final report

Project code: V.RMH.0096

Prepared by: Patrick Youil, François Tabbakh
Ready Retail Operations Australia Pty Ltd

Date published: 5 December 2020

PUBLISHED BY
Meat and Livestock Australia Limited
PO Box 1961
NORTH SYDNEY NSW 2059

Mince Cooling by Liquid Nitrogen Phase 1 feasibility

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

This publication is published by Meat & Livestock Australia Limited ABN 39 081 678 364 (MLA). Care is taken to ensure the accuracy of the information contained in this publication. However MLA cannot accept responsibility for the accuracy or completeness of the information or opinions contained in the publication. You should make your own enquiries before making decisions concerning your interests. Reproduction in whole or in part of this publication is prohibited without prior written consent of MLA.

Abstract

Ready Retail Operations Australia (RROA) uses liquid carbon dioxide (CO_2) for cooling minced meat during the mixing process prior to packaging. There are limited sources of supply for carbon dioxide and historically interruptions to these have occurred, impacting downstream user's operations. Business continuity planning is required for the event of supply interruption to carbon dioxide.

This project will trial and investigate the use of liquid nitrogen as an alternative coolant to carbon dioxide. Equipment modifications, production testing and food safety testing is required to ensure liquid nitrogen can be effectively used as an alternative coolant in the production of minced meat.

The use of liquid nitrogen for red meat mince cooling will be the first of its kind using the Coregas-Marel cooling solution in centralised value-added red meat processing in Australia. This will provide a business continuity plan for this high volume red meat product range in the event of carbon dioxide being unavailable, this contingency will be applicable to the wider red meat processing industry. The alternative cooling agent provides risk mitigation that will ensure customers always have available a high quality minced meat range at a consistent prices, providing customer value, satisfaction and maintaining red meat sales.

Executive summary

The current project was a case study pilot review of current nitrogen gas usage in plant chilling operations for the production of minced meat. Production trials were successfully completed and results have confirmed feasibility and indicate positive potential on both productivity and quality perspectives.

This concludes the feasibility phase, going forward it is proposed to pursue the evaluation of nitrogen cooling on a larger scale. A new project has been proposed for full scale production trials aimed at better defining consumption and coolant efficiency of liquid nitrogen compared to CO_2 in a full range of red meat mince cooling applications. This data will allow a reliable cost benefit analysis to be performed and enable Coles RROA to make a well-informed decision on the choice of primary coolant.

The positive results reported above confirm feasibility and indicate nitrogen may be a suitable alternative coolant to be used as a contingency in case of CO_2 shortage.

RROA is proposing to proceed with full scale trials, these would allow the validation of assumptions on the effects of different mince grades and species, confirm long term operability, and provide data for a cost benefit analysis.

Table of contents

1 Project Scope and purpose

1.1 Background

In large scale production of minced meat, liquid carbon dioxide (CO_2) is used for cooling the product during the mixing process prior to packaging. The cost impact to Coles Ready Retail Operations Australia (RROA) for lost sales due to the non-supply of minced meat for just one day would be significant. The non-supply would also have a negative response from consumers, who may direct their purchasing away from red meat. Minced meat is processed by adding liquid carbon dioxide in the mixing process in order to chill the product to the required temperature prior to forming minced portions for packaging. Coles RROA identified to MLA the commercial risks to current mince production due to the limited sources of carbon dioxide historically known to suffer interruptions impacting various end users' operations. The volatility of supply of carbon dioxide creates uncertainty with meeting supply demand planning requirements of red meat mince product lines. 3 grades of beef mince currently represent a large portion of supermarket sales plus utilise block trimmings each day.

Business continuity planning is required in consideration of a supply interruption to carbon dioxide, the desired outcome of this feasibility project aligns with MLA's Product and Packaging Program which considers new science and technology platforms, and demand imposts and opportunities for Australian red meat industry. The use of liquid nitrogen for red meat mince cooling will be the first of its kind using the Coregas-Marel cooling solution in centralised value-added red meat processing in Australia and will provide a business continuity plan for this high volume range of red meat in the event of carbon dioxide being unavailable, if successful this contingency measure would be applicable to the wider red meat processing industry. The alternative cooling agent provides risk mitigation that will ensure customers always have available a high quality minced meat range at a consistent quality, shelf life and price, providing customer value, satisfaction and maintaining red meat sales with in-stock position and ranging.

Currently liquid carbon dioxide (CO_2) is used for cooling minced meat as it is mixed in the Mixer Blenders and Grinders. This project will complete preliminary trials on beef variants in one of Coles RROA's Marel mixer using liquid nitrogen. Liquid nitrogen will be procured and, in place of CO_2, injected into the mixers over a mixing cycle to cool the product to approximately -1 deg C.

1.2 Project description and purpose

Fresh mince is a leading product item in supermarkets in Australia, with many meal occasions using beef, veal and lamb variants. In-stock position, reducing markdown rates and maintaining cherry red colour bloom and shelf life during display are key criteria for maintaining supply and growing demand for Australian red meat. For case ready manufacturing sites, temperature control during grinding meat and portioning mince into retail ready packs is a key parameter along with the latest equipment, packaging and refrigeration technology and cold-chain practice. For companies such as Coles Retail Ready Operations Australia (RROA), this is applied using carbon dioxide (CO2) which whilst has a proven quality outcome, represents a price cost of doing business price list if no other technical process or gas input (coolant) alternatives exist and are demonstrated as viable to ensure delivery of ground meat.

In turn, this project will evaluate the feasibility and business case for the use of Liquid Nitrogen (N2) as an alternative coolant to carbon dioxide in meat processing for ground meat products such as minced beef and lamb. A detailed work schedule will be developed for the required equipment modifications including detailed specifications, production testing and food safety testing to ensure liquid nitrogen can be effectively used as an alternative coolant in the minced meat process. The outcome of this feasibility will provide a detailed report on the business case, outcomes on initial pilot trials and a detailed work schedule including recommendations (where required) for a first to market phase 2 scale up commission & evaluation study in a commercial mode.

1.3 Current Gas Supply (case study – Coles RROA)

One of the main sources of CO_2 in Australia comes from the manufacture of ammonia fertiliser where CO_2 is a by-product. There are two manufacturers of CO_2 feedgas in NSW located at Kooragang Island, Newcastle and a second at Nowra. There are other plants on Gibson Island in Brisbane and Melbourne. Air Liquide and BOC process CO_2 and supply it to industry throughout Australia.

CO_2 is a product that is in high demand particularly in the food and beverage industry. Processes such as soft drink carbonisation, breweries, sanitation, meat cooling and modified air packaging applications all consume CO_2 supplies. The supply of CO_2 is totally dependent on the consistent operation of the limited number of fertiliser plants around Australia. In the past when an ammonia fertiliser plant has been unable to supply CO_2 to BOC or Air Liquide, there have been supply ramification to end users. This has seen end users needing to limit or even stop production.

Outages of CO_2 supply from the ammonia fertiliser plants can be drawn out for months. A recent example of CO_2 supply issues is in Western Australia where CSBP (Wesfarmers), the sole fertiliser plant, was unable to manufacture CO_2 after an unplanned shutdown in Feb 2018. Subsequently, the company noted it would take months to repair the equipment. This outage lasted several months longer than expected and forced industrial gas suppliers to mitigate the situation by importing CO_2 and using supplies from eastern states. Outages were also experienced in Queensland during the first half of 2018, which affected ACC's production to process meat and manufacture minced meat.

In 2012 Orica's Kooragang Island plant had an outage at the same time as CO_2 producers in Victoria, Origin and AWE's Lang Lang facilities had a shutdown for 4 months to undertake a plant upgrade. Beverage companies in NSW and Victoria had to restrict production for several months due to the limited supply of CO_2. Furthermore, in 2018 during the summer, Europe and the UK experienced severe shortages of CO_2 which in some cases caused production to stop at meat processors. The shortage was due to fertiliser plant slowing or stopping production due to the low prices for fertilisers and over supply.

RROA's two main mince lines operate every day using the Marel mixers with liquid CO_2 cooling. If an outage caused shortage of CO_2, the industrial gas supplier would most likely implement supply from interstate. Such supply would however be subject to restrictions given the number of businesses and operations also relying on the same supply.

There is a latent risk to the production of minced meat based on the dependency of CO_2 for mince cooling. The eventuation of that risk would lead to potential major business costs and disruption. RROA has identified this and decided to work on a business continuity plan for this major product line. Liquid nitrogen is currently used as an alternative coolant in Europe. This has been mainly in the poultry industry for chicken nuggets and pieces. Liquid nitrogen has been used as a coolant in Australia since 2013 and also in America for a greater length of time. Liquid nitrogen has been primarily used in poultry processing, and since 2013, its inception as a product coolant in Australian meat processing for QRS markets. This project will provide new knowledge for Coles RROA and wider Australian red meat industry on its further feasibility.

2 Project objectives

The overall goal of this feasibility project is to gain a preliminary understanding for use of liquid N_2 compared to CO_2 as a coolant in ground meat. This will inform recommended next steps, including business case in terms of cost of doing business, capital outlay, gas supply (and business planning and risk mitigation) and resultant product quality and shelf life from the new treatment (inclusion of liquid N_2 in mince). This will include Coles RROA coordinating and delivering a series of trials and completing a case study report (and delivering a demo day) that includes:

- An overview of retail ready mince (beef and lamb) and the use of coolants such as CO_2 (current practice in Australia) and liquid nitrogen (including European applications in chicken and the why, what, how is planned for evaluation in this project)
- Preliminary test and compare the quality, yield, cost and shelf life of minced beef with liquid nitrogen vs CO_2 coolant. Present key findings and describe key process specifications for its application and define a list of potential supply partnership options for liquid nitrogen supply and equipment / process modifications to current mode of operations and supply. Include a review of Food safety and OH&S and Australian Food labelling laws compliance for its possible inclusion.
- Complete a business case – cost benefit analysis and next step recommendations that considers technical feasibility, commercial viability (including CAPEX, production planning, contingency planning) and desirability (customer feedback that product quality is comparable and able and willing to change to liquid nitrogen from only CO_2 as a coolant).

3 Methodology

3.1 Trial Preparation and Support

3.1.1 Mince Mixer

One of RROA's Marel mince meat mixer was temporarily fitted with a new coolant injection manifold designed for liquid nitrogen. Marel supplied and installed the new manifold, upgraded the injection cooling control software, and provided technical assistance during the trial (see Photo 1).

Marel mixer

Nitrogen manifold inside mixer

Nitrogen supply lines to mixer manifold

Photo 1: Marel minced meat mixer temporarily fitted with a new coolant injection manifold designed for liquid nitrogen with supply lines installed.

3.1.2 Liquid Nitrogen Supply

Coregas, a specialised supplier of industrial gases and related equipment, provided liquid nitrogen via portable holding tanks along with all necessary valving and connection hoses to supply the injection manifold (see Photos 2 and 3). Coregas also provided onsite technical support and guidance on material and equipment handling during the trials.

Photo 2: Vacuum jacketed liquid nitrogen vessels.

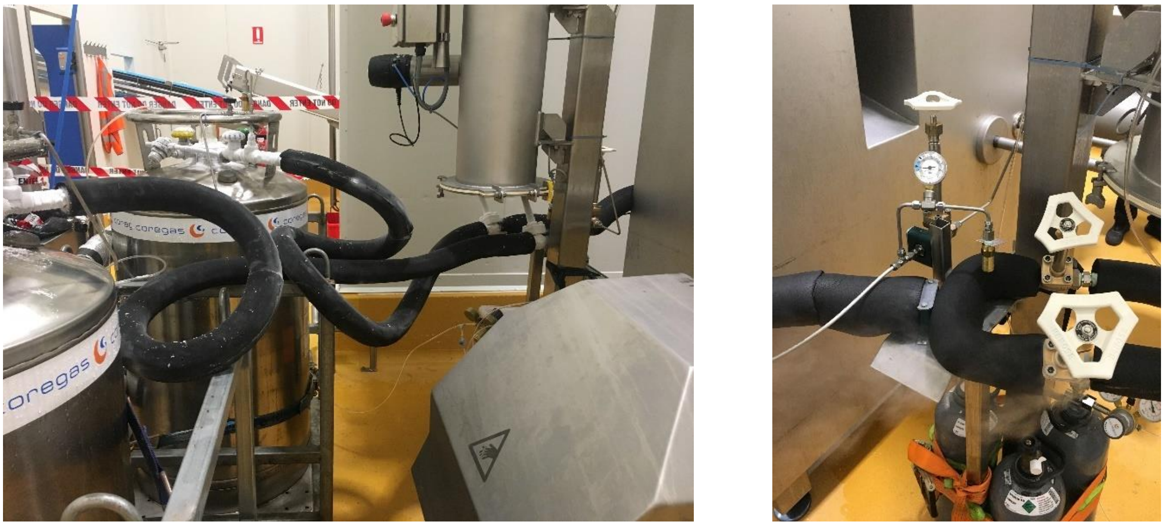

Photo 3: Nitrogen vessels and supply piping.

3.1.3 Safety Review

An internal safety review committee signed off on the final trial equipment setup, operation plan, and required safety procedures. Technical guidance on the required safety measures was also provided by both industry specialists Coregas and Marel (see Photos 4 and 5).

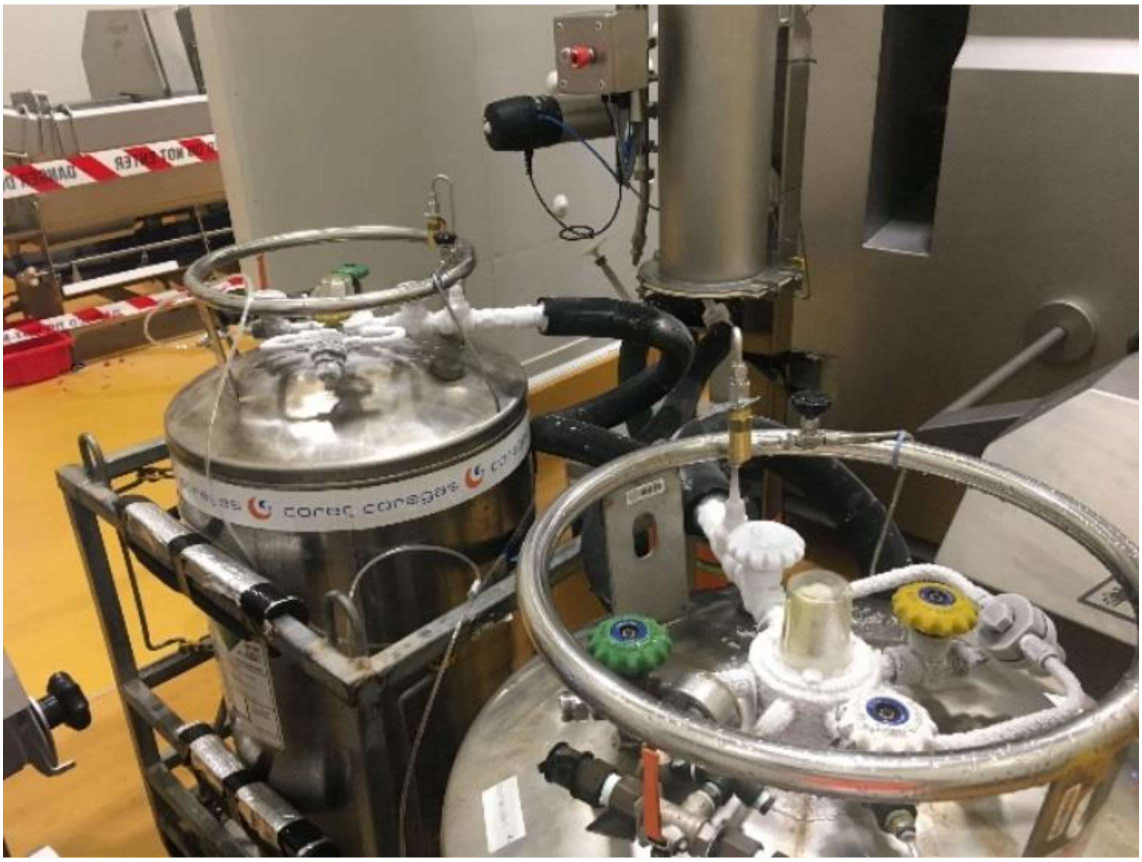

Photo 4: Safety perimeter around nitrogen vessels and mixer.

Photo 5: Continuous monitoring of oxygen levels.

3.2 Trial Execution

Given that the use of liquid nitrogen for mince meat cooling is new for RROA, the trial aimed to ascertain any impact on production process effectiveness and product attributes. Productivity and quality attributes were measured on 85 CL grade beef mince production (see Photos 6, 7, 8 and 9).

Photo 6: Mixer interface screen used for monitoring cooling cycle

Photo 7: 3 star 85CL Beef mince

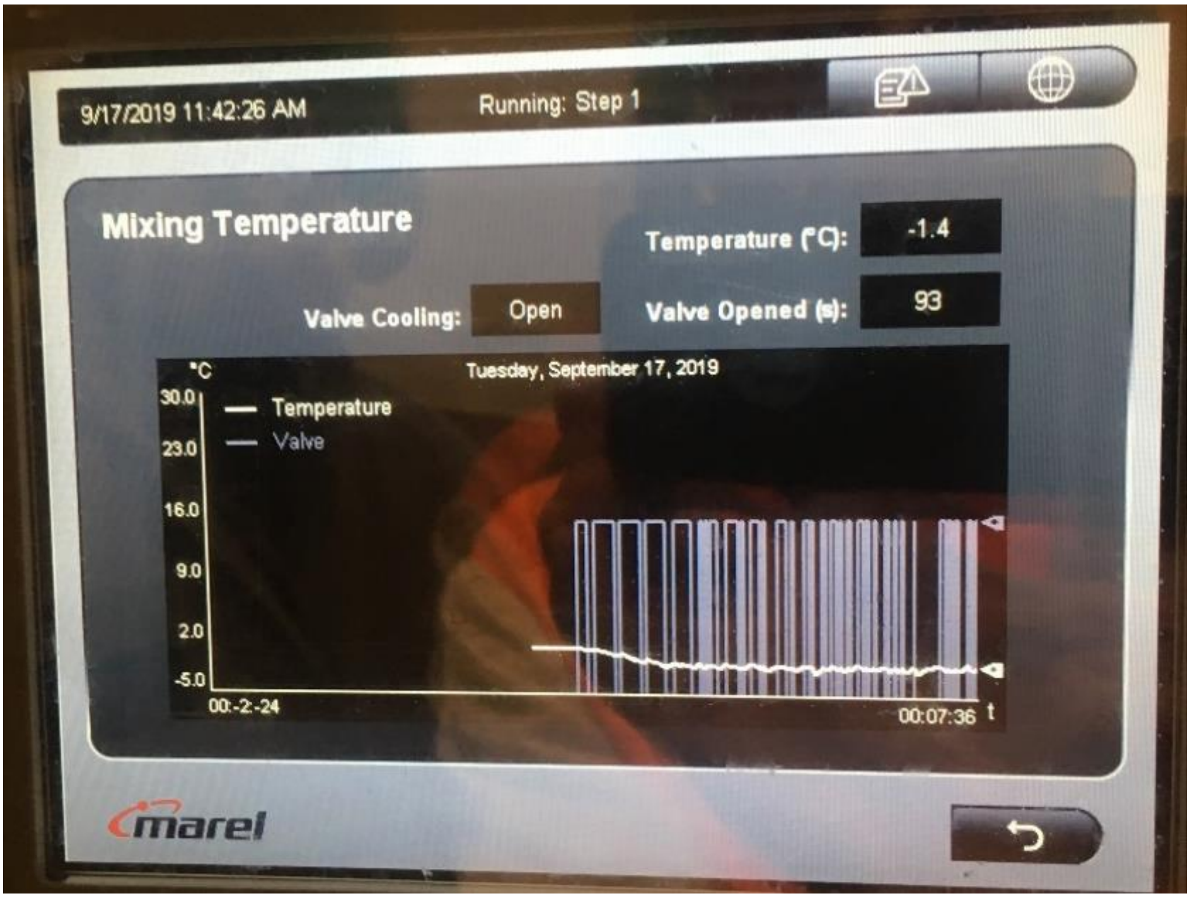

Photo 8: Mixer software controlling coolant injection to reach temperature setpoint.

Photo 9: Nitrogen gas vented from mixer to exhaust system.

The trial confirmed suitability of liquid nitrogen as a coolant for mince production by successfully cooling the mince to the required temperature. Preliminary observations during the trial indicate there were no negative impacts on productivity or product quality attributes (see Photo 10).

Photo 10: Final temperature verification

Approximately 3.5 tonnes of mince were produced during the trial, the product was packed in non-branded MAP packaging. Microbiology analysis of samples indicated good results in line with regular product standards, based on these results the packs were donated to Foodbank (see Photo 11).

Photo 11: Packed product from trial to be donated to Foodbank.

4 Summary of Key Findings

Production trials were successfully completed and the results indicate it is feasible to use liquid nitrogen to cool mince without negative impacts to the quality of the product.

However due to the limited size of the portable vessels used to supply liquid nitrogen, the preliminary trial could only cover a series of three batches. The cooling efficiency, measured in kilos of liquid nitrogen required to cool one tonne of mince, reduced considerably with each subsequent batch. This can be attributed to the initial cooling of the mixer which acts as a heat sink on start-up, the same effect occurs with the use of CO_2. Not reaching steady operation has limited the evaluation of performance, associated cost benefits, and observation of any effects from prolonged use.

Based on this Coles RROA has put forward a business case to proceed to the next phase of evaluation consisting of full scale production trials. This will require installation of new supply piping and modifications to the mixers enabling the use of either CO_2 or nitrogen as a coolant in mince mixing.

4.1 Quality

A full quality assessment has been conducted on the trial samples, the results from shelf life, microbiology analysis, and organoleptic evaluations all indicate no notable difference compared with the CO_2 baseline standard results.

4.2 Productivity

Data gathered during the limited small scale trial indicates the nitrogen cooling system has the potential to match the performance of the CO_2 system in terms of productivity, cycle time, and operability.

It is estimated the trends observed with 85CL beef mince will be similar on other beef grades and species, this assumption will need to be validated in the next phase.

The required manifold changeover for conversion between coolants was a relatively simple operation which should be easy to perform for production technicians. A procedure will need to be developed to define coolant line isolation sequence and changeover procedure to ensure efficient and safe work methods are used.

5 Discussion

Unlike CO_2, nitrogen cannot be maintained in its liquid state by pressurising the vessel or piping, it is maintained at -196 degrees C and in its liquid state by allowing a portion of the liquid to constantly vaporise (boil off). To minimise losses, the industry standard is to use vacuum jacketed piping which provides approximately 20 times the insulation performance of polyurethane foam. As a general rule, 10% loss due to vaporisation in storage and distribution is to be expected.

Both Marel and Coregas have reported instances of some other sites globally experiencing productivity losses with the use of nitrogen due to the presence and build-up of gaseous nitrogen in the liquid supply piping system (note this has not been reported in Australia). This may be due to design flaws, inadequate insulation, or poor understanding of liquid nitrogen handling requirements. During the trial, a manual gas purge system was used to ensure the liquid phase was supplied to the mixer for injection. The supply lines were also kept to a minimum length to minimise vaporisation of the liquid in the flexible hoses. To support full scale production, the design of permanent piping installations will need to consider vacuum insulation of the pipework as well as gas purge valves at key locations in the pipework to ensure consistent liquid supply to the mixers and minimal vapour losses.

6 Conclusions/recommendations

6.1 Conclusion

As outlined above, production trials were successfully completed and results have confirmed feasibility and indicate positive potential on both productivity and quality perspectives.

This concludes the feasibility phase, going forward it is proposed to pursue the evaluation of nitrogen cooling on a larger scale. A new project has been proposed for full scale production trials aimed at better defining consumption and coolant efficiency of liquid nitrogen compared to CO_2 in a full range of red meat mince cooling applications. This data will allow a reliable cost benefit analysis to be performed and enable Coles RROA to make a well-informed decision on the choice of primary coolant.

6.2 Recommendations

The positive results reported above confirm feasibility and indicate nitrogen may be a suitable alternative coolant to be used as a contingency in case of CO_2 shortage.

RROA is proposing to proceed with full scale trials, these would allow the validation of assumptions on the effects of different mince grades and species, confirm long term operability, and provide data for a cost benefit analysis.

Based on manufacturer consumption guidelines and current fluid costs, there is a potential for nitrogen consumption costs to breakeven with that of CO_2. This means liquid nitrogen could become the preferred coolant and CO_2 would become the contingency in case of nitrogen supply or system issues.

This is of high interest as change to nitrogen would be a major sustainability improvement by elimination of over 1000 tonnes of carbon dioxide emissions per year. This aligns with Coles Group values and sustainability objectives as well as growing interest from consumers. To support full scale production, the design of permanent piping installations will need to consider vacuum insulation of the pipework as well as gas purge valves at key locations in the pipework to ensure consistent liquid supply to the mixers and minimal vapour losses.

It is estimated the trends observed with 85CL beef mince will be similar on other beef grades and species, this assumption will need to be validated in the next phase. The required manifold changeover for conversion between coolants was a relatively simple operation which should be easy to perform for production technicians. A procedure will need to be developed to define coolant line isolation sequence and changeover procedure to ensure efficient and safe work methods are used.