

Rapid Chill Technology evaluation

Phase 1: Evaluate and understand the pH temperature decline and value proposition of the Rapid Chill system

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Project description

Rapid Chill, a technology utilised to chill fresh fruit, is a modular system where airflow and temperature are adjusted in each modular unit to optimise cooling of the product. Rapid Chill is applicable to the red meat processor sector as it improves carcass cooling and enables rapid heat removal through the innovative patented technology.

Retro-fitting the fruit unit, a research trial was conducted over 2 days onsite at Mildura by the University of New England (UNE) with 23 conventionally (Con) chilled versus 24 very fast chilled (Fast) lamb carcasses using the Rapid Chill system. **The project's purpose** was to validate the claim: The use of the Rapid Chill System can avoid cold shortening through carcasses hitting 0°C in <5 hours post-mortem across the entire lamb carcass. Carcasses across a wide weight range of 15.2 to 36.2 kilograms and GR fat depth of 3 to 25 millimetres were selected to test the chilling capacity of the Rapid Chill system. Carcasses were paired and split into Con and Fast. Con carcasses were chilled for 24 hours. Fast carcasses were in the Rapid Chill unit for 5 hours then transferred to the Con chillers. In a processing plant these carcasses at <1°C could be processed or loaded out. The 5-hour chilling window was chosen as this is the window where lamb carcasses need to be under 0°C to avoid being cold shortened.

Meat science testing was undertaken to investigate the impact of Rapid Chill on eating quality parameters and business implications. This included pH and temperature decline, carcass shrink, ultimate pH (pH_u), shear force (SF), meat colour, drip loss and purge loss for short loin, topside and bolar blade respectively (*longissimus lumborum* (LL), *semimembranosus* (SM) and *triceps brachii* (TB)).

To understand the financial and business implications from a smallstock processor's perspective, a business case analysis was undertaken, modelling the impact of increasing carcass throughput and reducing carcass shrink compared to conventional chillers, with and without the use of spray chilling, as the Rapid Chill system has a negligible carcass shrink comparable to using spray chilling.

Project content

This project was undertaken to validate if using Rapid Chill cold shortened lamb carcasses and if there were any other negative eating quality attributes from using very fast chilling. These results form the basis of developing a commercialisation strategy by Fresh Xpress and red meat industry partners. The independent eating quality analysis by UNE and financial and business implications by Greenleaf Enterprises was undertaken to underscore industry due diligence in a technology which offers energy efficiency and production throughput gains.

Three probes were placed in each carcass in the loin, topside and bolar blade areas. The temperature was measured every second and the data is graphed in Figure 1.

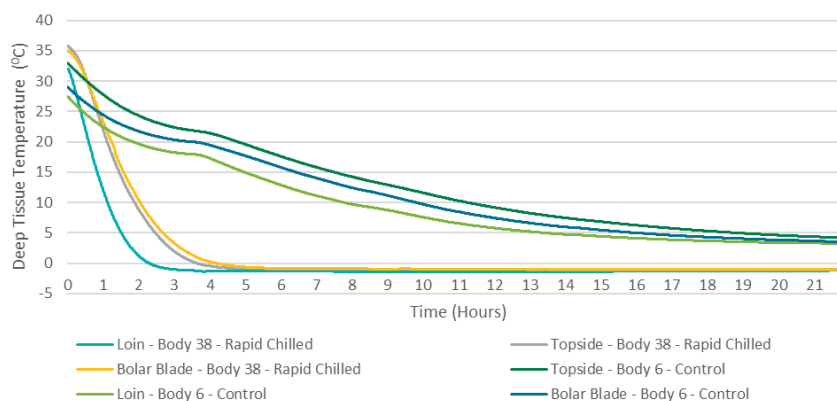


Figure 1: Temperature decline curves of similar sized carcasses under conventional (Con) and Rapid Chilling (Treatment)

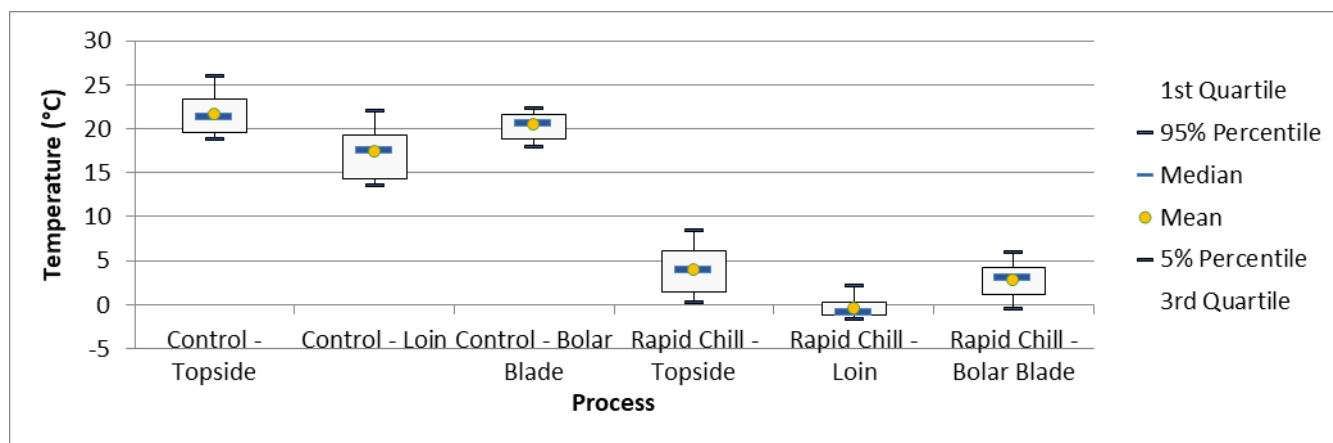


Figure 2: Three hours after embedding temperature probes by carcase location

The control or conventionally chilled group averaged between 17 and 21°C, whereas the Rapid Chill group averaged between -0.47 and 3.99°C for the loin and topside. The loin temperature of carcasses in the rapid chilling tunnel rapidly decreased in temperature with the lighter leaner carcasses decreasing in temperature more rapidly than the heavier, fatter carcasses.

The Rapid Chill system had negligible carcase shrink (0.48%) when the system was optimised. Twenty-four hours postmortem (PM) the pH in the Rapid Chill treatment (5.91) was significantly higher ($P < 0.001$) than that in the conventional treatment (5.82), however by day 5 there was no difference in pHu (Con 5.78 v Fast 5.79). The higher pH of the Rapid Chill treatment lambs is understandable because the cold temperatures reduced the speed of glycolysis and the subsequent production of lactic acid. There were no significant differences detected between Con and Fast chilling for colour brightness, lightness, red-greenness or yellow-blueness, Chroma or hue levels 24 hours PM or day 5 PM for the short loin (LL).

The average purge loss across the 3 muscles for Rapid Chill on day 5 was (8.03%) while the conventional chilling was (5.58%). There were significant differences between muscles, treatments, kill dates and carcasses requiring further analysis the impact the rate of temperature decline has on purge loss. The averaged day 5 drip loss across the three muscle types was 1.12% for the conventional chilling and 1.53% for the Rapid Chilled group.

A significant effect of treatment and muscle interaction ($P < 0.05$) on the SF of the muscles at 5 days ageing was observed. The treatment and muscle interaction effects caused a reduction of 7.1 N in the loin (LL) muscle from the Rapid Chilling (R) treatment group compared to the conventional group after 5 days of ageing as shown in Figure 3, meaning the Rapid Chilled product was more tender.

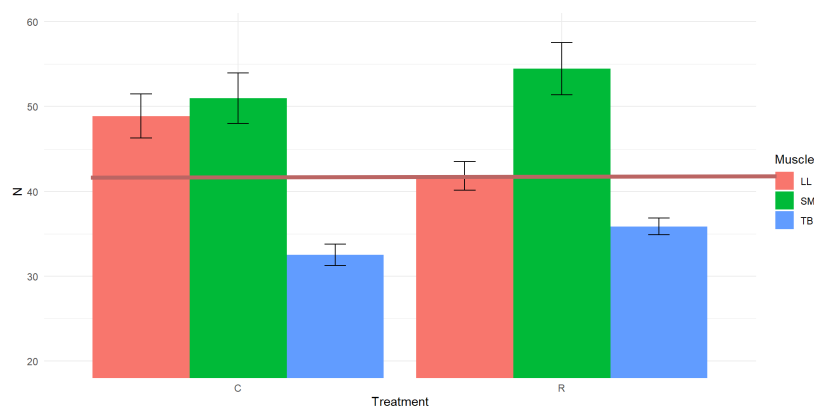


Figure 3: Treatment and muscle interaction effects on SF of the longissimus lumborum (LL), semimembranosus (SM) and triceps brachii (TB) muscles at five days post-mortem

Benefit Analysis

Different scenarios were modelled to calculate the overall plant benefit from installing a Rapid Chill system to chill carcasses. The net benefit for the different scenarios was calculated using industry data at a point in time with mutton carcass sale value at \$3.74/kilogram and lamb carcass sale value at \$11.41/kilogram with an average carcass weight of 22 kilograms per head for both mutton and lamb. Cost per kilowatt for electricity of \$0.15 and conventional shrink of between 2.1% to 3.1% without the use of spray chilling.

7 zone unit - Lamb plant

This scenario is based on a processor purchasing outright a 7-zone Rapid Chill system to chill 972,000 head per year in a single shift.

- Net return of between 1.07 and 1.36-years payback for plants that do not spray chill and between 1.78 and 2.01 years for a plant with spray chilling installed.
- The financial benefit per head varies between \$5.00 and \$9.40/head depending on the differing shrink levels and the throughput benefits.

Table 1: Lamb plant ROI of 7 zone Rapid Chill for carcasses

| SUMMARY PERFORMANCE MEASURES | | | | |
|------------------------------------|--|-------------------|--------------|---------------------------|
| | | No-Spray chilling | | Spray chilling |
| Hd / annum | | 972,000 | | 972,000 |
| | | From | To | From To |
| Capital cost (pmt option, upfront) | | \$9,800,870 | | \$9,800,870 |
| Gross return Per head | | \$7.43 | \$9.40 | \$5.01 \$5.66 |
| Total costs Per head | | \$1.01 | | \$1.01 |
| Net Benefit Per head | | \$6.42 | \$8.39 | \$4.00 \$4.65 |
| Annual Net Benefit for the plant | | \$ 6,240,045 | \$ 8,157,706 | \$ 3,884,159 \$ 4,520,085 |
| Annual Net Benefit for the ex cap | | \$ 7,220,132 | \$ 9,137,793 | \$ 4,864,246 \$ 5,500,172 |
| Pay back (years) | | 1.36 | 1.07 | 2.01 1.78 |
| Net Present Value of investment | | \$40,910,312 | \$54,379,162 | \$24,380,468 \$28,846,948 |

Table 2: Lamb plant business impact of installing 7 zone Rapid Chill for carcasses

| TOTAL BENEFIT | | | | | |
|---------------------------------------|--------------------------------------|-------------------|-------------|----------------|-------------|
| | | No-Spray chilling | | Spray chilling | |
| Benefit summary | | \$/hd From | \$/hd To | \$/hd From | \$/hd To |
| Processing benefits | Reduced Electricity cost | \$1.71 | \$1.55 | \$1.71 | \$1.55 |
| | Reduced carcass shrink | \$3.60 | \$5.10 | \$1.18 | \$1.36 |
| | Gross margin on additional livestock | \$0.45 | \$0.65 | \$0.45 | \$0.65 |
| | Reduced overhead costs per head | \$0.87 | \$1.31 | \$0.87 | \$1.31 |
| | Airfreight \$/kg Differential | \$0.02 | \$0.02 | \$0.02 | \$0.02 |
| | Market Access Price Differential | \$0.28 | \$0.28 | \$0.28 | \$0.28 |
| | Short Life Export Freezing | \$0.45 | \$0.45 | \$0.45 | \$0.45 |
| | Markdowns | \$0.04 | \$0.04 | \$0.04 | \$0.04 |
| Throughput costs - Chiller costs only | | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| OH&S costs | | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| Labour costs | Chiller Automation | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| Equipment costs | Maintenance | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| | Operation | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| \$ Benefit per head | | \$7.43 | \$9.40 | \$5.00 | \$5.66 |
| \$ Annual Benefit overall plant | | \$7,220,132 | \$9,137,793 | \$4,864,246 | \$5,500,172 |

Table 3: 7 zone unit processing plant assumptions

| Plant Specifics | | |
|---------------------------------|--------------|-----|
| System Size | Large System | |
| Percentage lamb processed | 80% | |
| Current daily processing volume | 3,600 | |
| | From | To |
| Increased throughput | 10% | 15% |

7 zone unit – Mutton plant

The benefits for a mutton processor using a 7 zone Rapid Chill unit processing 972,000 head per year, operating a single shift with mutton carcass sale value at \$3.74/kilogram and an average carcass weight of 22 kilograms per head.

- A net return of between 2.50 and 2.89-years payback for plants that do not spray chill and between 1.58 and 2.29 years for a plant with spray chilling installed or are hot boning.
- Benefits per head varies between \$3.48 and \$5.45/head depending on the differing shrink levels and the throughput benefits.

Table 4: Mutton plant ROI of 7 zone Rapid Chill for carcasses

| SUMMARY PERFORMANCE MEASURES | | | | |
|------------------------------------|--|-------------------|--------------|---------------------------|
| | | No-Spray chilling | | Spray chilling |
| Hd / annum | | 972,000 | | 972,000 |
| | | From | To | From To |
| Capital cost (pmt option, upfront) | | \$9,800,870 | | \$9,800,870 |
| Gross return Per head | | \$4.40 | \$5.45 | \$3.49 \$4.03 |
| Total costs Per head | | \$1.01 | | \$1.01 |
| Net Benefit Per head | | \$3.40 | \$4.44 | \$2.48 \$3.02 |
| Annual Net Benefit for the plant | | \$ 3,300,888 | \$ 4,312,791 | \$ 2,406,687 \$ 2,932,907 |
| Annual Net Benefit for the ex cap | | \$ 4,280,975 | \$ 5,292,878 | \$ 3,386,774 \$ 3,912,994 |
| Pay back (years) | | 2.29 | 1.85 | 2.89 2.50 |
| Net Present Value of investment | | \$20,266,909 | \$27,374,089 | \$14,003,325 \$17,699,276 |

Table 5: Mutton plant business impact of installing 7 zone Rapid Chill for carcasses

| TOTAL BENEFIT | | | | | |
|---------------------------------------|--------------------------------------|-------------------|-------------|----------------|-------------|
| | | No-Spray chilling | | Spray chilling | |
| Benefit summary | | \$/hd From | \$/hd To | \$/hd From | \$/hd To |
| Processing benefits | Reduced Electricity cost | \$1.71 | \$1.55 | \$1.71 | \$1.55 |
| | Reduced carcass shrink | \$1.37 | \$1.93 | \$0.45 | \$0.52 |
| | Gross margin on additional livestock | \$0.45 | \$0.65 | \$0.45 | \$0.65 |
| | Reduced overhead costs per head | \$0.87 | \$1.31 | \$0.87 | \$1.31 |
| | Airfreight \$/kg Differential | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| | Market Access Price Differential | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| | Short Life Export Freezing | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| | Markdowns | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| Throughput costs - Chiller costs only | | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| OH&S costs | | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| Labour costs | Chiller Automation | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| Equipment costs | Maintenance | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| | Operation | \$0.00 | \$0.00 | \$0.00 | \$0.00 |
| \$ Benefit per head | | \$4.40 | \$5.45 | \$3.48 | \$4.03 |
| \$ Annual Benefit overall plant | | \$4,280,975 | \$5,292,878 | \$3,386,774 | \$3,912,994 |

Table 6: Mutton processing plant assumptions for modelling

| Plant Specifics | | |
|---------------------------------|--------------|-----|
| System Size | Large System | |
| Percentage lamb processed | 0% | |
| Current daily processing volume | 3,600 | |
| | From | To |
| Increased throughput | 10% | 15% |

All the benefits included are calculated using industry standards from Greenleaf Enterprises. The benefits will vary from plant to plant with the range of benefits realisable by the processing industry shown in Table 7.

Table 7: Average annual gross benefit and Net Present Value (NPV) for each scenario modelled

| Business case scenario | Average Annual Net Benefit | | Average NPV* | |
|--|----------------------------|---------------------|-------------------|---------------------|
| | No Spray chilling | With spray chilling | No Spray chilling | With spray chilling |
| Company purchased system | | | | |
| Single shift lamb plant – based on 7 zone unit | \$ 7,198,875 | \$ 4,202,122 | \$ 47,644,737 | \$ 26,613,708 |
| Single shift mutton plant – based on 7 zone unit | \$ 3,806,840 | \$ 2,669,797 | \$ 23,820,499 | \$ 15,851,301 |
| Small to medium lamb plant (148/hour) – 2 zone unit | \$ 2,461,571 | \$ 1,321,447 | \$ 16,098,479 | \$ 8,107,635 |
| Small lamb plant (40/hour) – Entry level 2 zone unit | \$ 383,374 | \$ 188,784 | \$ 2,395,013 | \$ 1,045,209 |
| Leasing system | | | | |
| Single shift lamb plant – based on 7 zone unit | \$ 5,748,962 | \$ 2,752,209 | \$ 57,445,607 | \$ 36,414,578 |
| Single shift mutton plant – based on 7 zone unit | \$ 2,842,927 | \$ 1,705,884 | \$ 33,621,369 | \$ 25,652,171 |
| Small to medium lamb plant (148/hour) – 2 zone unit | \$ 2,062,371 | \$ 922,247 | \$ 20,098,479 | \$ 12,107,635 |
| Small lamb plant (40/hour) – Entry level 2 zone unit | \$ 267,374 | \$ 72,784 | \$ 3,395,013 | \$ 2,045,209 |

* NPV based on 10 year system life & discount rate of 7%

The lease fees applied to maintain a positive cash flow for the processor was \$2.50/head lamb, \$2/head mutton and for the two zone unit \$4/head.

The benefits included in the analysis are:

- Reduction in electricity consumed within the plant through more controlled chilling and processing of carcasses.
- Reduced carcase shrink through optimisation of the rapid chilling system (down from 2%).
- Increased processing plant capacity due to removal of the chilling bottle neck.
 - Increase gross margin on carcasses currently processed due to a reduction in fixed costs allocation.
 - The gross margin on the additional animals processed, this is based on a 10 to 15% increase in processing capacity.

The benefit cost analysis (BCA) utilised the findings from the meat science research to underpin assumptions in the modelling which was undertaken by Greenleaf Enterprises. The assumptions included:

1. Minimum carcase shrink (weight loss between hot and cold carcasses through chilling)
2. Carcasses can be chilled to <4.0°C within 5 hours in the retrofitted fruit Rapid Chill System. With a purpose built system for carcase chilling, the entire carcase of medium sized lambs can be chilled within 2 hours.
3. Increased processing plant throughput due to reduction in chilling bottlenecks of 10 to 15% which in turn reduces fixed costs per head processed.
4. Reduced chiller energy usage.

Project outcome

The Rapid Chill system enabled very fast chilling of carcasses, defined as reaching a temperature between -5°C to 0°C in the centre of muscle in <5 h post-mortem. Very fast chilling goes outside of the temperature pH decline curve, which is used to identify eating quality traits, for example optimal chilling verses cold shortening which results in a poor eating experience (tough meat).

Processor needs - Australian meat processors are looking for solutions to (1) reduce electricity usage, (2) increase chilled carcass throughput, (3) reduce pressure on existing carcass chiller space, (4) chill offal cartons prior to freezing and (5) reduce the temperature of primals post vacuum sealing and prior to boxing. The Rapid Chill system removes these bottlenecks without needing nitrogen, ammonia glycol or liquid carbon dioxide as the modular system is a stand-alone unit that can be added to the side of an existing processing plant facility.

Trials achieved rapid chilling targets - This research trial was undertaken in a retro-fitted fruit system enabling extensive and detailed meat science data to be collected and analysed on lamb carcasses. The temperature decline showed that smaller carcasses reached 0°C within an hour. The heavier fatter carcasses took longer than 1 hour.

Preliminary meat science results are positive - The Rapid Chill system has demonstrated that it does not cold shorten lamb carcasses and in fact could improve meat tenderness. Detailed analysis and results from UNE indicate a reduction in shear force, an increase in purge with muscle and carcass interactions (meaning further research is needed) and a minimal difference in meat colour. Adjustment to system settings like zone temperature and air speed produced a variation in results that indicate a meat specific multi zone system could be optimised to achieve optimal meat quality results.

Return on investment of \$6.42/hd – depending on the size of plant and mix of business and financing options to determine the payback period. For lamb with a capital outlay there was less than an 18-month payback period.

Modular design applies to 100% of industry – Given the system design concept enables modular configuration a commercial system can be designed and sized for any size meat processing plant.

Development of a commercial prototype is required - A commercial installation is required at a meat processing facility to test and validate shelf life and additional meat quality parameters such as drip loss and purge. The installation would also enable R&D to be undertaken on offal, boned product, mutton carcasses, cartons of hot 6-way mutton and goat.

Commercialisation pathways are developing - Investors were identified who were willing to lease the modular system to processing plants, minimising capital expenditure requirements and allowing adoption to be expedited. Several smallstock processors have expressed interest in being involved in carton and carcass trials if a modular / portable Rapid Chill unit was available with the view to invest in a 7 to 9 zone unit or a 2-zone unit for increasing chilled carcass sales.

Key findings

- **Reduction in carcass shrink.** If spray chilling is being used it is assumed there will be no gain from change in carcass shrink due to the use of Rapid Chill. If spray chilling is not installed or being used carcass shrink will be reduced. The location and configuration of the tunnel will also impact if there is a reduction in carcass shrink.
- **Reduced energy usage** when compared to conventional chilling of carcasses. The following operational implications need to be tested:
 - Rapid chilling of carcasses and boning the following day in alignment with the conventional process flows.

- Rapid chilling of carcasses in a two-shift operation, slaughtering in the morning and boning during night shift, reducing chiller space requirements and enabling carcasses chillers to be turned off overnight.
- Rapid chilling carcasses with an offset time period between slaughter and boning 3 to 4 hours after carcasses enter the chilling unit to enable carcasses to be slaughtered and boned on the same day. This will reduce the carcasses chilling capacity required.
- **Reduced labour** required in the processing plant through the automation of the carcass chilling process. This will be impacted by the different process flows utilised in plant.
- **Throughput increase** by increasing carcass chilling capacity at plants will result in the following benefits:
 - Reduction in fixed cost per head allocation due to increase processing capacity.
 - Increasing plant profits through the increase in carcasses processed.
 - Labour and throughput requirements by the plant will need to be considered as part of a future commercial installation.
- **Quicker time to freeze** carcasses or cartons particularly if previously processing hot or on the curve.
- **Offal temperature reduction:** by designing the tunnel to enable offal chilling simultaneously with carcass chilling:
 - Improved offal quality.
 - Reduced overall freezing capacity requirements as offal temperature is reduced prior to plate or blast freezing – reducing the need for capital investment to cope with additional offal and product volumes packed and frozen.
- **Reduced days aging** - Depending on the 3- and 5-days aging impact on the shear force results, there may also be a benefit of reduced aging requirements for aged frozen products. In that, if there is no difference in the quality of the product between 3 and 5 days (based on the MSA aging requirements), the product could be frozen 2 days earlier, reducing the capacity required in carton chillers.

Benefit for industry

The focus of the commercialisation research has been smallstock plants in Australia. In plants with existing bottlenecks around carcass and carton chilling, this will prevent expanding production to incorporate a second shift if the chilling and cold rooms are already at capacity.

Processing plants have indicated they are looking to install Rapid Chill to take advantage of the increase in demand for chilled carcasses, however, they are restricted by available chiller space inside the processing plant. The ability to install a modular Rapid Chill system on the side of the plant from where chilled carcasses can be directly loaded out provides a solution to the space and logistical bottlenecks.

The installation of a carcass and carton chilling system provides opportunities for processing plants which are primarily focused on frozen products. Improved shelf life due to rapid chilling could enable processing plants to export chilled products and switch from products from frozen to chilled. This requires research to confirm shelf-life impacts of different cuts.

Benefits for industry include:

Rapid Chill provides a lower cost alternative solution for carcase chilling compared to existing technology, with the added benefits of multi-directional circulation of $>-15^{\circ}\text{C}$ air in closed modular units which greatly improves cooling efficiencies in processing plants chilling carcasses to 0°C in less than 3 hours.

Rapid Chill provides the opportunity for industry to:

- Reduce carcase shrinkage in processing plants where spray chilling hasn't been installed (increased saleable meat yield by 2% per animal chilled using the Rapid Chill instead of using conventional chillers). It is anticipated that conventional chillers will be used to hold carcasses at $0-2^{\circ}\text{C}$, rather than needing to chill carcasses from 36°C to 2°C .
- Reduce energy usage, water for cleaning and carbon footprint for chilling carcasses.
- Processing plants can turn chillers off on weekends.
- Increase throughput of processing plants which have bottlenecks in chillers, carcase cold rooms and freezing capacity – to expand capacity using external module units. Increase in profitability for processing plants based on increased throughput achieved.
- Processing plants which are space constrained have mentioned they would expand boning and value adding into existing chiller space that would no longer be needed.
- Reduction in capital expenditure required to improve throughput based on installation of new cold rooms and chillers using the existing technology.
- Increased shift flexibility as processing plants are not waiting for carcasses in chillers to reach temperature to start boning.
- Increase in sales of chilled carcasses rather than frozen carcasses due to ability to load from end of the 7-zone unit directly into shipping containers and trucks for airfreight and delivery to customers.
- The modular units allow expansion and adjustment and can be used for cartons or carcasses depending on system design. They can be retrofitted for carcase or carton as the processing plant changes and invests in different technologies. The use of the units for chilling of meat and offal hasn't been tested although the unit was originally built for horticultural products packed in cartons and trays.

Rapid Chill has no requirement for liquid nitrogen, liquid carbon dioxide or ammonia glycol.

Useful resources

Fresh Xpress website with reports and analysis: <https://fresh-xp.com/>

Jacob, R. & Beatty, D. 2007 The potential of using very fast chilling systems for processing red meat, Meat and Livestock Australia Limited, Sydney,
www.mla.com.au/contentassets/c3dc562be290487db3811c33fec16cd2/p.psh.0267_very_fast_chilling_final_report.pdf