Trialling dry hulling of raw pistachios to improve pistachio processing

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Summary

The Australian pistachio industry has been continually seeking to improve processing methods to optimise the value of the annual crop produced by Australian pistachio growers. This project sought funding support to continue this endeavour by researching potential improvements to the primary stages in processing Australian pistachios which involved the removal of the inedible outer hull on the harvested nut.

This project sought to determine the methods and equipment requirements to effectively replace or supplement the current wet hulling methods of removing the hull with a dry hulling method. Information from these trials was to be used to enable improvements to production efficiencies and product quality.

The major outcomes from the project included:-

a) The un hulled nut separation would be incorporated into any future upgrade and/or alternative plant development.

b) The re-evaluate of the level of damage caused by the Magnuson wet hullers to ensure the comparison with the dry hullers was fair. So much water is used with wet hulling the capture of damaged nuts is more difficult compared to dry hulling.

c) Improved understanding of drying elements and the development of tools to optimize the performance of the drying plant was an underlying intention of this project and the outcomes from the trials conducted enabled this objective to be advanced considerably.

d) The gathering of information on the incoming moistures of pistachios and the moisture changes through the drying process. To assist with this understanding we were able to obtain empirical data around drying pistachios through the various drying studies conducted.

e) The production of a range of drying curves which will assist in the optimization of the drying plant performance and potential changes for either plant improvement or expansion.

f) The addition of the shufflo pre dryers for providing moisture control to the In Hull Nut Separators (IHNS) enabled an increase in the production of the higher value wide splits as well as increasing plant drying capacity.

g) **The 4% increase in wide splits achieved by the shufflo pre dryers is estimated to improve the relative value of the crop by $0.02/kg of dry marketable product or $30,000 gain for an average crop year.**

h) Gaining a better understanding of the operating cost of each element of the drying process which will assist with future capital expansion and drying improvements.

Keywords

Pistachios; dry hulling; wet hulling; *Sirora*; *Kerman*; In Hull Nut Separator (IHNS); Un hull nut separation; shufflo pre dryers; nut drying; drying curves.

Introduction

The Australian pistachio industry has been commercially growing pistachios since 1983 and commercially hulling pistachios since 1991. The single industry hulling/drying plant, operated by Australian Pioneer Pistachio Company (APPC,) has been steadily expanded to reach its current capacity of 2,000 tonnes (hulled, dry weight), handling around 98% of the Australian production. Further expansion of the plant to handle growth from the expected crops of new orchards will require a substantial rebuild and an expanded footprint – this will have substantial capital cost that would need to be passed to growers.

The current method of pistachio hulling employed uses a wet hulling system. "Potato" skinning style machines with abrasive rollers remove hull from the shell of the pistachio using a considerable amount of water in the process. Following the hulling process, the pistachios are dried using mechanical drying units to reduce the nut moisture to a shelf stable level under 7%. Wet hulling and drying is both capital and processing cost intensive especially as it is only required for a 4 to 6 week period each season.

The Australian *Sirora* variety, developed by CSIRO in the 1970s, has many favourable features that make it suitable for Australian conditions. However, it has some features that cause less than optimal processing outcomes compared to Californian and Iranian varieties. *Sirora* has a very uneven maturity so that there are always ripe and unripe nuts on the tree that cannot be separated at harvest despite the practice of Australian growers of harvesting twice, about 10 days apart. The unripe nuts are very difficult to hull. If the hullers are set to hull the unripe nuts, these settings are detrimental to the ripe nuts. If the immature nuts are not hulled correctly, they must be separated through the sorting process. Incorrectly hulled nuts creates a loss of value to the grower as a "pick out" rather than a first grade nut and causes additional processing expense to the grower.

The best grower returns are achieved from wide split nuts, i.e., nuts that smile at the consumer rather than narrow splits that cause finger nail breakage if the consumer is to obtain access to the edible kernel. Pistachio nuts split naturally on the tree, but, the width of the split is a function of the nut maturity and the method of drying. *Sirora* always has a mix of maturity so there are always some narrow splits, i.e. nuts that are only just mature and only just split. It has been noted that with aggressive drying the percentage of narrow splits can be reduced. However, the excessive use of heat in the drying is not only expensive; it can also remove the flavour of the nuts and damage the texture.

This project will attempt to tackle three important processing limitations with the Australian *Sirora* variety.

a) Dry Hulling of pistachios will be investigated and developed prior to wet hulling.

   Achieving effective dry hulling prior to wet hulling will enable increased capacity of the existing

plant at a potentially lower incremental capital cost than expanding wet hulling.

b) Effective separation of hulled from inadequately hulled pistachios.

This will enable the partly hulled nuts to be returned to the hulling process for rework. Iran has developed a machine to separate hulled from unhulled nuts

c) Establishing the optimal drying processes to maximise wide splits.

A lot of work has been undertaken to investigate this aspect but it has not been on a structured research oriented basis. This project will investigate and determine optimal drying for wide split recovery.

Methodology

Over the life of the project there were a large number of phases but each one built on the success failure of the previous phase. The following were the broad phases of the project:

a) Visits in 2013 by APPC directors to the USA and Iran

Chris Joyce and David Crawford visited the major pistachio producing countries, the USA and Iran, to evaluate each country's progress with dry hulling and associated processing methods.

The visits identified several options for dry hulling currently in use in these countries with potential to trial on the Australian bred pistachio variety, "*Sirora*".

b) Dry hulling trials were conducted during the 2014 season.

This included the bringing of Pistachio processing experts from Iran for the season to assist with these trials. In essence the evaluation consisted on trialling various machine settings with the Iranian dry huller and comparing these results in their own right and in comparison to existing Magnuson wet huller performance.

A Hassani Iranian dry huller with a different drum design that had been acquired previously was also used to compare results for part of these trials as well.

c) Consideration of the option of using a combination of dry hulling followed by wet hulling.

The aim was the separating of the un hulled nuts from dry hulling and then hulling the un hulled nuts, being the more difficult immature or "green" pistachios, through the wet hullers.

d) Trialling of dry hulling rollers with wet hullers.

The USA based manufacturer of the current wet hullers, Magnuson decided they wanted to trial some dry hulling roller concepts with their wet hullers and to advance the timeline.

This was commenced with our 2015 season. Magnuson and APPC trialled three roll concepts during the 2015 season comparing performance by way of percentage of nuts hulled, percentage of nuts un hulled and percentage of nuts damaged to the current wet huller performance.

Magnuson and APPC conducted some further trials on their preferred roller options during the 2016 Australian pistachio season.

e) Assessment of an impact style huller.

In 2015 some preliminary trials were conducted and assessed.

The impact huller was installed as a by pass to the wet hullers for the 2016 season to enable direct comparison to the wet hullers. Similarly to the above trials, the performance of this huller was assessed for throughput, percentage of nuts hulled, percentage of nuts un hulled and percentage of nuts damaged.

f) Determine how to separate hull from the hulled nuts.

A further element of dry hulling contingent of the success of the dry trials was to determine how to separate hull from the hulled nuts.

g) Assessment of the potential to implement the Iranian style separating equipment.

The next component of the project was to assess the potential to implement Iranian style separating equipment for sorting un hulled nuts from hulled nuts after hulling. Effective separation enables un hulled nuts to be recycled back into hulling for a second time through to increase the hulled nut % out turn.

An Iranian Hulled Nut Separator was sourced and trialled during the 2014 Australian pistachio season. The IHNS was assessed offline by testing the ability of the IHNS to sort hulled nuts from un hulled nuts at various levels of nut moisture.

h) The implementation of the Iranian "shufflo" dryers

The implementation of the Iranian "shufflo" dryers was also part of the other major aspect of this project which investigated the optimizing of drying. A number of aspects were investigated with drying including determining drying curves for pistachio nuts at various air flow and temperature settings, optimizing wide split out turns, comparison of plenum drying to continuous drying and determining the moisture level for nut opening stability

i) The recovery use of dry hull back into the orchards

Outputs

1. California and Iran Trip by Chris Joyce and David Crawford

During the visit the following information was gathered:-

a. 3 USA processors were using dry hulling concepts with one operating on a total dry hulling basis using an impact huller. One other was using pod style hullers to pre hull to prior to wet hullers and one was using an Iranian style huller manufactured in the USA.

b. The main US pistachio variety is "*Kerman*" and was found to have a more consistent maturity than the Australian variety, "*Sirora*".

(*Sirora* is a more difficult pistachio to dry hull due to the wide range of mature to immature nuts at harvest.)

c. Excess nut damage from dry hulling was evident at the USA dry huller plants.

d. Iran had built pistachio hulling around dry hulling and with varieties close to *Sirora*, the Iranian methodology for pistachio hulling and drying was considered favourable to our needs.

e. APPC was able to obtain Iranian pistachio processing expertise to assist with intended pistachio processing trials.

2. Iranian dry hulling outputs from the 2014 season

a. Momtazan unit as supplied:

The percentage hulled nuts was lower than the Magnusons as expected but the level of damage was higher than for the Magnusons.

b. Larger volume trialled and the front gate gap increased:

The throughput of the machine was only 75% of the claimed capacity with similar hulled and damaged nut percentages as above.

The left side of the machine produced less hulled nuts than the middle and right side.

c. Machine trialled at different drum speeds and front gate openings:

Increasing the drum speed increased the percentage of hulled nuts but increased the damaged to the nuts.

The 30mm front gap at a given drum speed achieved the highest percentage of hulled nuts for the least amount of damaged nuts although the percentage of damaged nuts still unacceptable.

d. Machine trialled on *Kerman* to compare with above *Sirora* results:

Overall the results for *Kerman* were better than for *Sirora.*

e. Machine drum bolts adjusted to reduce damage:

Smoothing the bolts reduced the level of damaged nuts.

f. Momtazan huller compared to the Hassani huller:

The Momtazan and Hassani machines produced similar results.

g. Determining Magnuson capacity if nuts are pre hulled through dry hulling:

The results were inconclusive for capacity improvement and showed a higher percentage of damaged nuts. This trial was rerun twice later in the season which confirmed the higher level of damage from this combined process but any capacity increase was difficult to gauge.

3 Magnuson dry hulling roller outputs for the 2015 and 2016 seasons

The following outputs resulted from the 2015 and 2016 trials:-

a. The 2015 season trials concluded that one style of dry hulling rollers (expanded metal style) supplied by Magnuson produced results similar to grit only rollers however the integrity of the preferred roller to last was questionable.

b. Magnuson conducted trials during the 2015 US season with the preferred option to compare the *Sirora* results to *Kerman.*

c. Magnuson provided two versions of the expanded metal style rollers for the 2016 season. The more robust design caused high levels of damage so the preferred option from 2015 was trialled further. Although this roller worked well, the trials proved the design was not robust enough.

d. Magnuson have since stopped any further development of the rollers as they work ok for the USA industry on *Kerman.*

e. A reduction in water consumption and the opportunity to recover "dry" hull are two positive outcomes from using Magnuson dry hulling rollers.

4 Impact huller output from the 2016 season

No matter what drum rotation speed or throughput was used, the level of damaged nuts was considered excessive so this dry hulling option was considered less desirable than any of the alternate options.

5 In hull Nut Separator output from the 2014 season

The results of the separation of the trial unit were considered so successful it was decided to implement a substantial investment into pre dryers (Iranian shufflo dryers) and Iranian In hull Nut Separators (IHNS) for the 2015 season.

The implementation of the INHSs to enable recycling of un hulled nuts back into the hullers has resulted in a substantial reduction in adhering hull of the dried product.

The introduction of the pre dryers associated with the INHSs has enabled a relative increase in the percentage of wide splits achieved as well as providing an increase in drying capacity of the plant.

6 Determining moisture level for wide split stability in the 2014 season

These trials indicated that the nut split is relatively stable once the nut moisture gets to around 12-14%.

7 Drying trials for the 2014 season

A number of drying trials attempting to determine drying curves for pistachios were conducted in the 2014 using a plenum dryer however these experiments were not successful due to interference with production priorities and control limitations with the plenum dryers.

8 Drying trials for the 2016 season

The value of shufflo pre drying was assessed for wide split optimization and the specific outputs from the 2016 season included:-

a. A 4% increase in wide splits due to effects of the shufflo pre drying.

b) The moisture levels of pistachio nuts after harvest were determined as inhull, shell, kernel and hull so that we now know the starting point for the drying process.

c) Using a pilot plant arrangement, drying curves for a range of airflow and hot air temperatures were devised to provide a basis for future drying efficiency improvements and/or capacity upgrades. Unfortunately these curves don't replicate the drying plant drying times. It seems the pilot scale drying is more efficient than the drying plant. The information is useful however to review relative performance of various air flows and hot air temperatures.

d) The various moisture meters in use at APPC were assessed against an infra red absolute moisture level detector to provide calibration of performance of these meters.

e) LPG meters were installed and monitored on several drying units to enable drying efficiency analyses to be conducted. The comparison of the drying efficiency for each of the drying units used is difficult because of the differing service requirements of each unit however this analysis has provide a good basis for future optimization of the drying plant.

f) Nut closure trials in silo confirmed that the lower the nut moisture entering a silo the lower the percentage of nut closing up from the pressure of storage.

Outcomes

1. Dry hulling

The three dry huller's trialled in the 2014, 2015 and 2016 seasons demonstrated the potential to hull a high percentage of the easy to hull nuts however it became apparent that these style of hullers cause an unacceptable level of nut damage in the hulling process. For comparison the damage level caused by the current Magnuson wet hulling method is estimated at less than 1%. As the damage caused by a dry huller was in the region of 3% on average, the potential relative loss in product value is around $0.25/kg of dry merchantable product. For an average on off crop volume of 1,500mt crop, this equates to a $375,000 loss for the crop year which makes justification for dry hulling very difficult despite possible capacity improvements from their introduction.

The enthusiasm to continue with the Iranian and USA impact hullers waned as a result of the trials however it is understood that such dynamic processes have a fine balance between optimizing performance (in this case hulling the easy to hull nuts at acceptable production rates) and minimizing consequential damage. We did not really find the sweet spot to achieve this balance in the trials and whilst we could continue to pursue investigating, given the range of the variables tested, it was felt the sweet spot would be elusive with these styles of dry hullers.

Nut maturity also has a role to play in the performance of dry hullers such that if the nuts had more consistent maturity with easy to peel hulls, the corresponding level of damage may be constrained to acceptable levels. However, the variable nature of the Sirora variety maturity indicates this would not be likely.

The trials using dry hulling rollers in the Magnuson proved very beneficial for future development although this direction will not solve one of the original objectives of this project: to determine a lower capital investment cost method for pistachio hulling. If the preferred expanded metal roller design could be made robust enough, existing Magnuson wet hullers could be retrofitted with such to reduce water consumption and hence reduced waste water disposal and to recover drier waste hull than is current.

2. Un hulled nut separation

This element of the project was very successful and has led to major changes to the APPC hulling and drying plant. Following successful trials with an Iranian made In Hull Nut Separator (IHNS) in 2014, the APPC plant was upgraded for the 2015 season to install Iranian made shufflo pre dryers and IHNSs. This installation has resulted in around 5% as un hulled nuts from primary hulling being returned back for re hulling and virtually eliminating the inshell defect, adhering hull, in the dry merchantable product. **The relative value recovered by recycling un hulled nuts back into hulling is estimated at $0.22/kg of dry merchantable product or $330,000 gain for an average crop year.**

3. Moisture level for nut opening stability

These trials confirmed the requirement to achieve less than 12% nut moisture with primary drying before the product is sent to silos to minimize the effects of the storage pressure closing up wide split nuts.

4 Drying improvements

The introduction of the shufflo pre dryers proved beneficial for maximizing wide split opening as well as improving the drying capacity of the plant. **The 4% increase in wide splits achieved by the shufflo pre dryers is estimated to improve the relative value of the crop by $0.02/kg of dry marketable product or $30,000 gain for an average crop year.**

The moistures for the incoming in hull pistachios were tested at around 59% for in hull, 22% for shell only, 45% for kernel only and 83% for the hull only. This now provides a good base for ongoing drying optimization studies.

The drying curves produced are beneficial for relativity with drying rates of airflow and hot air temperatures when considering drying improvements and capacity upgrades.

The studies on the various moisture meters has enabled a better understanding of where in the moisture range each of the units are most accurate.

The drying studies on the various drying units has provided base data for the cost of operating each of the drying units and enable drying optimization and best practice drying capacity upgrades.

Evaluation and Discussion

The project commenced with visits in 2013 by APPC directors Chris Joyce and David Crawford to the major pistachio producing countries, the USA and Iran, to evaluate each country's progress with dry hulling and associated processing methods.

The visits identified several options for dry hulling currently in use in these countries with potential to trial on the Australian bred pistachio variety, "*Sirora*". Two methods of dry hulling were finally recommended: an Iranian style dry huller and an impact style huller used in the USA. Other possible options such as cone, pod and shear roll hullers were also considered but were discounted for this project scope because the 2 methods selected were already in commercial use.

A Momtazan Iranian dry huller was sourced from Iran to facilitate dry hulling trials during the 2014 season. Pistachio processing experts from Iran were also brought out for the season to assist with these trials. In essence the evaluation consisted on trialling various machine settings with the Iranian dry huller and comparing these results in their own right and in comparison to existing Magnuson wet huller performance. There were four variables assessed during the evaluations: the back guide clearance, front plate clearance, drum bolt shape/size and drum speed. The performance of the unit was assessed by throughput, percentage of nuts hulled, percentage of nuts un hulled and percentage of nuts damaged. A Hassani Iranian dry huller with a different drum design that had been acquired previously was also used to compare results for part of these trials as well.

Another component of the assessment of the above dry hulling was to consider the option of using a combination of dry hulling followed by wet hulling by separating the un hulled nuts from dry hulling and then hulling the un hulled nuts, being the more difficult immature or "green" pistachios, through the wet hullers. The trials to separate un hulled nuts from hulled nuts is detailed below.

In 2014, the US based manufacturer of the current wet hullers, Magnuson decided they wanted to trial some dry hulling roller concepts with their wet hullers and to advance the timeline, they commenced these with our 2015 season. Magnuson and APPC trialled three roll concepts during the 2015 season comparing performance by way of % of nuts hulled, % of nuts un hulled and % of nuts damaged to the current wet huller performance. From these trials, Magnuson determined their preferred dry hulling roller option which they fined tuned for application and trialling for the 2015 US pistachio season which is six months counter seasonal to the southern hemisphere. Magnuson and APPC conducted some further trials on their preferred roller options during the 2016 Australian pistachio season.

An impact style huller was also sourced for the 2015 Australian pistachio season but unfortunately this unit was delayed in transport and although some preliminary trials were conducted, the season had virtually passed to allow any reasonable level of testing. The impact huller trials were held over to the 2016 season. The impact huller was installed as a bypass to the wet hullers for the 2016 season to enable direct comparison to the wet hullers. Similarly to the above trials, the performance of this huller was assessed for throughput, % of nuts hulled, % of nuts un hulled and % of nuts damaged.

A second element of dry hulling contingent of the success of the dry trials was to determine how to separate hull from the hulled nuts. Unfortunately as neither the Iranian nor the impact huller trials

proved successful with dry hulling of *Sirora* pistachios because of excess nut damage, this element of the project wasn't effectively pursued. However, a beneficial consequence of the Magnuson dry hulling trials indicated that if dry hulling rollers became an effective option for Magnuson hullers, their method of operation allows easy separation of dry hull, one of the original aims of the this project.

The next component of the project was to assess the potential to implement Iranian style separating equipment for sorting un hulled nuts from hulled nuts after hulling. Effective separation enables un hulled nuts to be recycled back into hulling for a second time through to increase the hulled nut % out turn. An Iranian Hulled Nut Separator was sourced and trialled during the 2014 Australian pistachio season. The IHNS was assessed offline by testing the ability of the IHNS to sort hulled nuts from un hulled nuts at various levels of nut moisture. This element of the project proved so successful, a full scale implementation of IHNS equipment was enacted prior to the 2015 season. An essential element for successful separation involves pre drying the nuts to achieve sufficient shell dryness to enable adequate frictional difference between un hulled nuts and hulled nuts for the separation. Iranian "shufflo" dryers were considered the best option for pre drying and so these were sourced and implemented. These pre dryers also provided additional benefits by increasing the drying plant capacity by reducing the close to surface nut moisture levels as well as providing the initial burst of heat associated with optimizing nut opening.

The implementation of the Iranian "shufflo" dryers was also part of the other major aspect of this project which investigated the optimizing of drying. A number of aspects were investigated with drying including determining drying curves for pistachio nuts at various air flow and temperature settings, optimizing wide split out turns, comparison of plenum drying to continuous drying and determining the moisture level for nut opening stability. For the 2014 season, the drying trials were conducted using plenum dryers however production pressures limited the extent of plenum dryer availability for the trials. For the 2016 season, a pilot drying rig was devised which enabled the drying curves to be produced. The drying equipment comparisons were achieved by installing LPG flow meters on key equipment to enable the comparison of performance.

The limited success of dry hulling and subsequent limited opportunity to produce any volume of dry hull precluded the significant efforts into the recovery use of dry hull back into the orchards during this project timeline. The orchards also raised concerns with pest and disease infiltration with recovered dry hull. Addressing this aspect was considered beyond the scope of this project.

The following is the evaluation of some of the more specific components of the project:-

DRY HULLING

The original intention for pursuing dry hulling was to determine if a lower capital cost hulling solution could be derived for industry expansion at either the current location and/or if another hulling and drying plant were to eventuate.

This project commenced with the belief that the best option to investigate the potential for dry hulling the Australian *Sirora* variety was with dry hulling equipment options already being used in other parts of the world. The outcomes of this project reflected that the level of damage caused by both dry hulling methods trialled caused too high a level compared to the current wet hulling method. The likelihood of pursuing either of these dry hulling options further is limited for now.

In the meanwhile the existing Magnuson hullers could be converted to dry hullers by using the

expanded metal rolls developed by Magnuson but until a more robust design is developed, this option too will sit in abeyance unless Magnuson is convinced or the rolls are developed by another party. The latter will be considered by APPC in future planning.

Another possibility is to review other dry hulling options considered but discounted for this project. Obviously these are now outside the scope of this project and so other funding considerations will need to be made.

One other aspect the project team considered is to re evaluate the level of damage caused by the Magnuson wet hullers to ensure the comparison with the dry hullers is fair. As so much water is used with wet hulling the capture of damaged nuts is more difficult compared to dry hulling.

UN HULLED NUT SEPARATION:

The most successful element of this project was the un hulled nut separation and this should be incorporated into any future upgrade and/or alternative plant development. The benefits to the hulling drying are not just enabling the re hulling of un hulled nuts but the pre drying requirement of the nut separators enables optimal wide split opening as well as providing additional primary drying capacity to the drying plant.

DRYING IMPROVEMENTS:

Improving our understanding of drying elements and developing tools to optimize the performance of the drying plant was an underlying intention of this project and the outcomes from the trials conducted enabled this objective to be advanced considerably.

From this project we were able to gather information on the incoming moistures of pistachios and the moisture changes through the drying process. To assist with this understand we were able to produce a range of drying curves which will assist in our optimization of the drying plant performance and potential changes for either plant improvement or expansion.

The addition of the shufflo pre dryers for providing moisture control to the In Hull Nut Separators enabled an increase in the production of the higher value wide splits as well as increasing plant drying capacity.

We also gained a better understanding of the operating cost of each element of the drying process which will assist with future capital expansion and drying improvements.

Recommendations

The Project Team has made the following recommendations:-

a) To re evaluate the level of damage caused by the Magnuson wet hullers to ensure the comparison with the dry hullers is fair.

b) The incorporation of the un hulled nut separation into any future upgrade and/or alternative plant development.

c) Review of the recovery use of dry hull back into the orchards and the associated biosecurity concerns with pest and disease infiltration with recovered dry hull.

Scientific Refereed Publications

None to report.

Intellectual Property/Commercialisation

The highly specialised nature of pistachio processing with a significant capital requirement for hulling and drying which is used for 3 to 4 weeks per annum has lead to the concentration of this process into one plant.

There are currently some small processors but the potential for new competitors is always present.

If this project establishes dry hulling as a success, a 'green fields' site will have a significant advantage over existing plants as they will design and construct the plant using dry hulling as the base. Existing plants will need to rebuild to incorporate the new technology – an inherently less efficient process than a green field site.

Given that situation PGAI would be looking for a window of confidentiality for any new process and/or technology developed for APPC and those members of the PGAI.

It is anticipated that based on the investment from industry confidentiality would be required for the life of the project and a further 18 months after the completion of the project.

References

None.

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Appendices