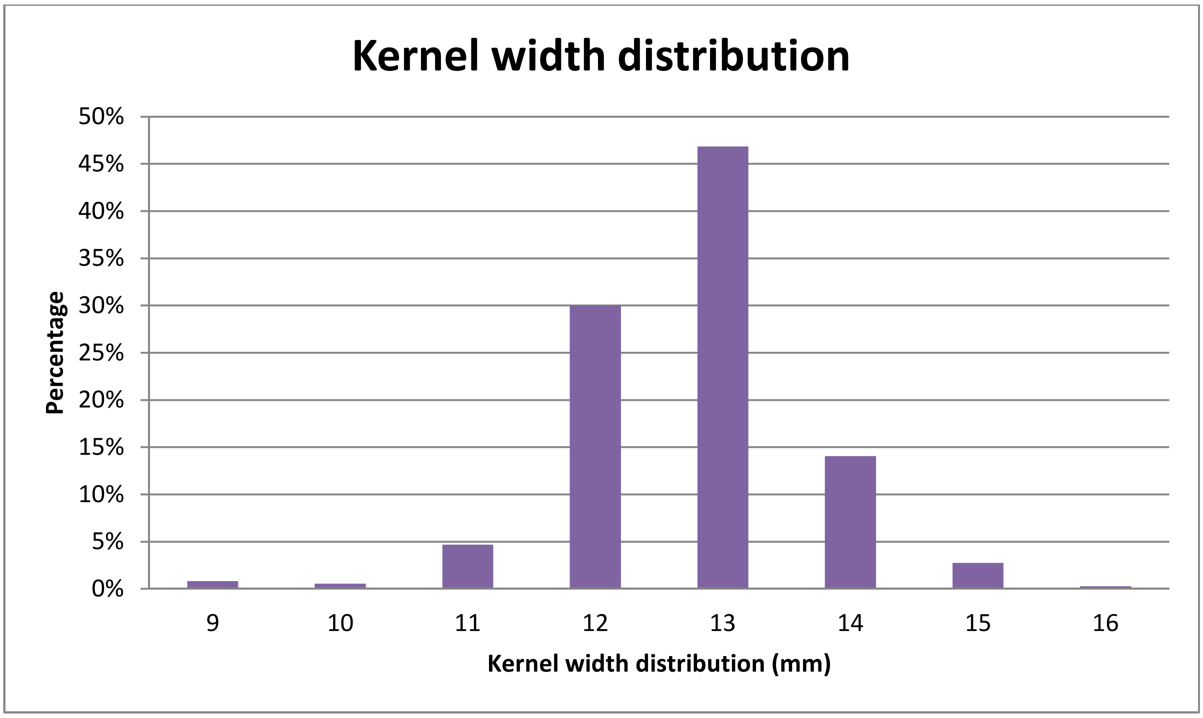


Figure 4.9 Width distribution of almond kernels.

The almond kernels were then measured using the slotted template and Figure 4.10 shows the resulting bell shaped distribution curve. The highest percentile of the kernels were 9 mm thick. All of the kernels fell within the range of 7 mm to 11 mm.

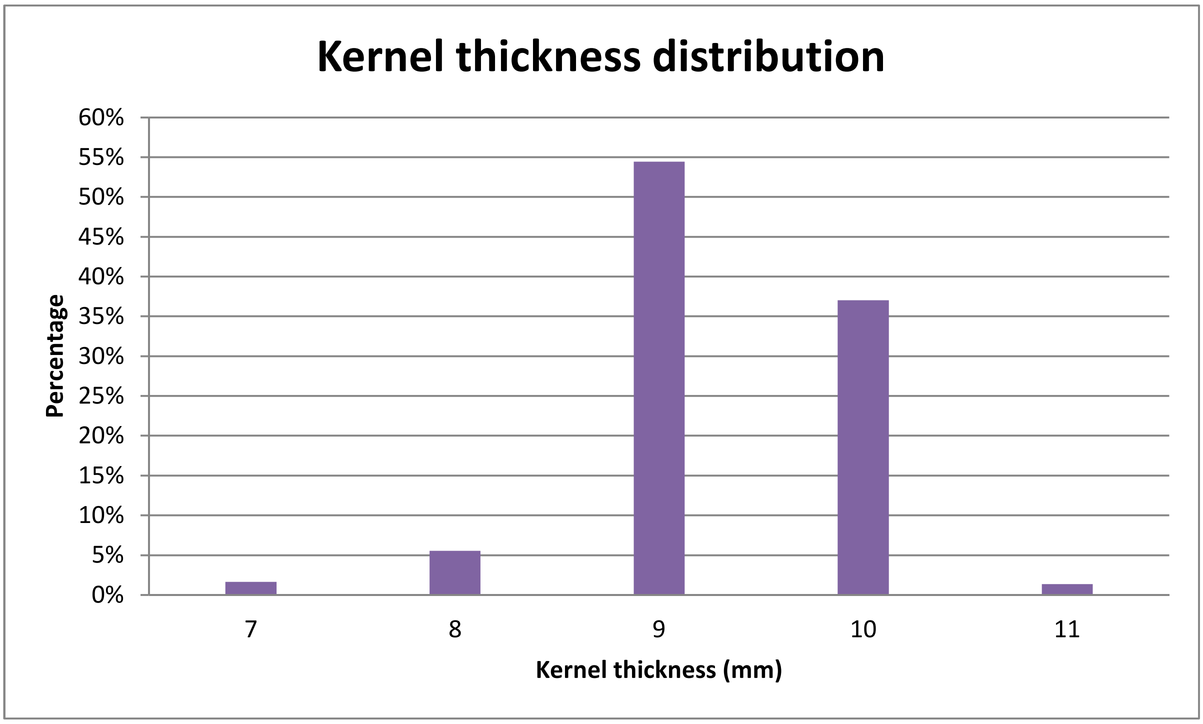


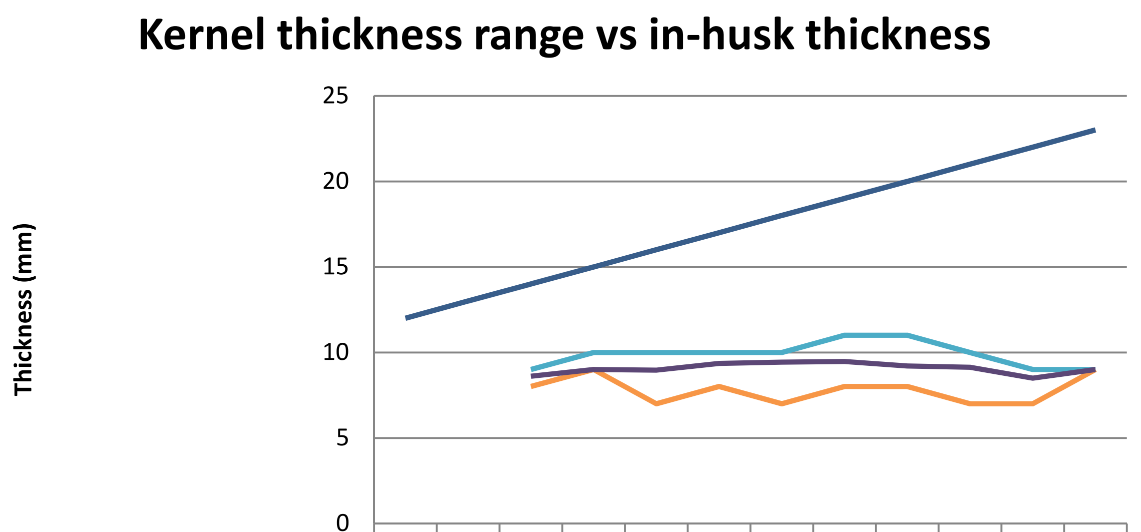
Figure 4.10 Thickness distribution of almond kernels measured using sizing template

4.5 Comparing in-husk, in-shell and kernel size

A study was carried out to find out if the kernel and in-shell size of the almonds increases proportionally with the in-husk size of the almond.

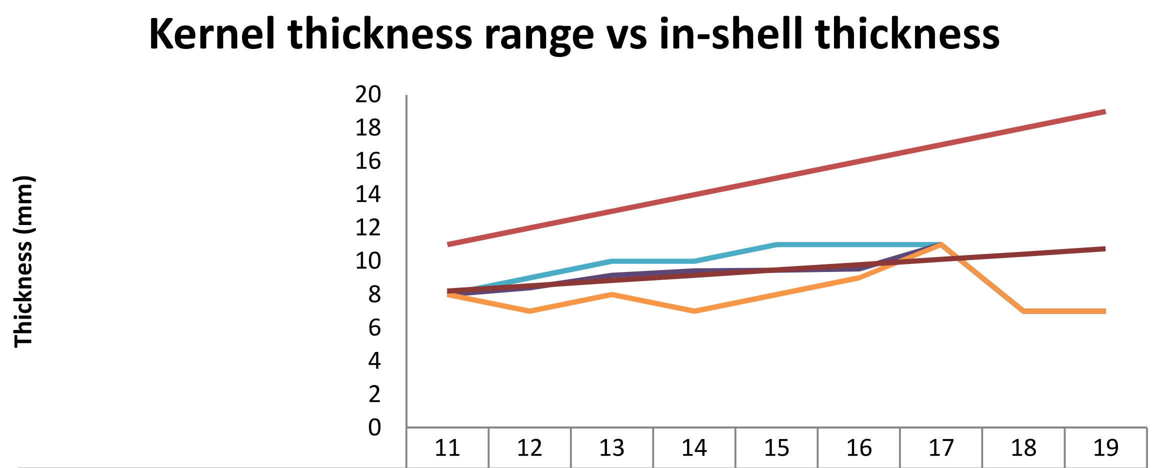
The method used was to measure the almond while it was still in its husk, remove the husk and measure the almond in its shell, and finally, remove the shell and measure the kernel inside. By following through on the whole process, data was obtained on the thickness ranges of each individual almond while in-husk, in-shell and kernel.

This study found that as the in-husk thickness of the almond increased, the in-shell thickness of the almond increased at a more gradual rate and the kernel size stayed within a narrow thickness range of 7 mm to 11mm as shown in figures 4.11 to 4.14. This means that even as the in-husk size of the almond increases, the kernel inside does not necessarily increase in thickness proportionally but stays within its narrow thickness range.



	12	13	14	15	16	17	18	19	20	21	22	23
Inhusk thickness	12	13	14	15	16	17	18	19	20	21	22	23
Max Kernel thickness	4		9	10	10	10	10	11	11	10	9	9
Min Kernel thickness	4		8	9	7	8	7	8	8	7	7	9
Mean thickness of Kernels	4.0		8.6	9.0	9.0	9.4	9.4	9.5	9.2	9.1	8.5	9.0
Quantity of Kernels	1	0	5	8	27	90	106	65	40	16	4	1

Figure 4.11 In-husk thickness of almond vs the thickness of the kernel inside.



	11	12	13	14	15	16	17	18	19
Inshell thickness	11	12	13	14	15	16	17	18	19
Max Kernel thickness	8	9	10	10	11	11	11	7	7
Kernel mean thickness	8.0	8.4	9.2	9.4	9.5	9.5	11.0	7.0	7.0
Min Kernel thickness	8	7	8	7	8	9	11	7	7
Trendline for Mean thickness of Kernals	8.2	8.5	8.8	9.2	9.5	9.8	10.1	10.4	10.7
Sample size	3	10	88	178	66	13	1	2	1

Figure 4.12 Kernel thickness with increase in almond in-shell thickness.

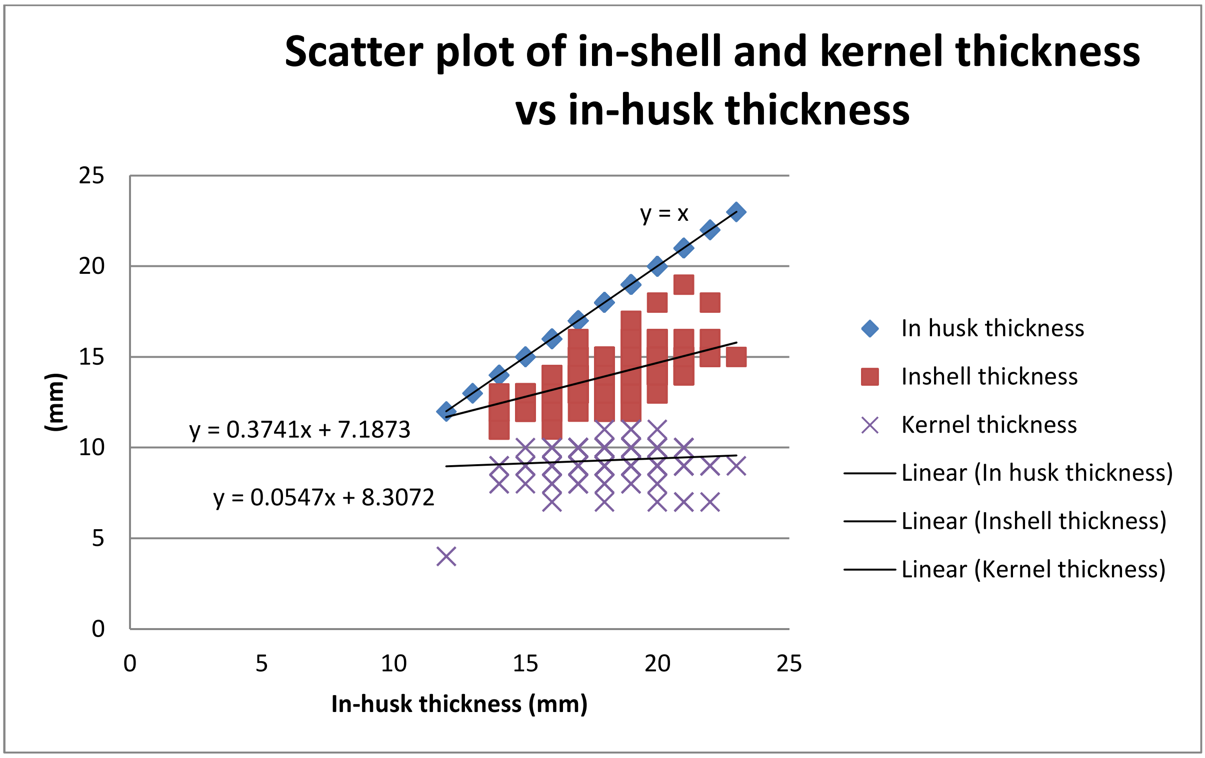
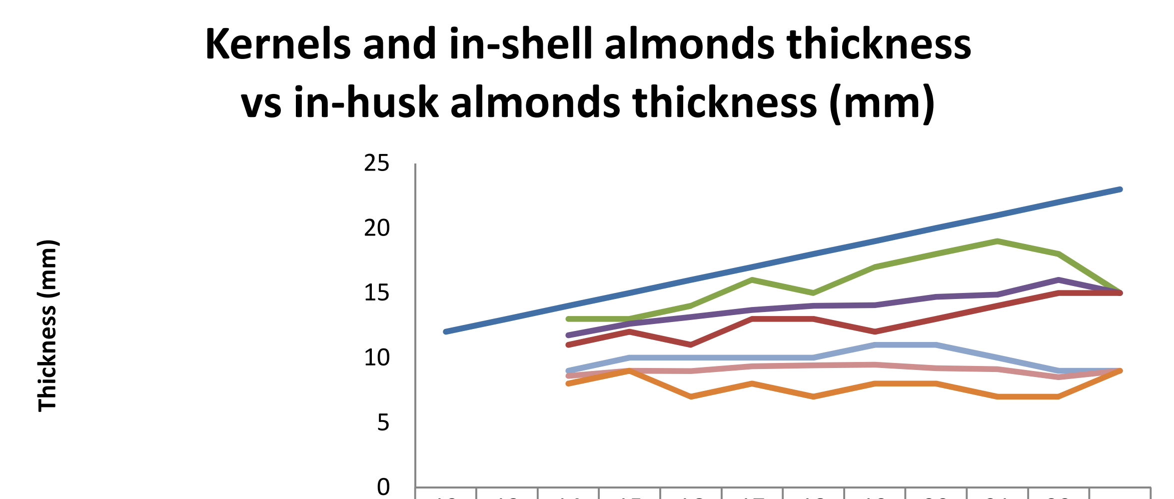


Figure 4.13 Scatter plot of the thickness of in-husk, in-shell and almond kernels.



	12	13	14	15	16	17	18	19	20	21	22	
Inhusk thickness	12	13	14	15	16	17	18	19	20	21	22	23
Max Inshell thickness			13	13	14	16	15	17	18	19	18	15
Mean thickness of Inshell Almonds			11.8	12.6	13.1	13.7	14.0	14.1	14.7	14.9	16.0	15.0
Min Inshell thickness			11	12	11	13	13	12	13	14	15	15
Max Kernel thickness	4		9	10	10	10	10	11	11	10	9	9
Mean thickness of Kernels	4.0		8.6	9.0	9.0	9.4	9.4	9.5	9.2	9.1	8.5	9.0
Min Kernel thickness	4		8	9	7	8	7	8	8	7	7	9
Quantity of Inshell Almonds	0		8	11	29	91	107	66	40	16	4	1

Figure 4.14 Results of measuring the almond thickness from in-husk, to in-shell through to kernel.

4.6 Finding the amount of clearance between the kernel and its shell

The size distribution of the almonds implied that there is a clearance between the kernel and its shell. In order to find data on the clearance between the kernel and its shell, the in-shell almond was measured, the kernel was then removed from its shell and the kernel and the thickness of its shell was measured. The in-shell almond and kernel were measured with the slotted template to find their thicknesses (as in Figure 4.3). The shell was measured with a point micrometer to find its thickness as illustrated in Figure 4.15.

Figure 4.15 Measuring the thickness of the almond shell with a point micrometer.

After data was acquired on the thickness of the in-shell almond, kernel and shell, the data was sorted. The results show that the clearance on one side between the kernel and its shell increases as the in-shell thickness of the almond increases as shown in Figure 4.16.

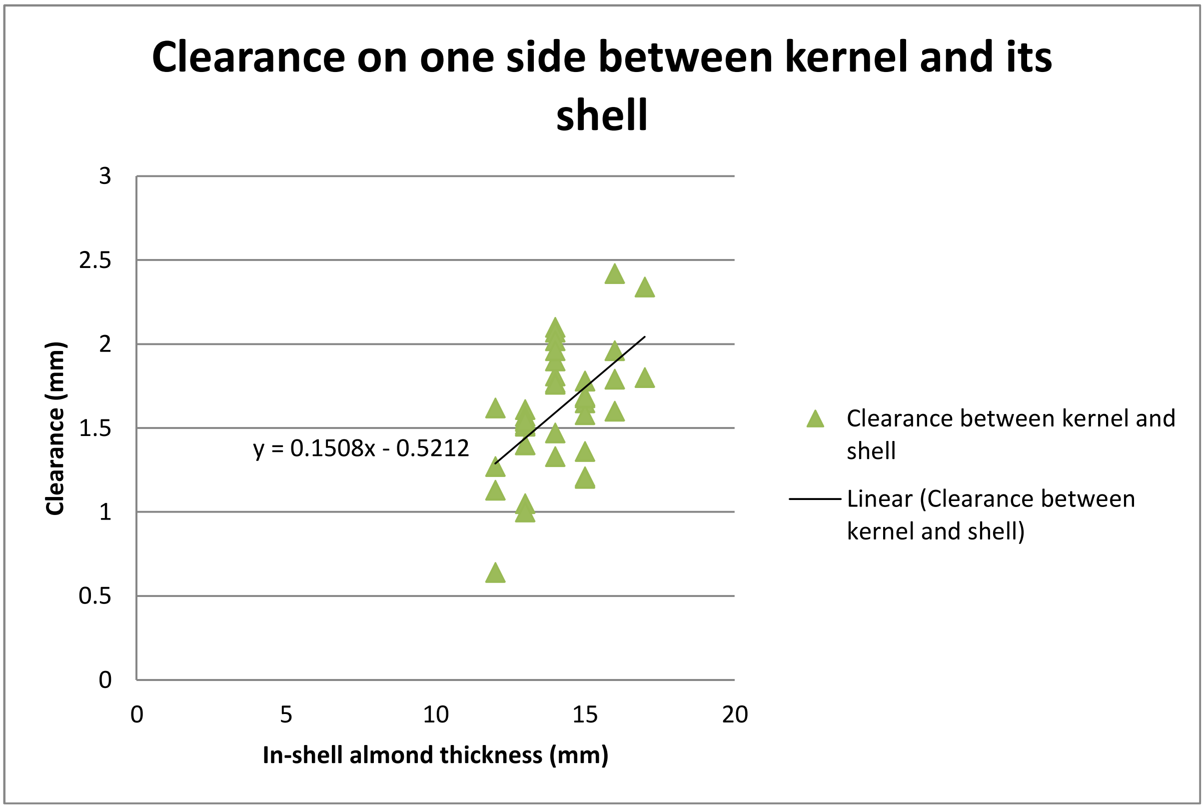


Figure 4.16 The clearance between the kernel and its shell increases as the in-shell thickness of the almond increases.

4.7 Results from size distribution study

The results of this study show that the width distribution of in-shell almonds and almond kernels has a broader range than the thickness distribution.

In-husk almonds measured had a width distribution range from 15 mm to 28 mm and a thickness distribution range of 12 to 23 mm. This is a 13 mm difference from the in-husk almond with the smallest to the largest width. There is an 11 mm difference from the in-husk almond with the smallest thickness to the largest thickness.

In-shell almonds measured had a width distribution range from 14 mm to 23 mm and a thickness distribution of 11 mm to 19 mm. This is a 9 mm difference from the in-shell almond with the smallest to the largest width. There is an 8 mm difference from the in-shell almond with the smallest thickness to the largest thickness.

Almond kernels measured had a width distribution range from 9 mm to 16 mm and a thickness distribution of 7 mm to 11 mm. This is a 7 mm difference from the in-shell almond with the smallest to the largest width. There is a 4 mm difference from the in-shell almond with the smallest thickness to the largest thickness.

There are in-husk almonds, in-shell almonds and almond kernels that have the same width sizes of between 14 mm to 16 mm as shown in Figure 4.17. If a round screen is used to collect almond kernels between the range of 14 mm to 16 mm, there will some in-husk and in-shell almonds collected along with the kernels.

There are in-shell almonds and almond kernels that have the same width of 11 mm as shown in Figure 4.18. Therefore, if a slotted screen is used to collect almond kernels there will be some in-shell almonds collected along with the kernels only for an 11 mm sized screen .

These results suggest that a smaller range of slotted screen sizes will be needed to achieve similar or better results to the round screens presently being used in the almond industry.

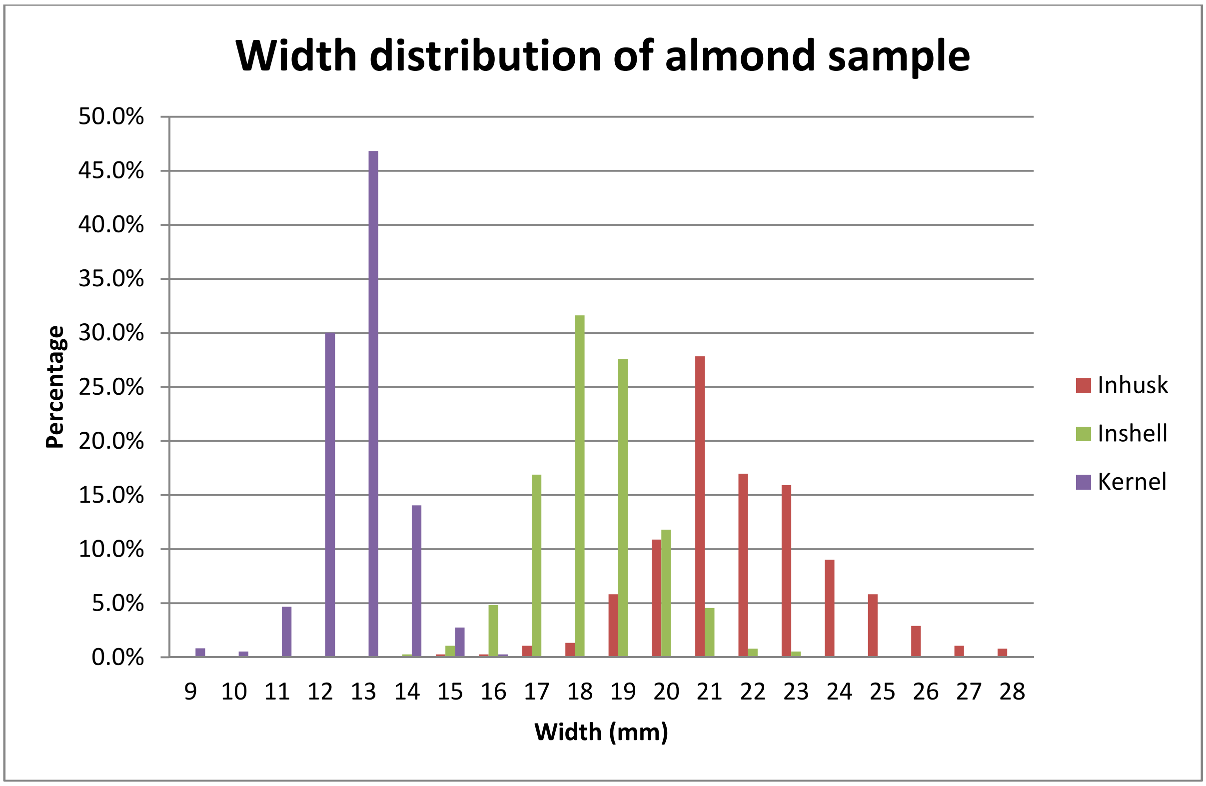


Figure 4.17 Width distribution of almond sample.

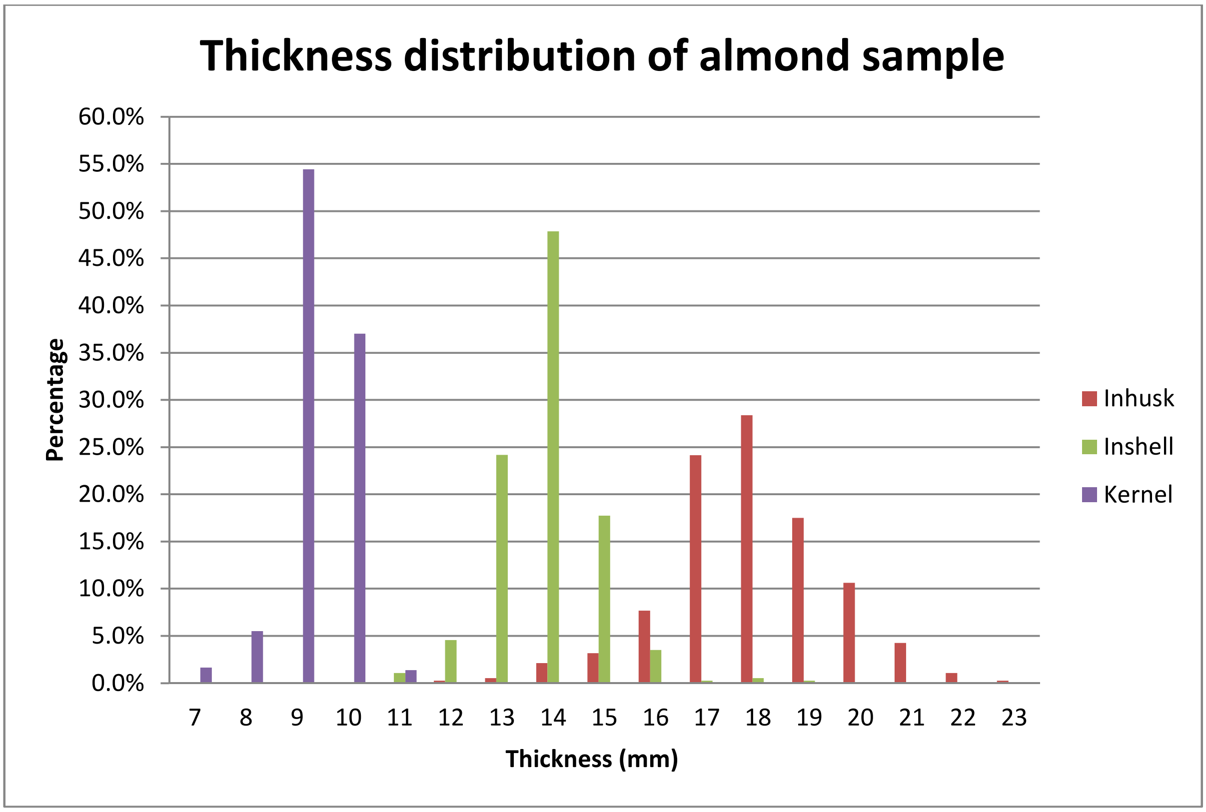


Figure 4.18 Thickness distribution of almond sample.

The comparison of in-husk, in-shell and kernel thicknesses shows that the kernel thickness does not increase proportionally to the almond's in-husk or in-shell thickness. As the thickness of the in-husk and in-shell increases, the almond kernel stays within the thickness range of 9 mm to 11 mm. The study also showed that there is a clearance between the kernel and its shell and this clearance increases with the size of the in-shell almond. This clearance starts from a minimum of 0.64 mm on one side and increases to a maximum of 2.42 mm on one side for the sample.

5. Finding the effects of impact energy/velocity and shear rolls hulling and shelling on almond damage

This part of the study produces a measured impact against an almond and obtains data on the impact energy required to create damage in almonds. The study also measured the velocities required to damage almonds. The aim of these tests is to find the impact energy and velocity that produces mechanical damage in almond kernels.

The final part of this study uses shear rolls to perform the hulling and shelling process and examines the damage caused to the almond kernels.

5.1 Damage sustained by almond from impact energy

The pendulum impact tester shown in Figure 5.1 was used to produce an impact against an almond being tested. There is an angular scale attached to the pendulum impact tester; the angle indicated on the scale corresponds to an increase in the height and potential energy of the anvil. The anvil of the pendulum impact tester was raised to specified angles before being released, so that it swings and attains kinetic energy before impacting the almond thereby producing the stated impact energy.

Figure 5.1 The pendulum impact tester used to create an impact against the almonds.

5.1.1 Damage sustained by almond from impact by a steel anvil

The first test produced an impact against an almond with the steel anvil of the pendulum impact tester. The anvil of the pendulum impact tester was raised to specified angles before being released, producing the impact energy shown as in Table 5.1.

Table 5.1 Categories and percentage of damage sustained by Nonpareil almond hit by a steel anvil

Angle (degrees)	Impact Energy (mJ)	Dent	Broken Skin	Chipped Almond	Cracked	Broken	Sample size
5	2.38	0%	0%	0%	0%	0%	30
10	11.5	0%	0%	0%	0%	0%	30
15	26.2	0%	0%	0%	0%	0%	30
20	46.7	0%	3%	3%	0%	0%	30
25	73	0%	0%	0%	10%	0%	30
30	105	0%	0%	0%	10%	0%	30
35	142.6	7%	7%	3%	13%	0%	30
36	150.9	0%	0%	0%	73%	0%	15
37	159.4	0%	0%	0%	80%	0%	15
38	168.1	0%	0%	0%	73%	0%	15
40	186.1	0%	5%	0%	60%	25%	20
45	235.3	0%	0%	0%	33%	67%	15
50	290.1	0%	0%	0%	27%	73%	15
55	350.7	0%	0%	0%	13%	87%	15
60	417.1	0%	0%	0%	0%	100%	15

The impact energy and the percentage of almonds damaged are shown in Figure 5.2. The first signs of damage appear at 46.7mJ of impact energy. There is a sharp increase in the number of cracked almonds at 150mJ of impact energy. This could be the critical point for damaging the almonds. At 186mJ of energy, the almonds that were tested start to break. At 235mJ of energy, 100% of the almonds were damaged. The test showed that as the level of the impact energy increases, the damage to the almonds becomes more extensive with more almonds being broken rather than chipped. When the energy level reaches 417mJ, 100% of the almonds tested were broken.

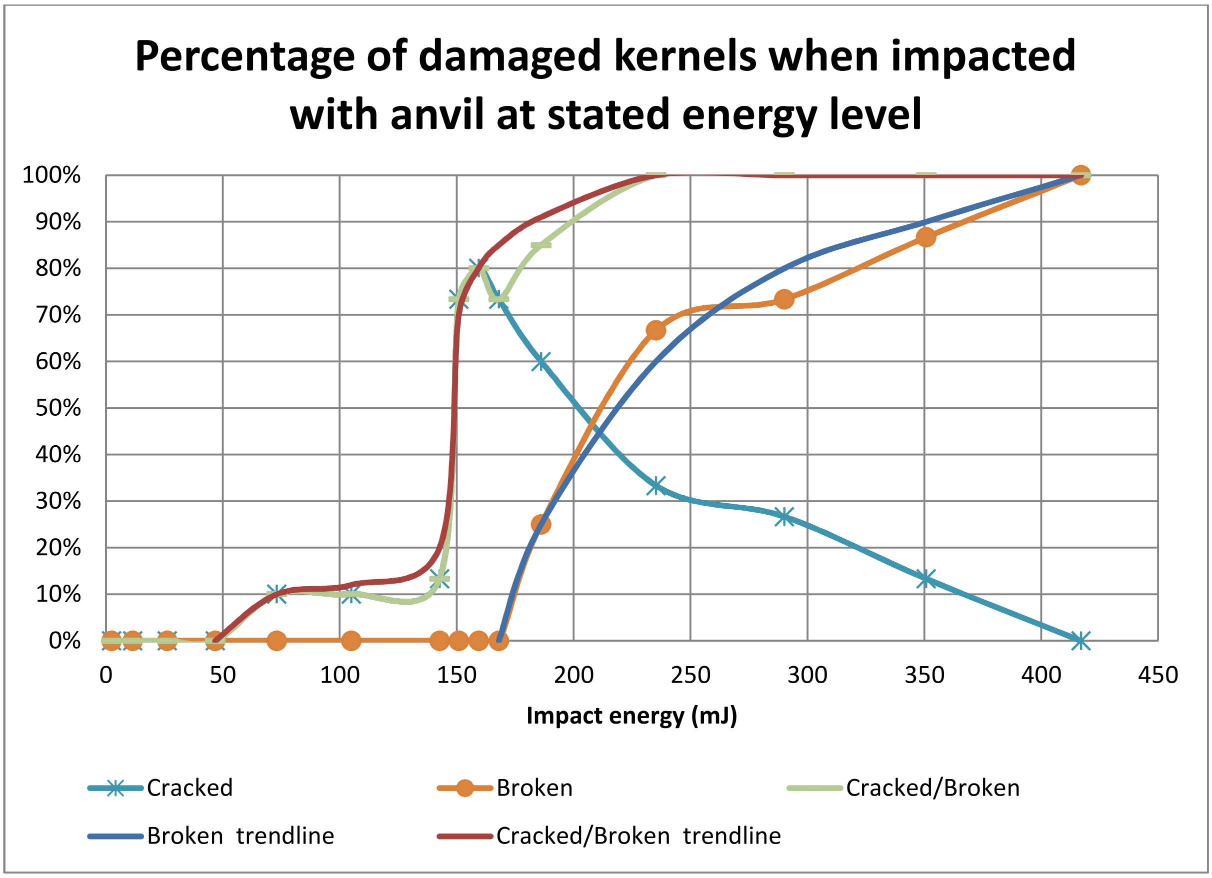


Figure 5.2 Percentage of kernels cracked or broken when hit by a steel anvil.

Figure 5.3 shows an almond kernel that was broken after being struck by the anvil of the pendulum impact tester. Figure 5.5 shows an almond kernel that was cracked after being struck by the anvil of the pendulum impact tester.

It was found that sometimes, the cracks in the kernels were not visible. The impact from the anvil caused damage to the inside of the almond kernel but the kernel skin showed no visible signs of damage from the outside. The skin remained intact and cracks could not be seen. However, when gentle pressure was applied, the almond immediately split, proving that it was not structurally sound but in fact had internal cracks. Such an almond kernel would be classified as cracked. All of the almond kernels that did not show signs of damage after impact were checked by applying gentle pressure to ascertain if there were any internal cracks in them. Figure 5.4 shows an example of the situation described.

Figure 5.3 Almond kernel that was broken by the anvil of the pendulum impact tester.

Figure 5.4 Almond kernel with no visible damage (left) shows cracks after gentle pressure was applied (right).

Figure 5.5 Almond with obvious crack after impact by steel anvil.

5.1.2 Damage sustained by almond from impact by an almond point

The next test produced an impact against an almond using the point of another almond. An almond was bonded to the anvil of the pendulum impact tester. The pointed tip of the almond was directed toward the other almond for the test to simulate the collision of an almond point at velocity against another almond. The set-up used in the experiment is shown in Figure 5.6.

Figure 5.6 Pendulum impact tester with an almond point.

The result of the test shows that signs of impact are visible from 7.13 mJ of energy and above. When the impact energy was increased to 11.5 mJ, the pointed almond tip started breaking the skin and chipping the almond kernel that was hit. As the amount of impact energy increased, the percentage of damage also increased as shown in Table 5.2 and Figure 5.7.

Table 5.2 Tabulated results of the test with almonds impacted by an almond point.

Angle (degrees)	Impact Energy (mJ)	Signs of impact	Broken Skin	Chipped Almond	Sample size
5	2.37	0%	0%	0%	50
8	7.13	52%	0%	0%	50
10	11.5		48%	12%	50
15	26.2		78%	34%	50
20	46.8		92%	72%	50

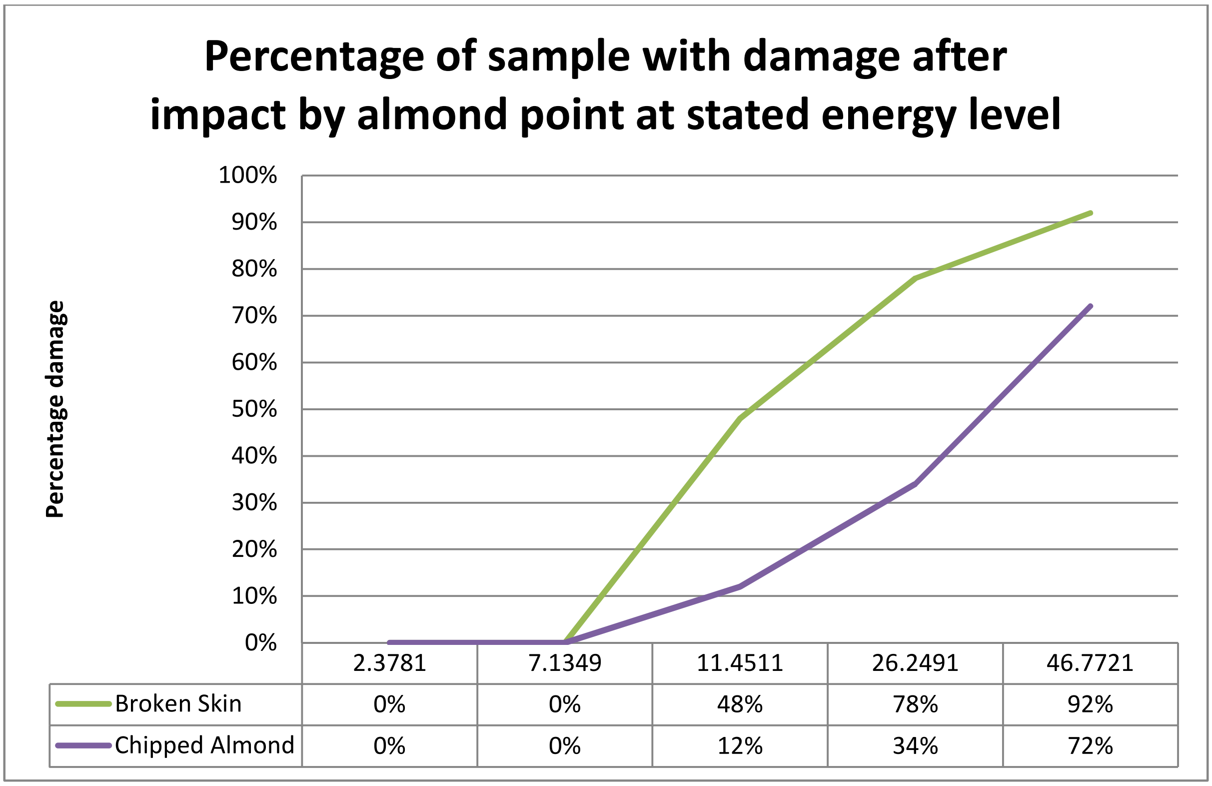


Figure 5.7 Percentage of damaged almonds increase with increase in impact energy.

5.1.3 Damage sustained by an almond with an offset from impact by an almond point

The previous impact experiment was conducted with the impact against the center of the almond kernel. This meant that the impact was directed at the thickest part of the kernel. The same experiment was attempted with the almond kernel offset so that the impact was against the taper of the almond kernel. This would result in an impact that glances off the surface. The reason for this test is to see if a glancing blow would result in damage at lower energy levels. The hypothesis is that if the impact is at an angle, the resultant force would be directed at the surface of the almond kernel rather than its internal structure. This may result in surface damage such as chips and scratches at lower impact energies.

The results of the test are shown in Table 5.3 and Figure 5.8. The first signs of damage start to occur at 7.1 mJ of impact energy. An impact at this energy level results in 50% of almond kernels with a break in the skin and 40% of the kernels being chipped. For these results, a chipped almond kernel is also considered in the tally for the percentage with broken skin as the skin has to be broken before the almond kernel is chipped.

Table 5.3 Damage to almond caused by an offset impact

Angle (degrees)	Impact Energy (mJ)	% Broke Skin	% Chipped
7	5.3	0%	0%
8	7.1	50%	40%
9	9.2	50%	30%
10	11.5	70%	50%

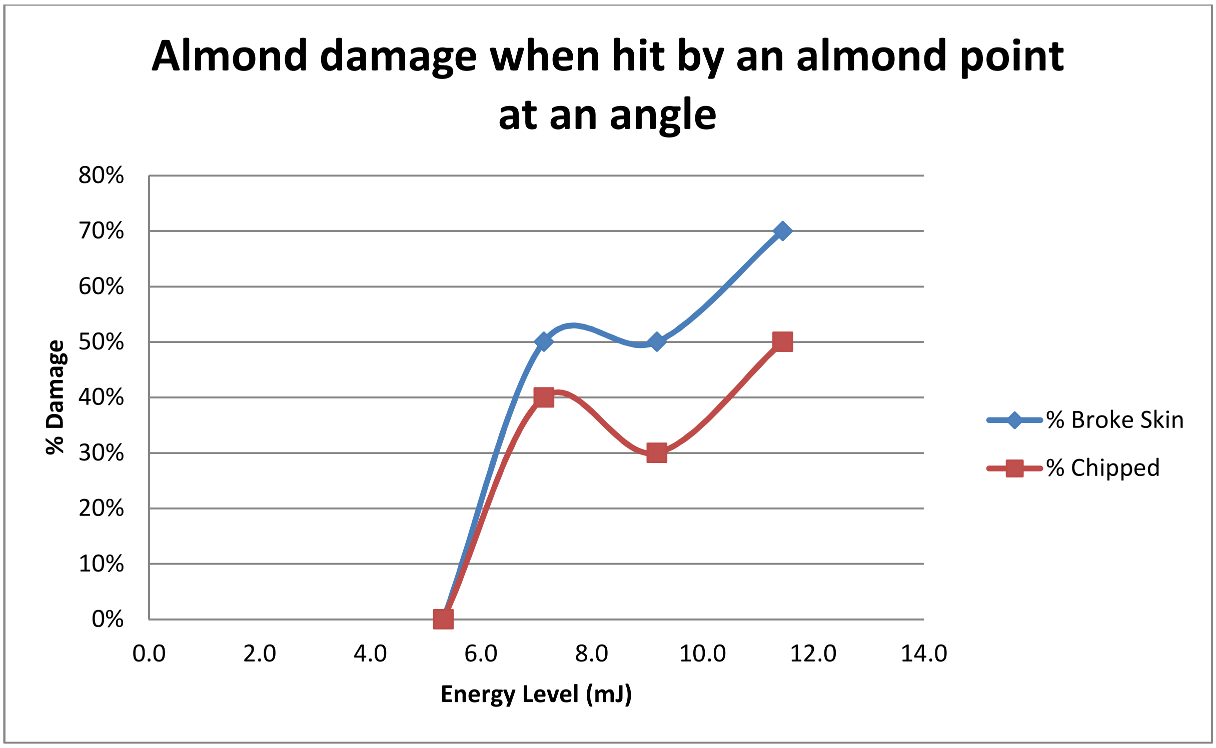


Figure 5.8 Graph showing the percentage of almonds with damage after being hit by an almond point at an offset with the stated energy level.

The results are quite consistent with expectations with the amount of damage increasing as the impact energy increases. The summarized results in Table 5.3 show that there are signs of damage from 7.1mJ onwards. When the results of Table 5.3 are compared with the results in Table 6.2, some similarities in impact energy required for damage was found. When the impact was at a right angle and absorbed by the thickest part of the almond kernel, there were signs of damage (an indentation) but no break in the skin at 7.1mJ of energy. When the test was carried out on almond kernels positioned at an offset allowing the impact to glance off the surface, 7.1mJ of energy was sufficient to cause a break in the skin in 50% of the sample. Furthermore, a 7.1mJ impact at an offset was also adequate to chip the almond kernel in 40% of the sample. This proves that less impact energy is required to cause visible damage to almond kernels if the impact is at an angle that allows the force to be directed along the surface of the almond kernel.

There was a dip in the quantity of damage at the energy level of 9.2 mJ. This could be the result of experimental errors as the test was done with a sample size of just 10 almonds at each energy level. If the test is carried out with a larger sample size, the accuracy of the results will increase.

5.2 Effects of velocity on almond damage

The next test was carried out to find the effects that velocity has on almond kernel damage. The rotary arm impact tester shown in Figure 5.9 was used to carry out the test. The rotating arm of the rotary arm impact tester can be controlled to rotate at the desired rotational velocity. This produces a controlled velocity at the end of the arm. Almond kernels are dropped into the tester through a pipe and the end of the rotating arm will hit the kernel at the controlled velocity.

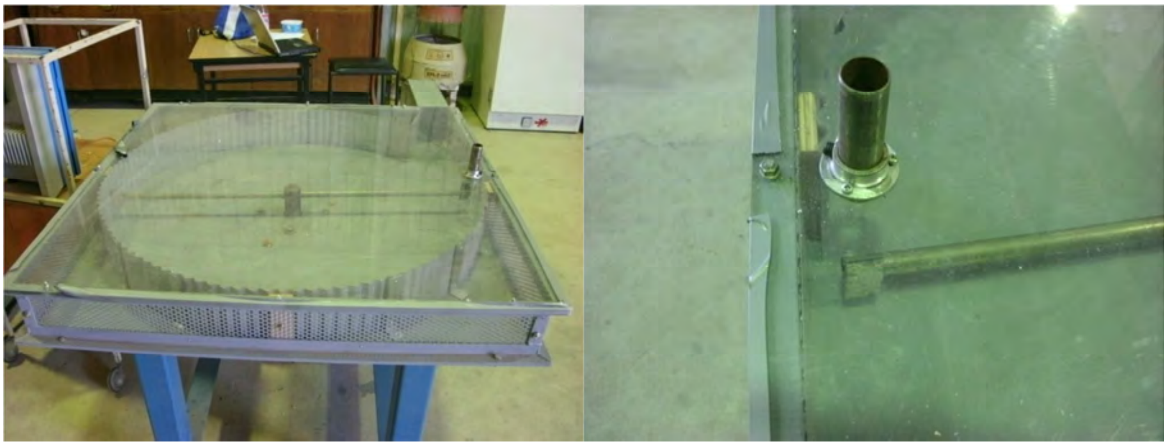


Figure 5.9 Rotary arm impact tester (left); entry point for the kernels and the end of the rotating arm (right).

The results of the test are shown in Table 5.4 and Figure 5.10. At 5.52 m/s, only 1 out of 10 almond kernels is chipped. The amount of damaged kernels and the extent of the damage increases as the velocity increases. At 11 m/s, 1 out of 30 kernels is broken into pieces, and at 13.8 m/s 7 out of 30 kernels are broken into pieces. At 24.8 m/s, all of the tested almond kernels are broken into pieces.

Table 5.4 Velocity test effect on almond kernel damage results.

Arm velocity (m/s)	Broken into pieces	Broken	Chipped	No damage	Sample size
5.5	0	0	1	9	10
8.3	0	0	11	19	30
11.0	1	2	12	15	30
13.8	7	9	11	3	30
16.5	12	8	7	3	30
19.3	7	3	0	0	10
22.1	7	3	0	0	10
24.8	10	0	0	0	10
27.6	10	0	0	0	10

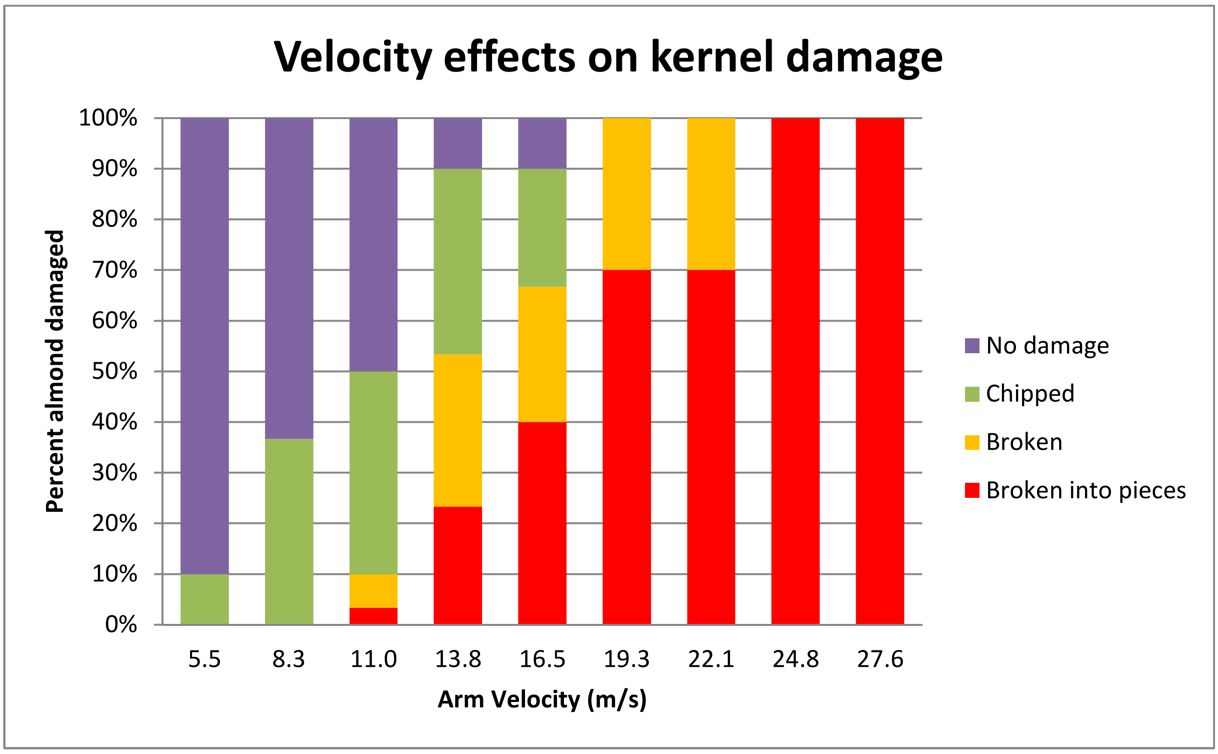


Figure 5.10 Velocity effects on kernel damage.

The damage to the kernels has been categorized into chipped, broken and broken into pieces. Figures 5.11 to 5.13 define the damage inflicted on the almonds.

Figure 5.11 Almond kernel Chipped at 5.5 m/s velocity.

Figure 5.12 Almond kernels broken at 19m/s.

Figure 5.13 Almond kernels broken into pieces at 13 m/s (left) and 24.8 m/s

5.3 Results of impact energy/velocity test compared with the machine settings used by Costa Almonds

The hulling and shelling process uses a pair of rollers and a roller and roller driven belt to hull and shell the almonds. The tangential velocity of each roller was calculated based on the machine settings data provided by Costa Almonds. The tangential velocity of the rollers gives an indication of the possible exit velocity of the almonds. The roller tangential velocity of the various stages as well as the kinetic energy calculated is shown in Formula 5.1 and 5.2.

The exit kinetic energy is worked out based on the formula of:

$$\textbf{Kinetic energy, } KE = \frac{1}{2}mv^2 \qquad \textbf{(5.1)}$$

Where:

m = the mass of the almond
v = almond's assumed velocity

The actual exit velocity of the almond is unknown, The calculations were carried out using the tangential velocity of both rollers on the assumption that the almond's exit velocity is equal to the roller's tangential velocity. The mass of the almond is another variable in the equation, thus, the mean mass of the almond was used in the calculations.

The roller tangential velocity is worked out based on the formula of:

$$\textbf{Velocity, } V = \frac{N\pi d}{60} \qquad \textbf{(5.2)}$$

Where:

N = roller speed in RPM
d = diameter of the roller

The hulling and shelling machines at each stage have a pair of hard shell steel rollers and a rubber lined roller and belt pair. Figure 5.14 shows a diagrammatical representation of the hulling and shelling stage with the hard shell steel rollers labeled as ‘A’ and ‘B’ and the rubber lined roller and belt pair labeled as ‘C’ and ‘D’ accordingly. There are two directional changes in the movement of almonds. These are labeled as point ‘a’ where the almonds will be projected against the belt ‘D’ and point ‘b’ where the almonds will be projected against a guard before dropping onto a screen.

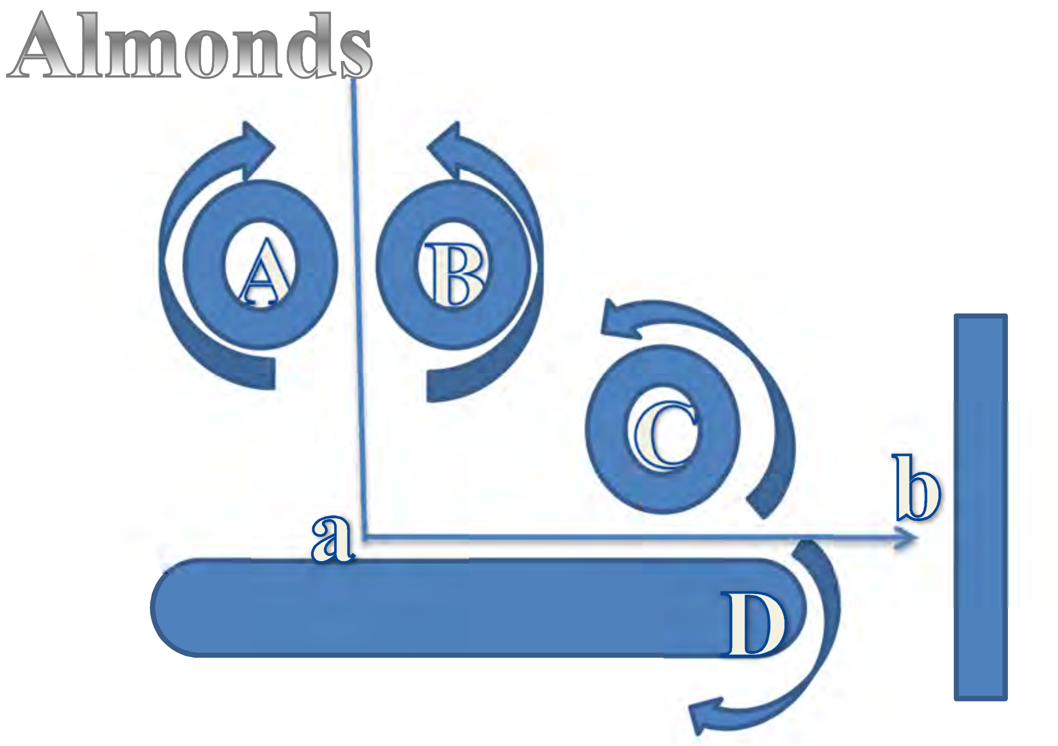


Figure 5.14 Diagrammatical representation of a stage of the hulling and shelling process.

The calculations for the kinetic energy of the almond kernels that are flung out from the rollers and belt with the mentioned assumptions are presented in Table 5.5.

Table 5.5 Tangential velocity of the various stages and the kinetic energy calculated for each stage of Costa Almonds' hulling and shelling process.

Calculations based on mean almond mass = 1.21 grams				
Cracker stage	Roller 'A' speed (RPM)	Diameter of hard shell roller 'A' (m)	Roller 'A' Tangential velocity (m/s)	Almond Average exit kinetic energy from 'A' (mJ)
1	288	0.21589	3.26	6.40
2	287	0.21589	3.24	6.36
3	287	0.21589	3.24	6.36
4	287	0.21589	3.24	6.36
5a	235	0.21589	2.66	4.26
5b	N/A	N/A	N/A	N/A
6	288	0.21589	3.26	6.40
Cracker stage	Roller 'B' speed (RPM)	Diameter of hard shell roller 'B' (m)	Roller 'B' Tangential velocity (m/s)	Almond Average exit kinetic energy from 'B' (mJ)
1	288	0.21589	3.26	6.40
2	287	0.21589	3.24	6.36
3	287	0.21589	3.24	6.36
4	287	0.21589	3.24	6.36
5a	235	0.21589	2.66	4.26
5b	N/A	N/A	N/A	N/A
6	288	0.21589	3.26	6.40
Cracker stage	Roller 'C' speed (RPM)	Diameter of rubber roller 'C' (m)	Roller 'C' Tangential velocity (m/s)	Almond Average exit kinetic energy from 'C' (mJ)
1	300	0.2667	4.19	10.6
2	310	0.21589	3.50	7.42
3	327	0.19685	3.37	6.86
4	300	0.21589	3.39	6.95
5a	306	0.24129	3.87	9.03
5b	306	0.22225	3.56	7.66
6	291	0.2667	4.06	9.98
Cracker stage	Roller and belt 'D' speed (RPM)	Diameter of roller and belt 'D' (m)	Roller and belt 'D' Tangential velocity (m/s)	Almond Average exit kinetic energy from 'D' (mJ)
1	150	0.22	1.73	1.80
2	150	0.22	1.73	1.80
3	150	0.22	1.73	1.80
4	150	0.22	1.73	1.80
5a	150	0.17	1.34	1.08
5b	150	0.17	1.34	1.08
6	72	0.22	0.83	0.42

Based on the results of Table 5.5, the possible exit velocities of the almonds ranges from a low of 0.83 m/s to a maximum of 4.19 m/s. The possible impact energy of the almonds ranges from a low of 0.42 mJ to 10.6 mJ of energy.

When the results are compared to the higher range of machine settings provided by Costa Almonds, rollers 'C' are running at approximately 300 RPM as shown in Table 5.5. This would result in a possible mean almond exit velocity of between 3.5 m/s to 4.19 m/s and energy levels of between 6.86 to 10.6 mJ of energy.

The impact test using an almond point directed at an offset almond kernel chipped 40% of the almond kernels tested at 7.1 mJ of energy. This falls within the range of the energy levels produced by rollers 'C'.

The velocity test showed that 1 out of 10 almonds will be chipped at 5.5 m/s and 11 out of 30 almonds will be chipped at 8.2 m/s. Both of these values are beyond the higher velocity range of the machine settings used by Costa Almonds.

When the results are compared to the lower range of machine settings provided by Costa Almonds, roller and belt 'D' is running from 72 RPM to 150 RPM as shown in Table 5.5. This would result in a possible mean almond exit velocity of between 0.83 m/s to 1.73 m/s and energy levels of between 0.42 mJ to 1.8 mJ of energy. This is much lower than the velocities and energy levels required to damage almonds in the test results.

The energy levels of the almonds being processed by the machine can be related to fall height using Equation 5.3.

Potential Energy, $PE = mgh$ **(5.3)**

Where:

m = the mass of the almond
g = gravitational acceleration
h = fall height

The results of converting the relevant energy levels to a corresponding fall height are shown in Table 5.6.

Table 5.6 Corresponding fall heights of the possible almonds exit energy from the rollers and belts.

Gravitational acceleration (m/s)	9.81	Almond mass (grams)	1.21
Almond Average exit kinetic energy from roller 'C' (mJ)	Fall height (m)	Almond Average exit kinetic energy from roller and belt 'D' (mJ)	Fall height (m)
10.6	0.893	1.8	0.152
7.42	0.625	1.8	0.152
6.86	0.578	1.8	0.152
6.95	0.586	1.8	0.152
9.03	0.761	1.08	0.091
7.66	0.645	1.08	0.091
9.98	0.841	0.42	0.035
Almond Average exit kinetic energy from roller 'A' (mJ)	Fall height (m)	Almond Average exit kinetic energy from 'B' (mJ)	Fall height (m)
6.4	0.539	6.4	0.539
6.36	0.536	6.36	0.536
6.36	0.536	6.36	0.536
6.36	0.536	6.36	0.536
4.26	0.359	4.26	0.359
N/A	N/A	N/A	N/A
6.4	0.539	6.4	0.539

The range of possible almond exit energy from the rollers corresponds to a fall height ranging from 0.035 m to 0.893 m. This is a fall height of less than 1 meter.

The corresponding fall heights for some of the values in the pendulum impact tester's anvil against almond kernel tests were calculated and are shown in Table 5.7. The results show that the almond kernels have to be dropped from a height of at least 3.9 m before 3% of the kernels are chipped.

Table 5.7 Corresponding fall height from anvil against almond impact test.

Impact Energy (mJ)	Chipped kernel	Cracked kernel	Fall Height (m)
46.7	3%	0%	3.934
73	0%	10%	6.150
105	0%	10%	8.846
142.6	3%	13%	12.013
150.9	0%	73%	12.713

The results from the tests have proved to be inconclusive as to the source of damage. The changes in the directional flow of the almonds at point ‘a’ and ‘b’ are potential areas for impact damage from an almond point projected against another almond to occur. However, due to the fact that the actual almond exit velocity from the rollers and belt is unknown, this study is unable to state conclusively if the velocity or impact at these points is a direct cause of mechanical damage in almond kernels.

5.4 Finding the effects of shear rolls in hulling and shelling almonds

This part of the study aims to find out the effects of using shear rolls to hull and shell almonds. The study was carried out using a shear rolls machine as shown in Figure 5.15. The machine has a pair of shear rolls that are controlled by separate motors. The motor speeds can be adjusted to provide the desired differential roller speed. The clearance between the shear rolls can also be adjusted. The almonds were dropped into the hopper on top of the machine; they would then fall through the pair of shear rolls and down the bottom into the bin.

Figure 5.15 Shear roll tester (left). Adjusting the clearance between the shear rolls (right).

5.4.1 Testing the effects of shear rolls on individual almonds

For this experiment, the speed of the first roller was set at 200 RPM and the second roller at 300 RPM to get a speed ratio of 1.5 (similar to the settings at Costa Almonds). The almonds were introduced into the shear roll tester individually in order to see the effect the shear rolls had on the almond. The process was then carried out for a total of 45 almonds. The shear rolls clearance was then reduced before the whole process was carried out again. The shear rollers clearance was initially set at 18.7 mm, and then reduced to 15.1 mm, 12.4 mm, 11 mm, 9.85 mm and 9.05 mm. This process resulted in all of the kernels being removed from their husks and shells. The result of the study is shown in Table 5.8.

For the purposes of this study, a hulled almond is an almond that has had its husk fully removed; a cracked shell almond is an almond that has its shell cracked and the kernel is still inside the shell. The results show that not all of the almonds are hulled or have their shells cracked before the kernels are removed. Only 19 out of 45 almonds had their husks removed and 24 out of 45 almonds had their shells cracked; the rest of the almonds had their husks and shells removed in one operation as shown in Figure 5.16.

Table 5.8 Results from the shear rolls test.

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	
Shear rolls Clearance (mm)	18.7	15.1	12.4	11	9.85	9.05	Total
No. of Almonds Hulled	9	9	1	0	0	0	19
No. of Almonds with Cracked Shell	1	2	12	7	2	0	24
No. of Undamaged Kernels	0	1	5	10	10	3	29
No. of Chipped Kernels	0	0	2	0	2	1	5
No. of Broken Kernels	0	0	2	4	5	0	11
Percentage of almonds hulled and shelled at each clearance setting							
Shear rolls Clearance (mm)	18.7	15.1	12.4	11	9.85	9.05	Total
Hulled	20%	20%	2%	0%	0%	0%	42%
Cracked Shell	2%	4%	27%	16%	4%	0%	53%
Loose Kernels	0%	2%	20%	31%	38%	9%	100%

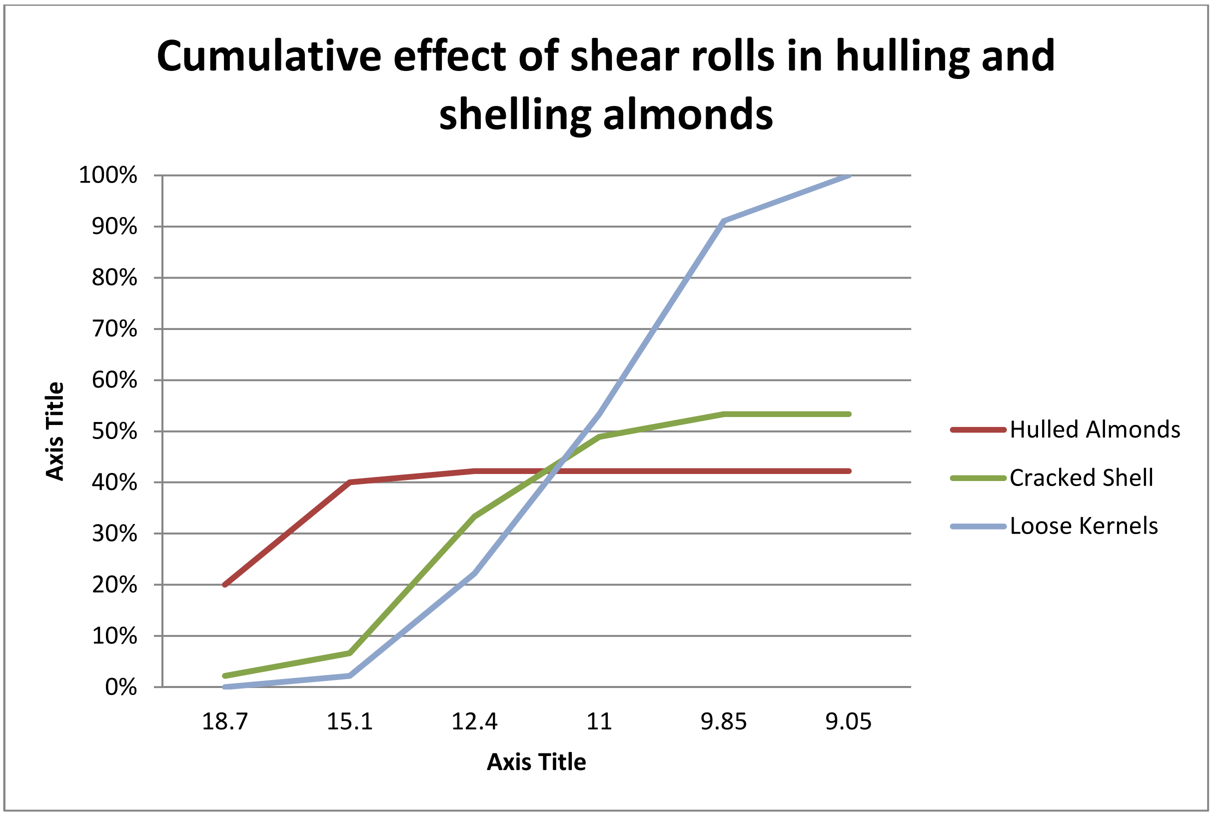


Figure 5.16 Cumulative effect of shear rolls on the almonds.

The mechanical damage caused to the kernels by hulling and shelling the almonds using shear rolls is shown in Table 5.9. There was 64% undamaged kernels, 11% chipped kernels and 24% broken kernels at the end of the whole experiment. The highest percentage of loose kernels was obtained at 11 mm and 9.85 mm shear rolls clearance as shown in Figure 5.17. The highest percentage of broken kernels was also obtained at the 11 mm and 9.85 mm shear rolls clearance setting.

Table 5.9 Mechanical damage caused by shear rolls.

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	
Clearance (mm)	18.7	15.1	12.4	11	9.85	9.05	Total
Kernel Undamaged	0%	2%	11%	22%	22%	7%	64%
Kernel Chipped	0%	0%	4%	0%	4%	2%	11%
Kernel Broken	0%	0%	4%	9%	11%	0%	24%
Loose Kernels	0%	2%	20%	31%	38%	9%	100%

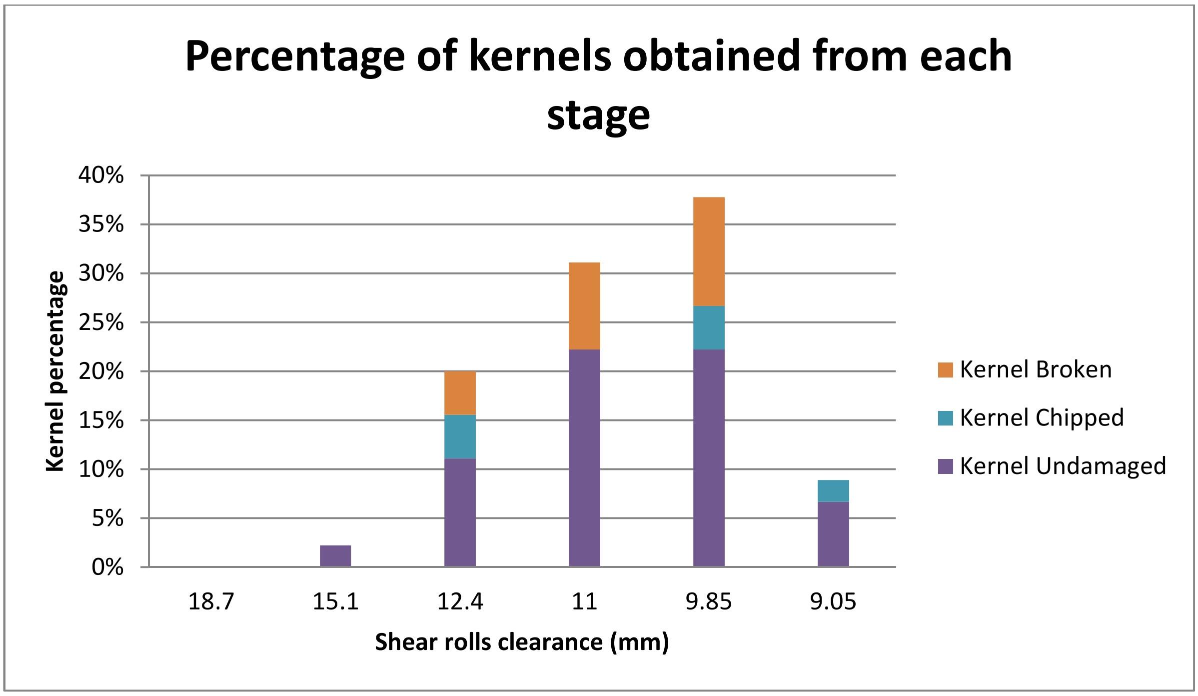


Figure 5.17 Percentage of kernels obtained at each shear rolls clearance setting.

The high percentage of broken kernels at the 11 mm and 9.85 mm shear rolls clearance setting could possibly be because the reduction in clearance by 1.15 mm was too drastic. Further tests could be carried out with the clearance being reduced more gradually in order to find possible ideal machine settings.

5.4.2 Finding a correlation between almond dimension and shear rolls clearance for almonds that have been worked on

The almond widths, shear rolls clearance and amount of almonds that had been worked on were compared to find a correlation between the amount of almond and roller interference and the hulling and shelling process. All of the almonds were wider than the shear rolls clearance as shown in Table 5.8 and Figure 5.18. No clear correlation was seen from the results.

Table 5.10 Almond width and roller interference effect on almonds.

Shear rolls clearance (mm)	18.7	15.1	12.4	11	9.85	9.05
Almond width > clearance + 5 mm	60%	78%	93%	86%	100%	80%
Almond width> clearance + 4 mm	71%	91%	100%	97%	100%	80%
Almond width > clearance + 3 mm	91%	96%	100%	100%	100%	80%
Almond width > clearance + 2 mm	96%	96%	100%	100%	100%	80%
Almond width > clearance< clearance+2 mm	4%	4%	0%	0%	0%	0%
Almond width < clearance	0%	0%	0%	0%	0%	0%
Hulled	20%	20%	2%	0%	0%	0%
Cracked Shell	2%	4%	27%	20%	10%	0%
Kernel Undamaged	0%	2%	11%	29%	48%	60%
Kernel Chipped	0%	0%	5%	0%	10%	20%
Kernel Broken	0%	0%	5%	11%	24%	0%
Affected almonds	22%	27%	50%	60%	90%	80%

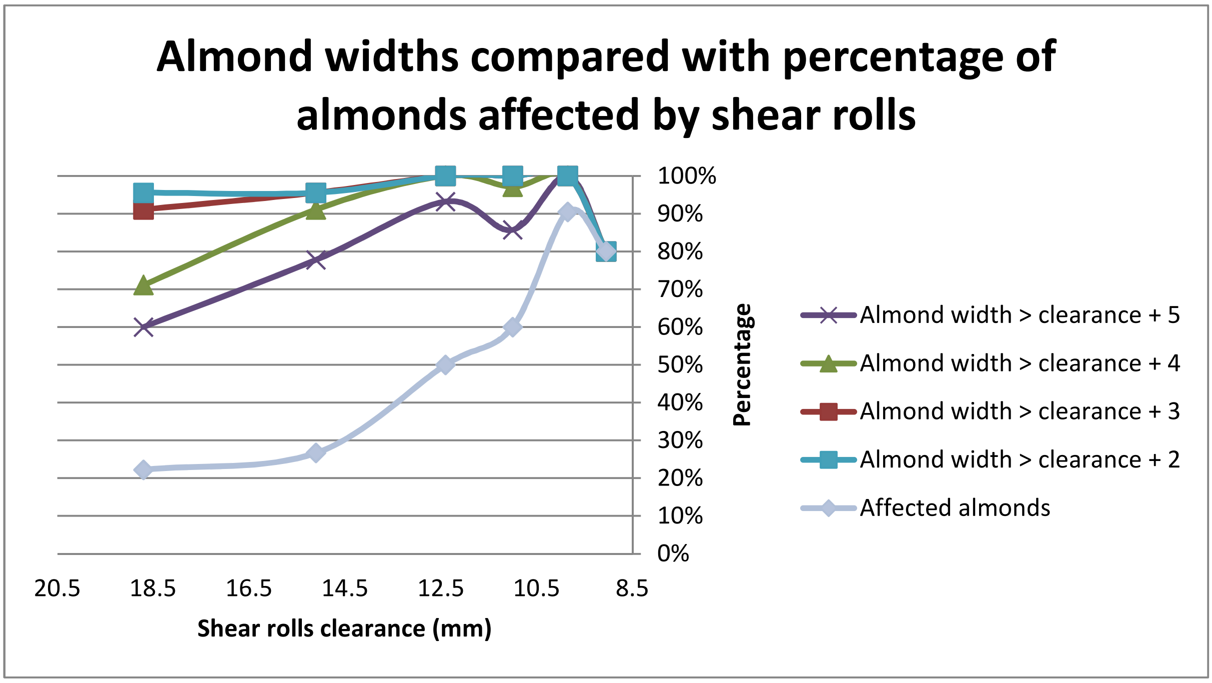


Figure 5.18 Almond widths at each shear rolls setting compared with the percentage of almonds affected by the shear rolls.

The almond thicknesses, shear rolls clearance and amount of almonds that had been worked on were then compared to find a correlation between the almond thickness and roller interference and the hulling and shelling process. There appeared to be a correlation between the affected almonds and their thickness as shown in Table 5.9. At 18.7 mm shear roll clearance, the percentage of almonds that had been worked on fell between the clearance +4 mm and +5 mm region. As the shear rolls clearance was reduced to 15.1 mm and 12.4 mm, the percentage of almonds that had been worked on seemed to trend towards the clearance +4 mm and +3 mm region. At the shear rolls settings of 11 mm, 9.85 mm and 9.05 mm, the percentage of almonds that had been worked on followed the Almond Thickness > clearance +3 mm curve closely as shown in Figure 5.19.

Table 5.11 Almond thickness and roller interference effect on almonds.

Shear rolls Clearance (mm)	18.7	15.1	12.4	11	9.85	9.05
Almond Thickness > clearance + 5 mm	16%	33%	39%	29%	29%	0%
Almond Thickness > clearance + 4 mm	31%	44%	52%	31%	76%	40%
Almond Thickness > clearance + 3 mm	49%	56%	59%	57%	95%	80%
Almond Thickness > clearance + 2 mm	56%	69%	75%	91%	100%	80%
Almond Thickness > clearance< clearance+2 mm	22%	9%	25%	9%	0%	0%
Almond Thickness < clearance	22%	22%	0%	0%	0%	0%
Hulled	20%	20%	2%	0%	0%	0%
Cracked Shell	2%	4%	27%	20%	10%	0%
Kernel Undamaged	0%	2%	11%	29%	48%	60%
Kernel Chipped	0%	0%	5%	0%	10%	20%
Kernel Broken	0%	0%	5%	11%	24%	0%
Affected almonds	22%	27%	50%	60%	90%	80%

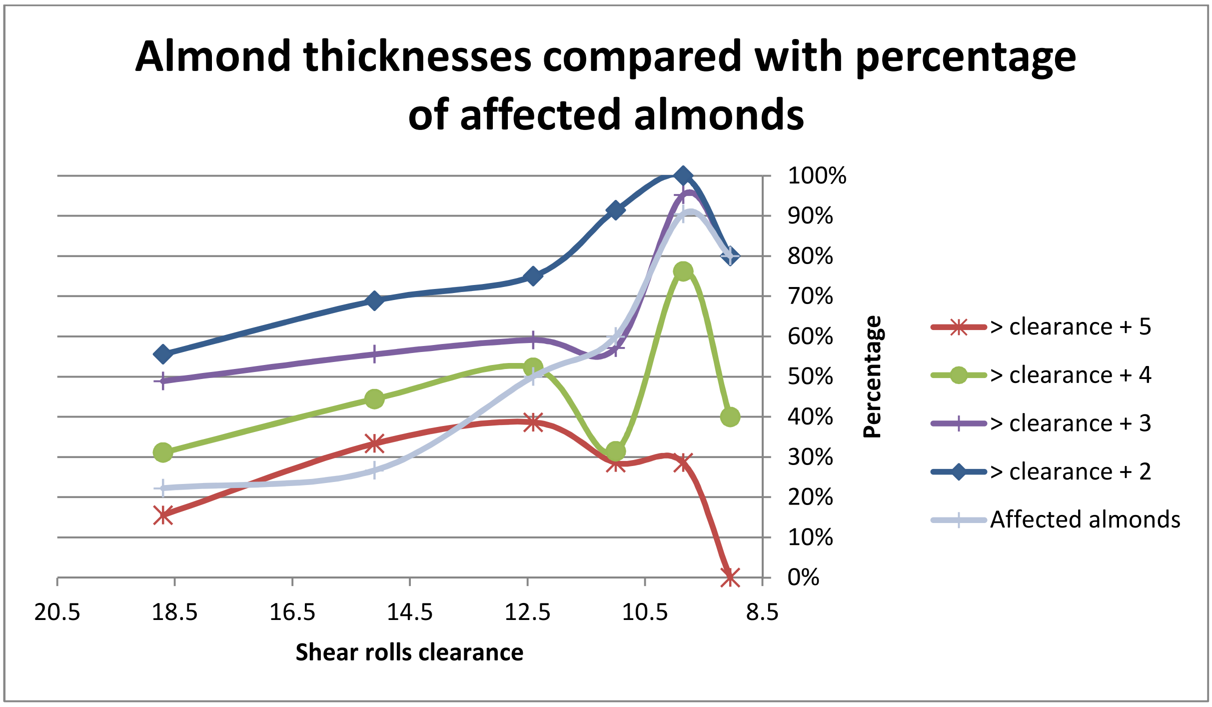


Figure 5.19 Almond thicknesses at each shear rolls setting compared with the percentage of almonds affected by the shear rolls.

The data was analyzed again to check the thicknesses of almonds that were worked on by the shear rolls. The difference between the almond widths and shear rolls clearance ranged from 0 mm to 12.4 mm thicker than the shear roll clearance with only 2 almonds falling below the 2 mm threshold as shown in Figure 5.20. Therefore, the almonds would have to be at least as thick as the shear rolls clearance before they can be worked on as shown in Figure 5.20.

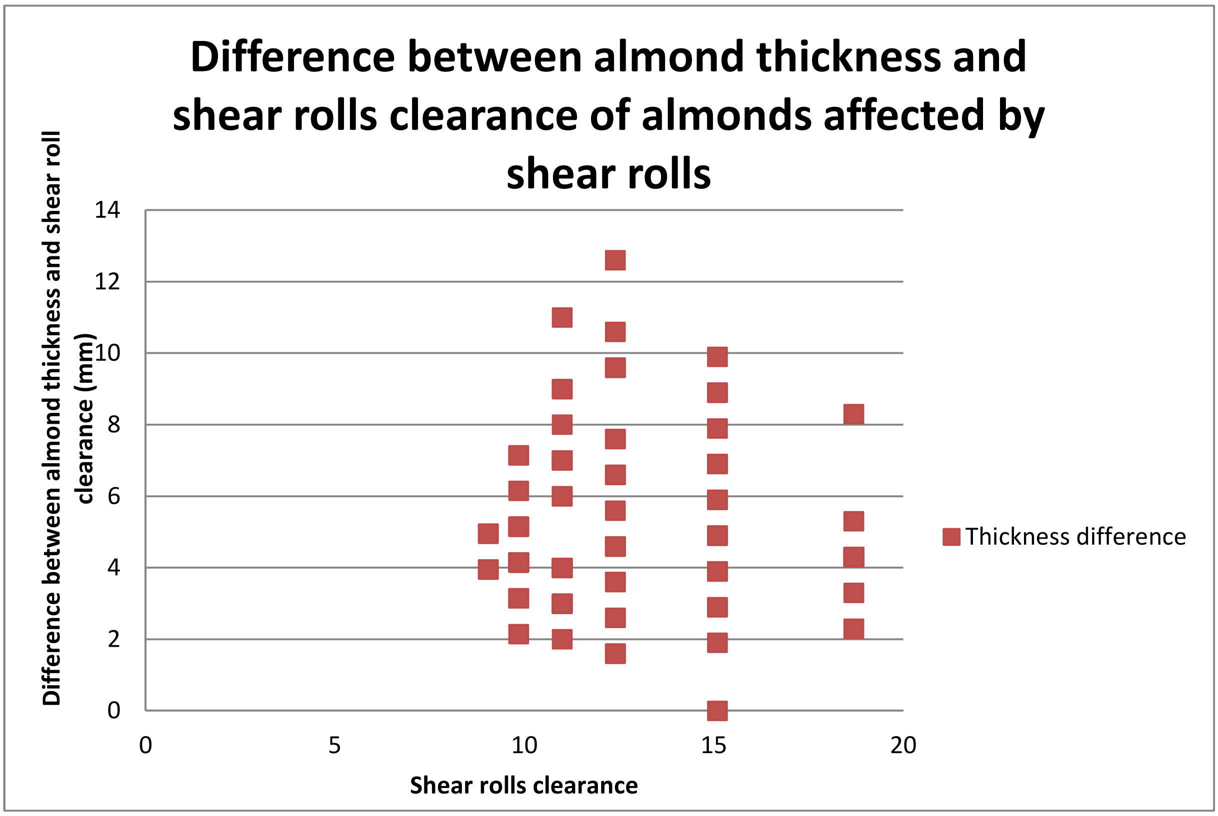


Figure 5.20 Difference between almond thickness and shear rolls clearance of almonds that have been worked on by shear rolls.

When the data on the widths of the almonds that had been worked on by the shear rolls was analyzed, it was found that all of the worked on almonds had widths greater than the shear rolls clearance. The difference between the almond widths and shear rolls clearance ranged from 3.9 mm to 13.6 mm with only one almond falling below the 4 mm threshold as shown in Figure 5.21. Therefore, the almonds would have to be at least 4 mm wider than the shear rolls clearance before they can be worked on.

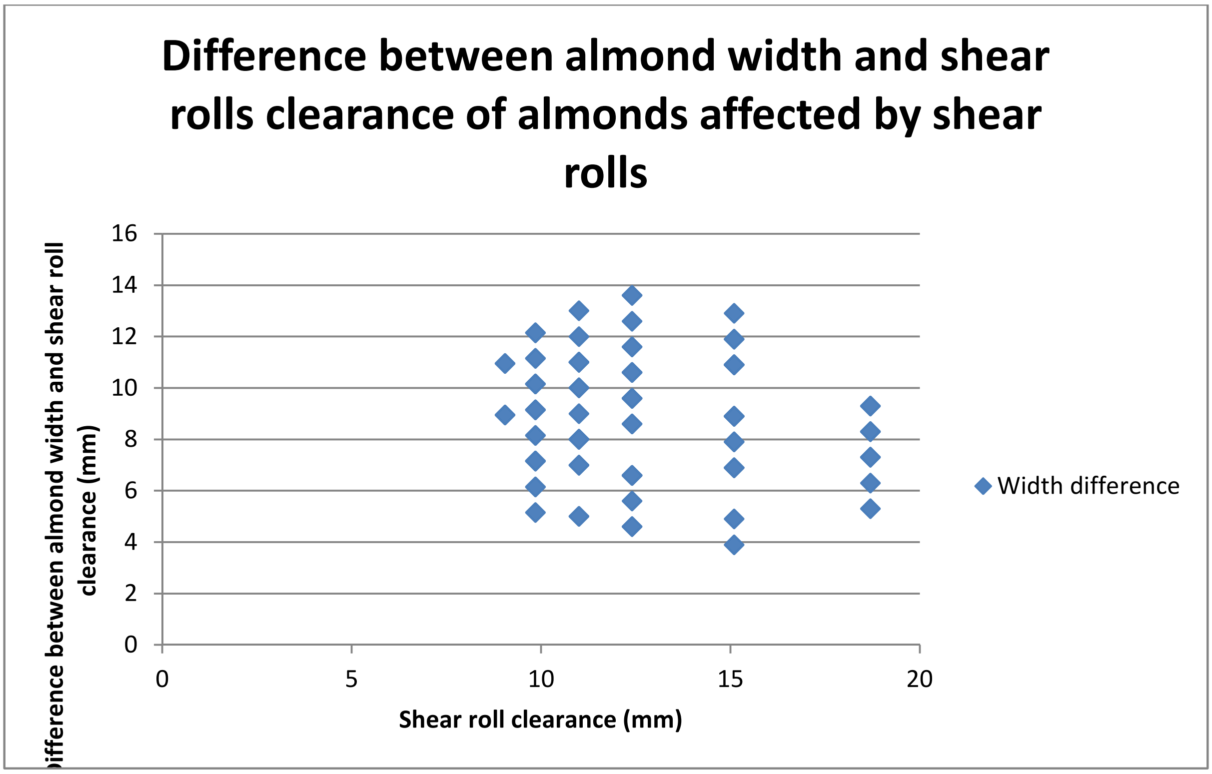


Figure 5.21 Difference between almond widths and shear rolls clearance of almonds that have been worked on by shear rolls.

5.4.3 Testing the effects of shear rolls on multiple almonds

The shear rolls test was then carried out on multiple almonds added at once. For this test, 30 in husk almonds were dropped into the hopper at once and the resulting damage to the almond kernels were recorded. The test was then carried out on 30 almond kernels. The test was carried out at shear rolls clearances of 12.15 mm, 10.8 mm and 9.08 mm; the results are shown in Table 5.12.

Table 5.12 Results of multiple almonds put through shear rolls at once.

In-husk Almonds			
Clearance (mm)	12.15	10.8	9.05
No. of almonds still in husk	11	12	0
Damaged kernel in husk	1	5	0
No. of almonds still in shell	9	0	0
Damaged kernel in shell	5	0	0
No. of loose kernels	10	18	30
Total number of damaged kernels	10	16	30
Kernels 8 mm to 9 mm thickness			
Clearance (mm)	12.15	10.8	9.05
Broken	0	0	3
Chipped	1	4	1
Undamaged	29	26	26

When the in-husk almonds are put through a shear roll clearance of 12.15 mm, a total of 10 kernels are damaged. Out of these 10 damaged kernels, 1 was still in its husk and 5 were still in their shells. When the shear rolls clearance was reduced to 10.8 mm, there were 5 damaged almond kernels still in their husks. When the shear rolls clearance was further reduced to 9.05 mm, all of the almond kernels were broken. Therefore, it is possible to damage kernels that are still in their husks and shells if the first stage of shear rollers has a clearance that is too narrow. Therefore, if the first stage of shear rollers starts off with a clearance that is 12.15 mm and the almonds are allowed to go through the shear rolls together rather than individually, 6 out of 30 almonds will be damaged before their husks and shells are removed. As the clearance of the shear rolls is decreased, the quantities of damaged kernels also increase.

When the almond kernels were put through the shear rolls with a 12.15 mm clearance, 1 out of 30 kernels was damaged. At 10.8 mm and 9.05 mm clearance, 4 out of 30 kernels were damaged. Therefore, if the kernels are allowed to go through the shear rolls together rather than individually, 1 out of 30 almonds will be damaged at 12.15 mm shear roll clearance despite all the kernels having a smaller thickness than the shear rolls clearance. When the clearance is reduced so that it is up to 0.5 mm more than the kernel thickness, there will be 4 out of 30 kernels damaged.

6. Conclusion

This study started out with the aims of identifying and ranking sources of mechanical damage, finding the dimensional characteristics of almonds and to rate the sorting capability of the machines used by the secondary processors.

6.1 Sources of mechanical damage

The study found that the mechanical damage to the kernels were occurring after the kernels were removed from their shells by the hulling and shelling machines. This implies that the kernels should be kept in their shells until ready for the hulling and shelling process.

The hulling and shelling machines at the secondary processers has been identified as a significant contributor to mechanical damage in the almond kernels. The source of the mechanical damage has been narrowed down to the shear rolls and belts. However, the exact cause of the damage has not been identified. Further studies can be carried out to find the effects of the machine settings on the kernels.

6.2 Dimensional characteristics of almonds

The width and thickness distribution of almonds was found in this study. The study found that the almond kernel thickness and width does not increase proportionally with in-shell or in-husk thickness and width. The study also found that there is a clearance between the kernel and its shell and this clearance increases as the in-shell size of the almond increases. All of this information could be used in future studies.

6.3 Current sorting capability

The current sorting capability is still leaving some insect and rodent damaged kernels in the sample. In order to remove all of the insect and rodent damaged kernels, at least an additional pass will be required. This could be accomplished by having another group of machines to do the next pass after the kernels have gone through the first group of machines.

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APPENDICES

Appendix A - Data for almond size distribution

Table A1 Almond width distribution

Sampled Almonds Measured Using Round Holed Template (Width)				
Width	Quantity	Total Mass (g)	Average Mass per Almond	%
15	1	1.1	1.1	0%
16	1	1	1.0	0%
17	4	4.8	1.2	1%
18	5	9.31	1.9	1%
19	22	15.5	0.7	6%
20	41	117.6	2.9	11%
21	105	347.3	3.3	28%
22	64	232	3.6	17%
23	60	237	4.0	16%
24	34	138.7	4.1	9%
25	22	99	4.5	6%
26	11	53.8	4.9	3%
27	4	18	4.5	1%
28	3	12.8	4.3	1%
Total:	377	1287.91		100%

Table A2 Almond thickness distribution data

Thickness	Inhusk Quantity	Inshell Quantity	Kernel Quantity	Inhusk %	Inshell %	Kernel %
7	0	0	6	0%	0%	2%
8	0	0	20	0%	0%	6%
9	0	0	197	0%	0%	54%
10	0	0	134	0%	0%	37%
11	0	4	5	0%	1%	1%
12	1	17	0	0%	5%	0%
13	2	90	0	1%	24%	0%
14	8	178	0	2%	48%	0%
15	12	66	0	3%	18%	0%
16	29	13	0	8%	3%	0%
17	91	1	0	24%	0%	0%
18	107	2	0	28%	1%	0%
19	66	1	0	18%	0%	0%
20	40	0	0	11%	0%	0%
21	16	0	0	4%	0%	0%
22	4	0	0	1%	0%	0%
23	1	0	0	0%	0%	0%
Total	377	372	362	100%	100%	100%

Table A3 Almond size distribution breakdown data

In-husk Width	In-husk Thickness	In-shell Width	In-shell Thickness	Kernel Width	Kernel Thickness
28	19	20	14	13	9
28	21	17	15	12	9
28	17	20	14	13	10
27	21	20	14	14	9
27	19	19	15	14	9
27	18	19	14	15	9
27	21	23	14	16	9
26	20	21	18	12	7
26	19	20	14	15	9
26	23	21	15	14	9
26	20	20	14	13	9
26	22	21	15	14	9
25	19	21	14	14	10
25	20	20	16	13	9
25	20	20	14	13	10
25	18	18	14	13	10
25	20	19	15	13	9
24	19	20	14	14	9
24	18	19	14	15	10
24	21	20	14	14	9
24	19	21	16	15	11
24	19	20	14	14	9
23	19	18	15	13	10
23	17	18	13	12	9
23	19	19	14	14	10
23	19	19	14	14	10
23	20	19	14	14	9
22	18	19	14	13	10
22	18	18	15	13	9
22	18	18	12	12	8
22	17	18	15	12	8
22	19	19	16	14	10

In-husk Width	In-husk Thickness	In-shell Width	In-shell Thickness	Kernel Width	Kernel Thickness
21	18	17	14	12	9
21	18	18	15	13	10
21	17	20	14	14	9
21	18	18	14	12	10
21	18	19	15	12	10
20	17	17	14	12	9
20	16	17	13	12	8
20	18	19	13	13	9
20	17	18	14	13	10
20	18	18	14	13	9
19	17	18	15	12	10
19	16	17	14	12	10
19	17	16	13	11	9
19	16	17	12		
19	18	17	15	12	9
18	16	16	13	12	9
18	14	15	13		
18	16	17	13	11	9
18	15	17	13	12	9
18	15	17	12		
17	13				
17	13				
17	14	14	11	9	8
17	15				
16	14	15	11		
15	12			9	4

Table A4 Shell thickness distribution data

In-shell Thickness	Kernel Thickness	Shell Thickness	Clearance between kernel and shell
12	10	0.36	0.64
12	8	0.73	1.27
12	9	0.37	1.13
12	8	0.38	1.62
13	9	0.39	1.61
13	9	0.49	1.51
13	9	0.43	1.57
13	9	0.45	1.55
13	10	0.45	1.05
13	10	0.5	1
13	9	0.6	1.4
13	9	0.6	1.4
13	9	0.48	1.52
13	9	0.46	1.54
14	9	0.69	1.81
14	8	0.9	2.1
14	9	0.73	1.77
14	10	0.67	1.33
14	9	0.6	1.9
14	9	0.43	2.07
14	9	0.48	2.02
14	10	0.53	1.47
14	9	0.54	1.96
14	9	0.74	1.76
15	10	1.14	1.36
15	10	0.81	1.69
15	10	0.72	1.78
15	10	0.85	1.65
15	9	1.22	1.78
15	9	1.79	1.21
15	10	0.92	1.58
15	10	0.82	1.68
15	10	0.82	1.68
15	10	1.3	1.2

In-shell Thickness	Kernel Thickness	Shell Thickness	Clearance between kernel and shell
16	9	1.71	1.79
16	9	1.08	2.42
16	10	1.4	1.6
16	9	1.54	1.96
17	9	1.66	2.34
17	10	1.7	1.8

Appendix B - Data for almond damage analysis at Costa Almonds

Table B1 Damage breakdown for sampling checks at each stage of Costa Almonds hulling and shelling process

	Before processing			End of pre-cleaning (A)			% of all almonds
	In-husk	In-shell		In-husk	In-shell	Kernel	
Good	208	57		147	30	82	
Broken				1		4	2%
Chipped							0%
Scratched						5	2%
Rodent damage	1					2	
Insect damage		2					
Mouldy	3						
Sticktights				1			
Total	**212**	**59**	**271**	**149**	**30**	**93**	**272**
Total %	**78%**	**22%**		**55%**	**11%**	**34%**	
C/B/S Total (% of Kernel)						**10%**	**4%**
Broken (% of Kernel)						**4%**	
Chipped (% of Kernel)						**0%**	
Scratched (% of Kernel)						**5%**	

	End of 1st Huller (B1)			% of all almonds
	In-husk	In-shell	Kernel	
Good	56	251	25	
Broken			2	0.6%
Chipped				0%
Scratched			6	1.7%
Rodent damage			1	
Insect damage				
Mouldy			1	
Sticktights	2			
Total	**58**	**251**	**35**	**344**
Total %	**17%**	**73%**	**10%**	
C/B/S Total (% of Kernel)			**23%**	**2.3%**
Broken (% of Kernel)			**6%**	
Chipped (% of Kernel)			**0%**	
Scratched (% of Kernel)			**17%**	
	End of 1st Screen(C1)			% of all almonds
	In-husk	In-shell	Kernel	
Good		2	114	
Broken			8	6%
Chipped			5	4%
Scratched			7	5%
Rodent damage				
Insect damage				
Mouldy				
Sticktights				
Total	**0**	**2**	**134**	**136**
Total %	**0%**	**1%**	**99%**	
C/B/S Total (% of Kernel)			**15%**	**15%**
Broken (% of Kernel)			**6%**	
Chipped (% of Kernel)			**4%**	
Scratched (% of Kernel)			**5%**	

	End of 2nd Huller (B2)			% of all almonds
	In-husk	In-shell	Kernel	
Good	72	447	23	
Broken				0.0%
Chipped			1	0.2%
Scratched			2	0.4%
Rodent damage				
Insect damage		1		
Mouldy				
Sticktights	5			
Total	**77**	**448**	**26**	**551**
Total %	**14%**	**81%**	**5%**	
C/B/S Total (% of Kernel)			**12%**	**0.5%**
Broken (% of Kernel)			**0%**	
Chipped (% of Kernel)			**4%**	
Scratched (% of Kernel)			**8%**	
	End of 2nd Screen (C2)			% of all almonds
	In-husk	In-shell	Kernel	
Good		1	96	
Broken			3	3%
Chipped			2	2%
Scratched			3	3%
Rodent damage			2	
Insect damage				
Mouldy				
Sticktights				
Total	**0**	**1**	**106**	**107**
Total %	**0%**	**1%**	**99%**	
C/B/S Total (% of Kernel)			**8%**	**7%**
Broken (% of Kernel)			**3%**	
Chipped (% of Kernel)			**2%**	
Scratched (% of Kernel)			**3%**	

	End of 3rd Huller (B3)			% of all almonds
	In-husk	In-shell	Kernel	
Good	20	531	201	
Broken			1	0%
Chipped			7	1%
Scratched			15	2%
Rodent damage				
Insect damage				
Mouldy			1	
Sticktights	4			
Total	**24**	**531**	**225**	**780**
Total %	**3%**	**68%**	**29%**	
C/B/S Total (% of Kernel)			**10%**	**3%**
Broken (% of Kernel)			**0%**	
Chipped (% of Kernel)			**3%**	
Scratched (% of Kernel)			**7%**	
	End of 3rd Screen (C3)			% of all almonds
	In-husk	In-shell	Kernel	
Good		3	433	
Broken			5	1.0%
Chipped			18	3.6%
Scratched			37	7.4%
Rodent damage			2	
Insect damage				
Mouldy				
Sticktights				
Total	**0**	**3**	**495**	**498**
Total %	**0%**	**1%**	**99%**	
C/B/S Total (% of Kernel)			**12%**	**12.0%**
Broken (% of Kernel)			**1%**	
Chipped (% of Kernel)			**4%**	
Scratched (% of Kernel)			**7%**	

	End of 4th Huller (B4)			% of all almonds
	In-husk	In-shell	Kernel	
Good	24	620	176	
Broken			2	0%
Chipped			12	1%
Scratched			28	3%
Rodent damage			1	
Insect damage				
Mouldy				
Sticktights				
Total	**24**	**620**	**219**	**863**
Total %	**3%**	**72%**	**25%**	
C/B/S Total (% of Kernel)			**19%**	**5%**
Broken (% of Kernel)			**1%**	
Chipped (% of Kernel)			**5%**	
Scratched (% of Kernel)			**13%**	
	End of 4th Screen (C4)			% of all almonds
	In-husk	In-shell	Kernel	
Good		5	356	
Broken			7	2%
Chipped			17	4%
Scratched			46	11%
Rodent damage				
Insect damage				
Mouldy				
Sticktights				
Total	**0**	**5**	**426**	**431**
Total %	**0%**	**1%**	**99%**	
C/B/S Total (% of Kernel)			**16%**	**16%**
Broken (% of Kernel)			**2%**	
Chipped (% of Kernel)			**4%**	
Scratched (% of Kernel)			**11%**	

	End of 5th Huller (B5)			% of all almonds
	In-husk	In-shell	Kernel	
Good	4	101	224	
Broken			3	1%
Chipped			53	13%
Scratched			17	4%
Rodent damage				
Insect damage		4		
Mouldy			1	
Sticktights	88			
Total	**4**	**105**	**298**	**407**
Total %	**1%**	**26%**	**73%**	
C/B/S Total (% of Kernel)			**24%**	**18%**
Broken (% of Kernel)			**1%**	
Chipped (% of Kernel)			**18%**	
Scratched (% of Kernel)			**6%**	
	End of 5th Screen (C5)			% of all almonds
	In-husk	In-shell	Kernel	
Good		76	295	
Broken			11	2.5%
Chipped			9	2.0%
Scratched			49	11.1%
Rodent damage				
Insect damage				
Mouldy				
Sticktights				
Total	**0**	**76**	**364**	**440**
Total %	**0%**	**17%**	**83%**	
C/B/S Total (% of Kernel)			**19%**	**15.7%**
Broken (% of Kernel)			**3%**	
Chipped (% of Kernel)			**2%**	
Scratched (% of Kernel)			**13%**	

	End of processing (D)			% of all almonds
	In-husk	In-shell	Kernel	
Good		66	4732	
Broken			111	1.9%
Chipped			410	7.0%
Scratched			519	8.9%
Rodent damage				
Insect damage			2	
Mouldy			9	
Sticktights	2			
Total	**2**	**66**	**5783**	**5851**
Total %	**0.03%**	**1.13%**	**98.84%**	
C/B/S Total (% of Kernel)			**18%**	**17.8%**
Broken (% of Kernel)			**2%**	
Chipped (% of Kernel)			**7%**	
Scratched (% of Kernel)			**9%**	

Appendix C – Final seminar PowerPoint charts

IDENTIFYING SOURCES OF MECHANICAL DAMAGE IN ALMOND PROCESSING

Final year project thesis for BEng Mechanical

Samuel Kwang Ming Tok
Supervised by
Associate Prof John Fielke

UNDERSTANDING THE INDUSTRY

- A number of site visits were carried out to gather background information on the almond industry in Australia
- Visits were to the almond orchards, primary processing and secondary processing facilities.
- Primary processing is the removal of the husk and shell of the almonds, known as hulling and shelling.
- Secondary processing is the removal of poor quality almonds and foreign material before packing it for the customer.

PRIMARY PROCESSING – HULLERS AND SHELLERS

- The almond's husk and shell is removed by shearing the almonds between a pair of rollers and then between a roller and belt that rotate with a speed differential.
- The shearing effect removes the hulls cracks the shells from the kernel.
- The almonds are then passed over a screen to remove the loose kernels before repeating the process on the next stage.
- The space between each subsequent stage of rollers and belt is reduced to hull and shell increasingly smaller almonds.

SECONDARY PROCESSING - PACKERS

- Almonds go through a colour sorter that picks out 'out of spec' almonds based on colour.
- The product is then packed into bulk bags or cartons for the customer.

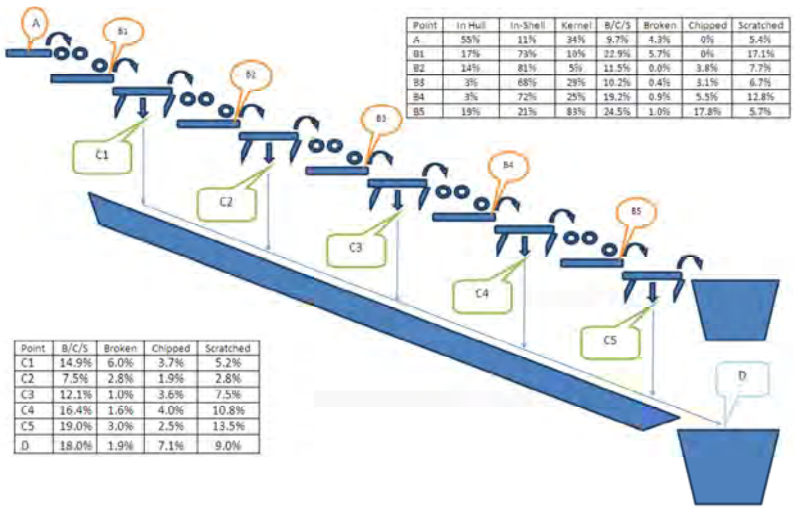
SAMPLING AT SECONDARY PROCESSOR FOR MECHANICAL DAMAGE

- Sample taken at the start and end of the colour sorting process.
- Results show that about 40% of the almond kernels arrive at the packers with some form of mechanical damage.

Table 1 Results of Riverland Almond's sampling

	Before		After	
	Quantity	%	Quantity	%
Good	455	58.5	588	70.33
Chipped	253	33	193	23.9
Scratched	34	7.5	52	8.84
Insect/Rodent Damaged	36	4.6	3	0.36
Doubles	5		0	

SAMPLING FOR MECHANICAL DAMAGE AT PRIMARY PROCESSOR



Point	In Hull	In-Shell	Kernel	B/C/S	Broken	Chipped	Scratched
A	55%	11%	34%	9.7%	4.3%	0%	5.4%
B1	17%	73%	10%	22.9%	5.7%	0%	17.1%
B2	14%	81%	5%	11.5%	0.0%	3.8%	7.7%
B3	3%	68%	29%	10.2%	0.4%	3.1%	6.7%
B4	3%	72%	25%	19.2%	0.9%	5.5%	12.8%
B5	19%	21%	83%	24.5%	1.0%	17.8%	5.7%

Point	B/C/S	Broken	Chipped	Scratched
C1	14.9%	6.0%	3.7%	5.2%
C2	7.5%	2.8%	1.9%	2.8%
C3	12.1%	1.0%	3.6%	7.5%
C4	16.4%	1.6%	4.0%	10.8%
C5	19.0%	3.0%	2.5%	13.5%
D	18.0%	1.9%	7.1%	9.0%

SAMPLING FOR MECHANICAL DAMAGE AT PRIMARY PROCESSOR

Table 2 Results from sampling for mechanical damage at secondary processor

Point	In husk	In shell	kernel	B/C/S	Broken	Chipped	Scratched
A	54.8%	11%	34%	9.7%	4.3%	0.0%	5.4%
B1	16.9%	73.0%	10.2%	22.9%	5.7%	0%	17.1%
B2	16.9%	81.3%	4.7%	11.5%	0.0%	3.8%	7.7%
B3	3.1%	68.1%	28.8%	10.2%	0.4%	3.1%	6.7%
B4	2.8%	71.8%	25.4%	19.2%	0.9%	5.5%	12.8%
B5	1.0%	25.8%	73.2%	24.5%	1.0%	17.8%	5.7%
	Remaining Kernels	Kernels Removed	No. of kernels in sample	B/C/S	Broken	Chipped	Scratched
		10.2%	134				

RESEARCH WITH PENDULUM IMPACT TESTER

- Attempt to find the impact energy necessary to create damage to the almond kernel.

RESEARCH WITH PENDULUM IMPACT TESTER

Table 3 Results of test with pendulum tester – anvil against almond.

Impact Energy (mJ)	Angle	Dent	Broken Skin	Chipped Almond	Cracked	Broken	Sample size
2.38	5	0%	0%	0%	0%	0%	30
11.5	10	0%	0%	0%	0%	0%	30
26.2	15	0%	0%	0%	0%	0%	30
46.7	20	0%	3%	3%	0%	0%	30
73	25	0%	0%	0%	10%	0%	30
105	30	0%	0%	0%	10%	0%	30
142.6	35	7%	7%	3%	13%	0%	30
150.9	36	0%	0%	0%	73%	0%	15
159.4	37	0%	0%	0%	80%	0%	15
168.1	38	0%	0%	0%	73%	0%	15
186.1	40	0%	5%	0%	60%	25%	20
235.3	45	0%	0%	0%	33%	67%	15
290.1	50	0%	0%	0%	27%	73%	15
350.7	55	0%	0%	0%	13%	87%	15
417.1	60	0%	0%	0%	0%	100%	15

RESEARCH WITH PENDULUM IMPACT TESTER

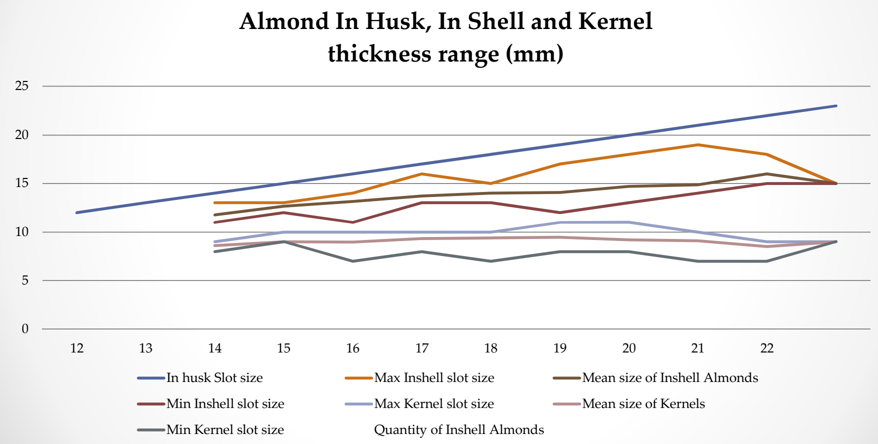
Table 4 Results of test with pendulum tester – almond point against almond

Angle	Impact Energy (mJ)	Signs of impact	Broken Skin	Chipped Almond	Sample size
5	2.3	0%	0%	0%	50
8	7.1	52%	0%	0%	50
10	11.5		48%	12%	50
15	26.2		78%	34%	50
20	46.8		92%	72%	50

Table 4 Results of test with pendulum tester – almond point against offset almond

Impact Energy (mJ)	% Broke Skin	% Chipped	Sample Size
5.3	0%	0%	10
7.1	50%	40%	10
9.2	50%	30%	10
11.5	70%	50%	10

Measuring almonds to find range of dimensions



CONCLUSION

- Various other test have been carried out their results are not presented here.
- Anticipated results would be information on energy level, velocity and roller clearances required to damage almond kernels.
- These results can be used in further studies or research to improve the machines and process so that mechanical damage is minimised.

Appendix D – Project diary

Project Number	Project Title: **Identifying sources of mechanical damage in almond processing**	
	Student Name:Samuel Tok Student ID Number: 110063633	University Supervisor **John Fielke**

Program	Units	Study Period	Honours	Confidentiality
LBMR	**18**	**2 and 5**	**No**	**N/A**

Date	**Description of activities**	**Duration (hours)**	**Progress (Result of effort)**
11/03/11	Project meeting, library consultation on research. Research.	10	Obtained some background on harvesting and processing. Understanding of Almond industry's OHS issues.
18/03/11	Trip up to Berri to visit Almond Co, Simarloo and Jubilee Almonds	13	Observed firsthand Almond processing from harvesting through to packing.
22/03/11	Project meeting	1.5	Agreement on outline of project
24/03/11	Research on optical sorting technologies and companies	8	Found some commercial optical sorters
25/03/11	Project meeting. Research.	10	Finalization of project proposal. Found related citation sources for background and optical sorting.
11-13/4/11	Trip to Almond Co, Riverland Almonds, Laragon, Omega Orchard,	57	Observe firsthand processing at other companies.

	Pistachio Farm, Select Harvest Orchards.		Gain understanding regarding the processing flow and methods used in hulling and shelling and sorting process.
5/4/11	Project Meeting with John Fielke and Lee Sang Heon	2.5	Guidance on project and background.
12/4/11	Thesis Writing	8	Wrote part of Thesis background.
14/4/11	Thesis Writing	10	Wrote part of Thesis background.
17/4/11	Thesis Writing	8	Wrote part of Thesis background.
19/4/11	Research for literature review	10	Found literature on optical sorting methods and studies.
26/04/11	Research and Thesis Writing	8	Literature review on optical sorting methods and studies.
27/04/11	Research and Thesis Writing	8	Literature review on optical sorting methods and studies.
29/04/11	Research	8	Found literature on optical sorting methods and studies.
5/5/11	Project meeting	1	Guidance on thesis
24/5/11	Project meeting, Thesis writing	6	Guidance on thesis
28/5/11	Thesis writing, formatting citations	10	Wrote part of thesis

29/5/11	Thesis writing	12	Formatted thesis document
4/6/11	Research and Thesis Writing	6	Found related citation sources. Wrote part of the-sis on secondary pro-cessing.
5/6/11	Almond sorting field work	8	Sort and tabulate results
6/6/11	Thesis writing	10	Wrote part of thesis on secondary processing
7/6/11	Thesis writing, project meeting	8	Wrote part of thesis on secondary processing, guidance on how to pro-ceed with project.
9/6/11	Almond measuring field work	10	Gathered data on almond size distribution
10/6/11	Almond measuring field work	12	Gathered data on almond size distribution
14/6/11	Sort and analyze data gathered	8	Obtain information on anatomy of almonds
16/6/11	Site visit to Costa Almonds	2	Understand process used at Costa Almonds.
21/6/11	Almond measuring field work	12	Gathered data on almond size distribution
23/6/11	Almond sampling field work at Cos-ta Almonds	10	Gathered data on mechani-cal damage
24/6/11	Almond sampling field work (Costa Almonds)	10	Gathered data on mechani-cal damage
25/6/11	Almond sampling field work	8	Gathered data on mechani-

	(Costa Almonds)		cal damage
4/7/11	Almond sampling field work (Costa Almonds)	9	Gathered data on mechanical damage
5/7/11	Sort and analyze data gathered Thesis writing	7	Sort data into information on anatomy of almonds. Wrote part of thesis on almond anatomy.
6/7/11	Sort and analyze data gathered Thesis writing	8	Sort data into information on almond damage. Wrote part of thesis on almond damage.
7/7/11	Almond sampling field work (Costa Almonds)	9	Gathered data on mechanical damage
8/7/11	Almond sampling field work (Costa Almonds)	8	Gathered data on mechanical damage
16/7/11	Sort and analyze data gathered Thesis writing	10	Plotted some relevant graphs from the data. Wrote part of thesis on almond damage.
18/7/11	Project Meeting	1	Presented data and got advice on how to proceed.
19/7/11	Sort and analyze data gathered Thesis writing	8	Convert data and graphs to percentage.
20/7/11	Sort and analyze data gathered	6	Flow chart for almond hulling and shelling process
22/7/11	Project Meeting, Thesis writing	8	Flow chart for almond

			hulling and shelling process
23/7/11	Sort and analyze data gathered	6	Plotted almond comparison graphs
26/7/11	Thesis writing, literature review for studies on nut damage.	10	Wrote part of thesis for almond damage.
27/7/11	Thesis writing, literature review for studies on nut damage.	7	Wrote part of thesis for almond damage
1/8/11	Project Meeting, literature review for studies on nut damage.	5	Got advice on how to proceed
5/8/11	Thesis writing, literature review for related nut damage.	8	Wrote part of thesis on almond damage
7/8/11	Thesis writing, literature review for related nut damage.	8	Wrote part of thesis on almond damage
10/8/11	Thesis writing, literature review for related nut cracking patents.	8	Wrote part of thesis on almond damage
11/8/11	Thesis writing, literature review for related nut cracking patents.	6	Wrote part of thesis on almond damage
13/8/11	Thesis writing.	12	Wrote part of thesis
15/8/11	Thesis writing. Contact Costa Almonds for information.	8	Wrote part of thesis
31/8/11	Project Meeting	3	Got advice on how to proceed
1/9/11	Analyze data provided by Costa Almonds	5	Acquired data on machine settings
7/9/11	Thesis writing.	8	Wrote part of thesis on almond damage.

10/9/11	Sort and analyze data gathered	8	Plotted almond size comparison graphs
11/9/11	Sort and analyze data gathered	12	Plotted almond size comparison graphs
12/9/11	Almond Impact Testing	5	Acquired data on impact energy effects on kernel.
13/9/11	Almond Impact Testing	2	Acquired data on impact energy effects on kernel.
14/9/11	Sort and analyze data gathered	6	Plotted almond size comparison graphs
15/9/11	Contact Costa Almonds for further information. Thesis Writing. Sent graphs for supervisor's comments	4	Wrote part of thesis on almond anatomy.
19/9/11	Thesis writing	7	Wrote part of thesis on primary processing
20/9/11	Thesis writing	8	Wrote part of thesis on primary processing
21/9/11	Project Meeting, Almond Impact Testing	6	Acquired data on kernel impact characteristics
5/10/11	Thesis writing find references online	8	Wrote part of thesis on primary processing
6/10/11	Thesis writing	8	Wrote part of thesis on primary processing
7/10/11	Thesis writing	8	Wrote part of thesis on primary processing
13/10/11	Project Meeting, Thesis writing	8	Got pointers and comments on thesis, wrote part of the-

			sis on impact tests
14/10/11	Thesis writing	4	Wrote part of thesis
15/10/11	Thesis writing	8	Wrote part of thesis
16/10/11	Thesis writing	10	Wrote part of thesis
17/10/11	Project Meeting, Almond velocity Testing, data analysis	10	Acquired data on velocity effects on kernel.
25/10/11	Project Meeting, Almond shear roll testing	8	Acquired data on shear roll effect on kernel.
26/10/11	Almond shear roll testing, velocity testing.	8	Acquired data on shear roll and velocity effect on kernel.
28/10/11	Thesis writing	12	Wrote part of thesis on impact tests.
29/10/11	Thesis writing, Prepare presentation	10	Wrote part of thesis, PowerPoint slides for presentation.
30/10/11	Thesis writing	10	Wrote part of thesis on impact tests.
2/11/11	Project Meeting, Thesis writing	8	Got pointers and comments on thesis, wrote part of thesis on impact tests.
3/11/11	Thesis writing	8	Wrote part of thesis on velocity tests.
4/11/11	**Project presentation**	6	Present project and watch the presentation of peers on their projects.
5/11/11	Thesis writing.	12	Abstract, impact tests.

6/11/11	Thesis writing	10	Wrote part of thesis on velocity tests.
7/11/11	Thesis writing	6	Wrote part of thesis on velocity tests.
9/11/11	Thesis writing	6	Update and finalise project plan.
10/11/11	Thesis writing on shear rolls test.	10	Wrote part of thesis on shear rolls tests.
14/11/11	Project meeting, thesis writing.	8	Improve on various parts of thesis.
15/11/11	Analyse data on shear rolls test.	10	Wrote part of thesis on shear rolls tests.
16/11/11	Project meeting. Thesis writing on shear rolls test.	8	Wrote part of thesis on shear rolls tests.
17/11/11	Thesis writing on shear rolls test.	8	Wrote part of thesis on shear rolls tests.
18/11/11	Project meeting. Thesis writing.	6	Improve on various parts of thesis.
19/11/11	Thesis writing.	10	Improve on various parts of thesis and formatting
20/11/11	Thesis writing.	10	Improve on various parts of thesis and formatting
21/11/11	Project meeting.	1	Hand in thesis, discussion on shear rolls results.
	Total Hours:	760	

14 Appendix 5 – R&D Brief, Advanced Production Systems Super Project

R&D PROJECT BRIEF:

ADVANCED PRODUCTION SYSTEMS SUPER PROJECT

Prepared by: Ben Brown & Ross Skinner

Background

The Australian almond industry is in an unprecedented expansion phase with approximately three quarters of the plantings yet to reach full maturity and production expected to double to greater than 80,000 tonnes by 2015. The increased production will place increased pressure on current industry resources and traditional farm management systems, particularly harvesting, storing and processing.

As you are well aware, the Australian almond industry is predominantly planted to Californian varieties, which whilst widely accepted in the market place, are vulnerable to food safety concerns. This vulnerability arises from their soft shell, lack of shell seal, susceptibility to fungal and microbial contamination, ground harvesting techniques, variable moisture levels and open storage facilities.

Despite this, the Australian almond industry has during a decade of little summer rainfall produced a high quality product that delivered a premium price. Much has been written and spoken about climate variability and change and whether a believer or a sceptic the weather records indicate the Murray Valley suffers more rain events during the harvest period than in California, and these may be set to become more severe in future, as they were in 2010/11.

The last decade has seen extreme weather events with some of the driest and wettest seasons experienced since the commencement of weather data collection - this begs the question, what is a normal year?

Long term data indicates harvest rainfall in the major almond growing regions of Australia is approximately 43mm and >50mm in 1 in 3 years (Figure 1). This data therefore indicates, the major Australian almond growing regions are not a true Mediterranean climate with summer (and therefore harvest) rainfall a common occurrence; this in stark contrast to California where there is little or no summer rainfall (Figure 2).

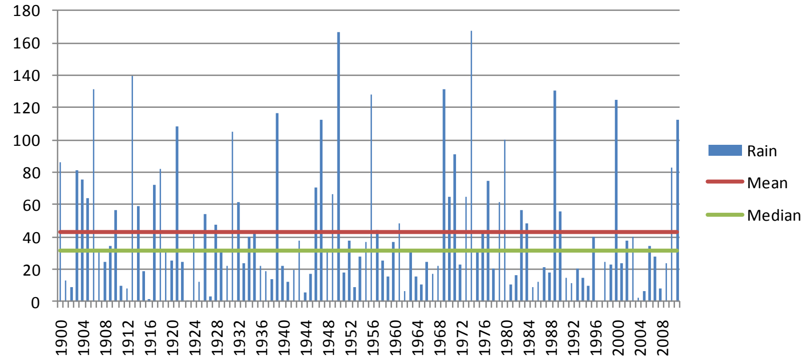


Figure 1: Mildura rainfall, 15th February to 15th April 1900 to 2011.

Almond Board of Australia
ABN: 31 709 079 099
9 William Street
PO Box 2246 BERRI SA 5343 Australia

T +61 8 8582 2055
F +61 8 8582 3503
admin@australianalmonds.com.au
www.australianalmonds.com.au

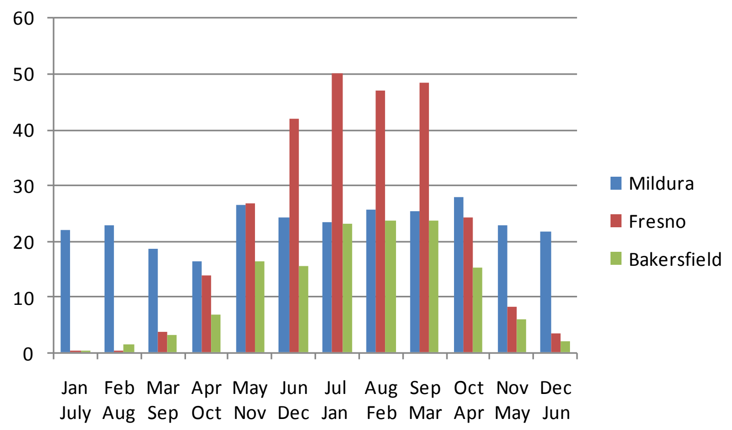


Figure 2: Average Monthly rainfall, Mildura, Fresno and Bakersfield

Other industries have led the world in developing production technologies that better manage harvest risks and have delivered more efficient and reliable management systems. Whilst almonds are considered quite mechanised, the Australian industry believes further opportunities exist to deliver increased cost efficiency, yield maximisation and enhanced product quality. To address these objectives, the following project is proposed.

R&D Project Scope

1. On-Farm

1.1. Fruit Maturation and Windfalls

Windfalls are a key challenge to overcome and succeed at "shaking and catching" almonds. Almonds prematurely fall to the ground prior to harvest through wind, rain, farm management operations and other events. Whilst the experience of the wet 2010/11 season and high proportion of windfalls was significant and fresh in our mind, there is little information available that quantifies and qualifies the problem.

This project would address the following areas:

- Physiological reasons for fruit maturation and premature fruit drop
- Quantify the challenge (i.e. how many and when)
- Qualify the effects (e.g. contribution to food safety risks, financial losses if the crop is unharvested or unsalvageable, etc)

1.2. Harvest

Food safety risk management is an increasing requirement, and maintaining the position as a preferred market supplier a clear industry objective, it is proposed the current harvesting method of shaking fruit to the ground is not the most appropriate harvesting method.

This project would look to evaluate the current fruit maturation process, harvesting system and the most appropriate alternative. For example:

- Sample fruit from hull split to harvest to map the fruit moisture content
- Assess the requirement of dehydrating fruit at the various fruit moisture contents, the effects to fruit quality, and therefore determine the feasibility of harvesting fruit earlier

- Compare and evaluate the traditional almond harvesting equipment in comparison to the side-by-side (e.g. Pistachio and Prune) harvesting equipment
- Improvements to the alternative side-by-side harvesting equipment such as: GPS/guidance systems/triangulation; objectively measure and control shake times to improve orchard hygiene, efficiency, etc; in-orchard product handling and logistics; etc

2. Post Harvest

2.1. Storage, aeration & drying

Once harvested the fruit is still prone to quality deterioration and food safety risks. Controlled post harvest systems are utilised to maximise product yield and quality by better managing risk of crop loss and product deterioration by eliminating the vagaries of nature.

Aeration for the grain industry was developed over 20 years ago and has been successfully used in the grain industry to maintain product quality in storage for longer, by avoiding the build up of moulds or insects in high moisture environments. Aeration can be either used to cool stored product with low flow rate air movement or used to dry product and remove moisture using high flow rate air movement and/or heated air drying.

Pressure will continue to increase on on-farm storage and the capacity of the industry's primary and secondary processing facilities. Opportunities exist in almonds to apply the same principles as the grains industry and better manage moisture from rain events or green fruit from beginning harvest earlier and lengthening the harvest "window".

Thus, the project would look to undertake the following investigations and trials:

- Clean and condition whole harvested fruit
- Aerate whole harvested fruit or almond kernel to enable earlier harvesting and risk management of small rainfall events
- Dehydrate whole harvested fruit or almond kernel to enable earlier harvesting and risk management of significant rainfall events
- Storage facilities for whole and/or hulled fruit (e.g. silos or well designed bunkers)

2.2. De-hulling on-farm

Infield de-hulling would enable greater efficiencies in transport and storage. Whole harvested fruit has a low bulk density (approximately 260kg/m3), with the hull accounting for approximately 60% of the total fruit weight.

This project would research the feasibility of infield de-hulling and if the results are positive, design the most appropriate system for commercialisation.

2.3. Primary and Secondary Processing

It is the industry's aim to review the processing chain and develop processes to minimise kernel damage, maximise out-turns, increase throughput, maximise efficiency, and ultimately aid the profitability of the industry. Opportunities may exist in the modification of current hulling and shelling equipment, design of new hulling and shelling equipment, types or sorting equipment, the order of the sorting equipment, or the amount of sorting equipment required.

2.4. Alternative Waste

Investigate the chemical and physical properties of almond waste (hulls & shells) in the context of increasing and promoting the value of almond waste and generating novel alternative uses that subsidise hulling and shelling costs

Currently, almond hull and shell ("waste") in the Australian almond industry has little economic value. A lot of effort, resources and expense are invested into growing the hull and shell in order to achieve the primary goal of growing almond kernels. The waste equates to approximately 70% of the total harvested fruit weight and 60% of the annual fertiliser applications (i.e. approximately 100 kg/ha and 200 kg/ha of nitrogen and potassium applications, respectively).

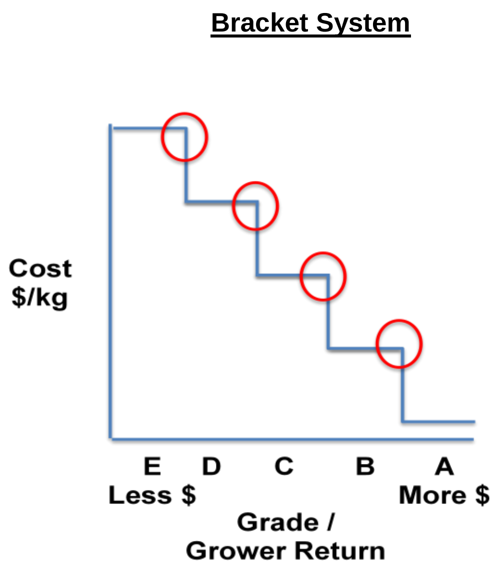
Not only is growing and harvesting the almond waste an expensive process, the removal of it (i.e. cracking) is also a significant cost. Almond hulling and shelling (cracking) costs are estimated at approximately $0.30/kg and in a study conducted by Pocock 2007, cracking was calculated as 15% of an almond orchards costs or nearly $1,000/ha (assuming a 3.2 t/ha yield). Cracking expenses were ranked as the second most expensive cost, behind unallocated labour; and more expensive than fertiliser, irrigation, harvest and bee hire costs. Since 2007 there have been considerable fluctuations and increases in water and fertiliser costs, but it is estimated that cracking costs are still one of the most expensive operations.

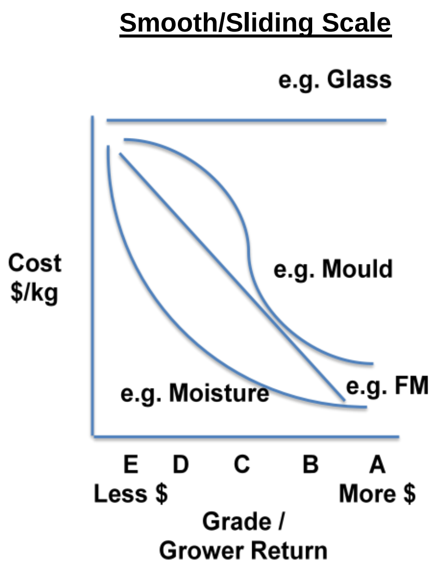
In Australia, almond waste currently has a price of approximately $25-35/tonne; where as in California, almond waste is a valuable commodity and attracts prices of greater than 130USD/US tonne. The price differential is largely to do with logistical costs where in Australia the transport of the waste to feedlots is across long distances and expensive, where as the transport in California is short and cheap. The final price paid for the waste by the feedlot industry is roughly equivalent. Nevertheless, for most Californian hullers and shellers, there is no charge to the grower for cracking as the profits are made from the sale of the waste.

It is the Australian industry's wish to research the properties of the waste, research its potential uses (feedlots, bioenergy, nursery and garden industry, etc), promote its use and subsidise the cracking costs, adding approximately $1,000/ha to the bottom line of growing almonds.

2.5. Quality Assurance and Product Reward/Penalty Assessment

The condition and quality of harvested almond fruit greatly influences primary and secondary processing costs, market opportunities and ultimately grower returns. Although there are significant efforts within almond industry to manage product integrity and food safety risks, there is no detailed reward/penalty system that clearly and transparently provides a basis on which costs and therefore, grower returns are calculated. There is a wide belief there needs to be such a system to encourage the "upstream" part of the supply chain (i.e. growers and/or processors) to optimise product quality and that this would be best achieved by a user pays system that is not based on brackets, but rather a smooth/sliding scale for each "cost". The bracket system also has This project would aim to determine what the individual "costs" are, and deliver mathematical equations/algorithms the packers and marketers could then assign a "value" to and more accurately determine grower returns. An arbitrary example is provided below.





R&D Project Collaboration

This super project is a multi-discipline project and it is strongly recommended this project would benefit greatly from collaboration with other R&D providers such as:

- Department of Primary Industries, Victoria (e.g. Dr Karl Sommer and Dr Chin Gouk)
- Trimble (e.g. Mark Heyward)
- Department of Employment, Economic Development and Innvoation, Queensland (e.g. Philip Burrill)
- Department of Agriculture and Food, Western Australia (e.g. Chris Newman)
- Customvac Australia Pty Ltd, Toowoomba (e.g. Alan Andrews)

R&D Project Budget

The following is a budget allocation assuming Australian almond industry levy and HAL matched funding. It does not include any co-investment from other agencies or Voluntary Contributions from almond industry project partners.

Funding Source	**2011/12**	**2012/13**	**2013/14**	**2014/15**
Almond industry levy and matched government funding (i.e. HAL)	$66,000	$166,000	$166,000	$166,000