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AUSTRALIAN Pork

Chiller management – delivering processing efficiencies.

Final Report
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Executive Summary

When circulation of blood within the body is stopped substantial change in the metabolism of muscle occurs. The inability to remove lactate from cells results in the pH of the muscle falling, commencing the conversion of muscle to meat. The rate and extent of pH decline post-slaughter influences ultimate meat quality, with these factors determined by the condition of the muscle at stunning.

A sudden drop in muscle pH will cause denaturation of proteins within muscles reducing the water-holding capacity of meat, resulting in PSE pork of inferior eating quality. Whilst muscles with high glycolytic potential sees the pH continue to decline to where it approaches the isoelectric point of muscle reducing water-holding capacity.

The purpose of chilling is to remove heat from the carcase after slaughter to improve shelf-life and control the rate and extant of pH decline. Lowering the temperature of the muscle controls pH decline through slowing the metabolic processes and thus reducing the rate of lactate production. The decline of pH in pork is more rapid when compared to other red meat species, due to the higher proportion of white, type IIb muscle fibres with a higher glycogen content resulting in low ultimate pH. Therefore, rapid chilling of the muscles is required to prevent low ultimate pH.

Blast or quick chill systems consist of two distinct phases of cooling – quick chill and then equalisation. Working on a continuous chain, the quick chill tunnel subjects the carcase to below-freezing temperatures and very fast air velocity upon exit from the slaughter floor for 1 to 3 hours followed by equalisation chillers where they are held at low temperature and low air velocity. Whereas, conventional chilling, as used by the majority of Australian pork abattoirs, sees batches of pigs placed within a chiller 45 minutes post-slaughter and subjected to temperatures of 0-3°C and fast fan speeds, often in a stepped manner, for 12 to 24 hours.

The objectives of this project were to optimize chiller operations of a new, to Australia, carcase chilling system using a combination of quick chill and equalisation chillers, and to determine differences in temperature and pH declines.

Since October 2019, the SunPork Group abattoir has been operating with a back-loading group CO_2 stunner, combined with a quick chill tunnel and equalisation chiller combination. There has been a clear improvement in outcome with the new system, with the higher initial pH from reduced stress associated with group stunning and the rapid chilling of the carcase resulting in an ultimate pH that is approximately 0.2 units higher.

Increased cooling of the carcase being reflected in a slower rate of pH decline is further observed when looking at light versus heavy carcases, with the greater tissue mass of the larger carcase slowing the rate of muscle cooling resulting in a faster rate of pH decline when compared to the rapidly chilling lighter carcase. This effect is also observed in differences between the temperature and pH decline when comparing the loin muscle to those of the larger ham.

An advantage of this system is that each carcase is chilled optimally. In conventional chilling carcases are loaded into a chiller over a period of time and therefore subject to the conditions of the chiller open entry, whereas each carcase enters the quick chill tunnel at the same time post-slaughter, is held at lower temperatures and enters the equalisation chillers at the same time after they are killed. This will reduce the variation in carcase quality.

This project shows that improvements seen in ultimate pH, and therefore meat quality, that are achieved when single-file stunners are replaced with group-stunning systems can be further enhanced through the implementation of a chilling system that utilises a combination of quick chill and equalisation.

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1. Background to Research

When the circulation of blood within the body is stopped because of sticking it initiates substantial change in the metabolism of muscle tissue. Amongst other consequences, the cessation of oxygen supply results in glycogen metabolism shifting to anaerobic pathways, ultimately resulting in the production of lactate. With the ability to remove this lactate from cells also halted by the lack of blood flow, the pH of the muscle begins to fall, commencing the conversion of muscle to meat.

Both the rate and extent of pH decline post-slaughter have the ability to influence ultimate meat quality, with these factors determined by the physiological condition of the muscle at the time of stunning. A sudden drop in muscle pH immediately after slaughter while the body is still warm will cause denaturation of proteins within muscles (Bowker *et al.*, 2000) reducing the water-holding capacity of meat, resulting in what is referred to as Pale, Soft, Exudative (PSE) pork of inferior eating quality. Whilst muscles with a high glycolytic potential, can have a normal rate of pH decline, but the pH continues to decline to low ultimate pH values and as it approaches the isoelectric point of muscle the water-holding capacity reduces dramatically (McKeith *et al.*, 1998).

Whilst there are specific genotypical differences, such as the "halothane gene" and the Rn- gene (Salas and Mingala, 2017) that have known influence on energy metabolism in both live and post-mortem muscles and can be selected against, differences in the response to handling and slaughter can be observed in genotypes or populations. Modern processing facilities are designed to reduce these pre-disposing factors through lairage design, environmental control and improved handling in the period prior to stunning, with Matthews *et al.* (2019) showing a significantly higher initial pH when pigs were group stunned when compared to single-file stunning. Whilst effective chilling systems to remove heat from the carcase can be used to control the rate of pH decline and the ultimate pH reached.

The purpose of chilling is to remove heat from the carcase after slaughter to improve shelf-life (McNeil *et al.*, 1991) and control the rate and extant of pH decline (Springer *et al.*, 2003). Heat is present from the living animal itself as well as the hydrolysis of ATP during anaerobic muscle metabolism (de Meis, 2001). Lowering the temperature of the muscle controls pH decline through slowing the metabolic processes and thus reducing the rate of lactate production, reducing the severity of protein denaturation, maintaining water holding capacity.

The decline of pH in pork is more rapid when compared to other red meat species, due to the higher proportion of white, type IIb muscle fibres with a higher glycogen content (Channon and Warner, 2011), with ultimate pH as low as 5.3 to 5.4 being observed in Australia (Jose, 2013). Therefore, rapid chilling of the muscles is required to prevent low ultimate pH.

The mechanism of chilling occurs concurrently through both convection and conduction in the pork carcase (Huff-Lonergan and Page, 2006). Convection occurs because of the warmer carcase 'losing' heat to the environment, with both the difference in temperature between the carcase and the environment and the speed at which the environment moves other the carcase influencing the rate of chilling. Conduction transfers heat within the carcase, as heat from the centre of the carcase moves to the cooler surface, again the temperature gradient influences the rate at which this transfer occurs.

Conventional chilling, as used by the majority of Australian pork abattoirs, sees batches of pigs placed within a chiller 45 minutes post-slaughter and subjected to temperatures of 0-3°C and fast fan speeds, often in a stepped manner, for 12 to 24 hours (Channon and Warner, 2011). Depending on chiller management practices and the size of the chiller, carcases may experience a period of warmer temperatures before the program is 'activated', or may not receive the full steps if they arrive into the chiller after the chill cycle has commenced.

Blast or quick chill systems have been adopted in many overseas markets and consists of two distinct phases of cooling – quick chill and then equalisation. Working on a continuous chain, the quick chill tunnel subjects the carcase to below-freezing temperatures (-20 to -40°C) and very fast air velocity (up to 5 times faster than conventional chilling) upon exit from the slaughter floor (within 45 minutes post-sticking) for 1 to 3 hours (Huff-Lonergan and Paige, 2006), and then entering equalisation chillers where they are held at low temperature (1-3°C) and low air velocity.

Rybarczyk *et al.* (2015) split sides between blast and conventional chilling and showed loin muscle temperatures of 16.26°C in blast chilling compared with 30.27°C in conventional chilling two hours post-sticking when the carcases exited the blast chill, with a resultant pH difference 6.02 *c.f.* 5.84 at this time. Temperature and pH differences continued at 6 hours post-sticking but did not differ between treatments at 24 hours. Blast chilling resulted in significantly darker meat (L* 55.06 *c.f.* 57.32), with lower 48h drip loss (2.98 *c.f.* 3.72) although sensory tenderness score was reduced (3.45 *c.f.* 3.86). Juárez *et al.* (2009) showed similar differences in 48h drip loss (3.75 *c.f.* 4.17), with no differences in sensory characteristics. Matthews *et al.* (2019) also showed that the benefits of group stunning on initial pH was only maintained through to ultimate pH when aggressive chilling was applied.

The SunPork Group commissioned a quick chill and equalisation chilling system in October 2016 and this report highlights the work undertaken to optimize chiller operations.

2. Objectives of the Research Project

The objectives of this project were to optimize chiller operations of a new, to Australia, carcase chilling system using a combination of quick chill and equalisation chillers, and to determine differences in temperature and pH declines.

3. Results

The collection of data on common populations of pigs, although with potential changes due to genetic selection programs, allows us the opportunity to understand how different systems can influence objective measures of meat quality. Channon *et al.* (2018a; 2018b) collected pH and temperature declines of carcases subjected to different farm and abattoir management practices when SunPork operated an abattoir that employed a single-file, side-loading CO_2 stunner, with conventional chilling post-slaughter (Figure 1). The ultimate pH in these studies is in line with industry expectations at the time (Jose, 2013) with pH values of 5.5 or less 24 hours after sticking, well below the "ideal" range of 5.7 - 6.1 (PIC, 2003), although these low values were not commonly associated with evidence of PSE.

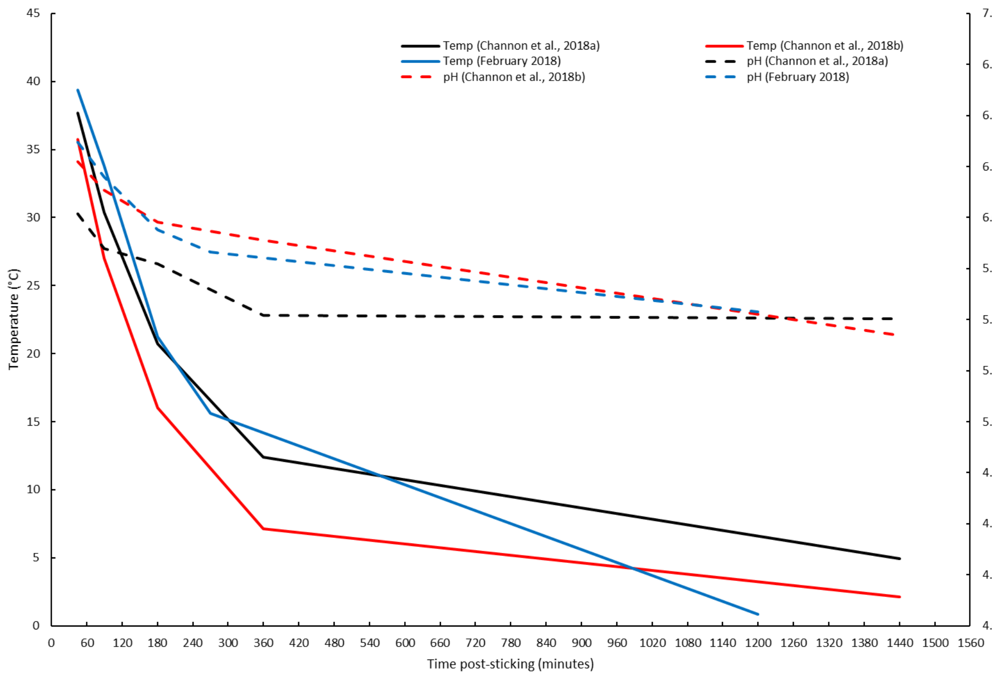

Figure 1. Loin pH and temperature profiles of carcases stunned utilising a side-loading single file CO_2 stunner and chilled under conventional chilling (Channon et al., 2018a (black); Channon et al., 2018b (red); unpublished data (blue)).

Since October 2019, the SunPork Group abattoir has been operating with a back-loading group CO_2 stunner, combined with a quick chill tunnel and equalisation chiller combination. Whilst acknowledging the potential issues with comparing data across separate time periods, let alone systems, there is a clear improvement in outcome with the new system (Figure 2). The higher initial pH from reduced stress associated with group stunning and the rapid chilling of the carcase results in an ultimate pH that is approximately 0.2 units higher.

This effect of increased cooling of the carcase being reflected in a slower rate of pH decline is further observed when looking at light versus heavy carcases (Figure 3). The greater tissue mass of the larger carcase slows the rate of muscle cooling resulting in a faster rate of pH decline when compared to the rapidly chilling lighter carcase, where the initial pH decline is arrested as the muscle rapidly reaches temperatures below the critical temperature for metabolism to continue. This effect is also observed in differences between the temperature and pH decline when comparing the loin muscle to those of the larger ham (Figure 4).

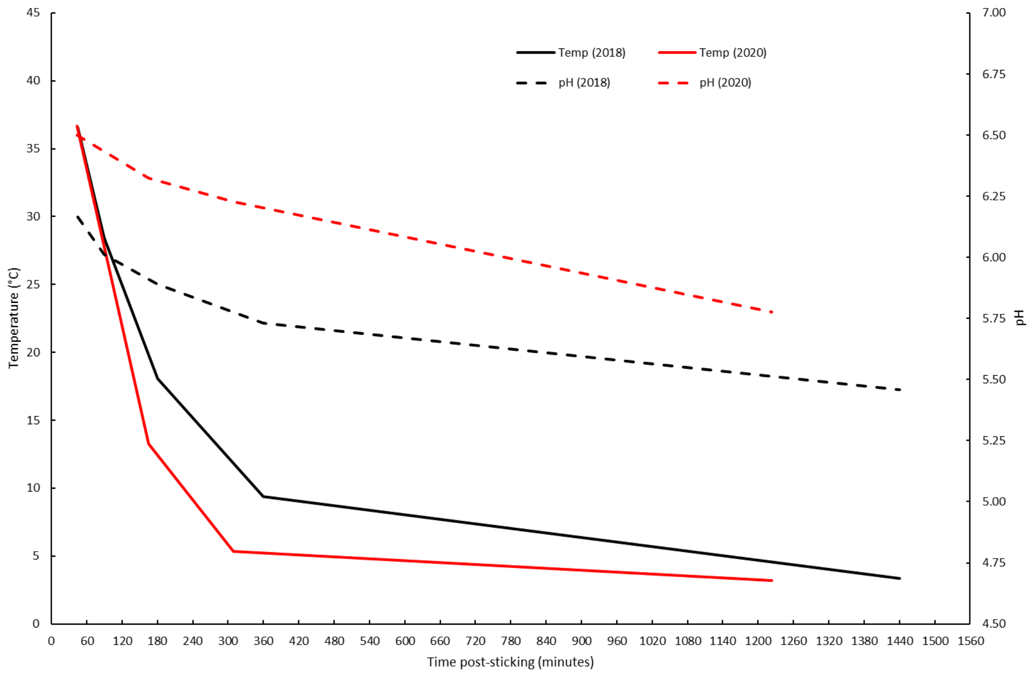

Figure 2. Loin pH and temperature profiles of carcases stunned utilising a side-loading single-file CO_2 stunner and chilled under conventional chilling (2018, black) compared to carcases stunned utilising a back-loading group CO_2 stunner and chilled using a quick chill tunnel and equalisation chiller system (2020, red).

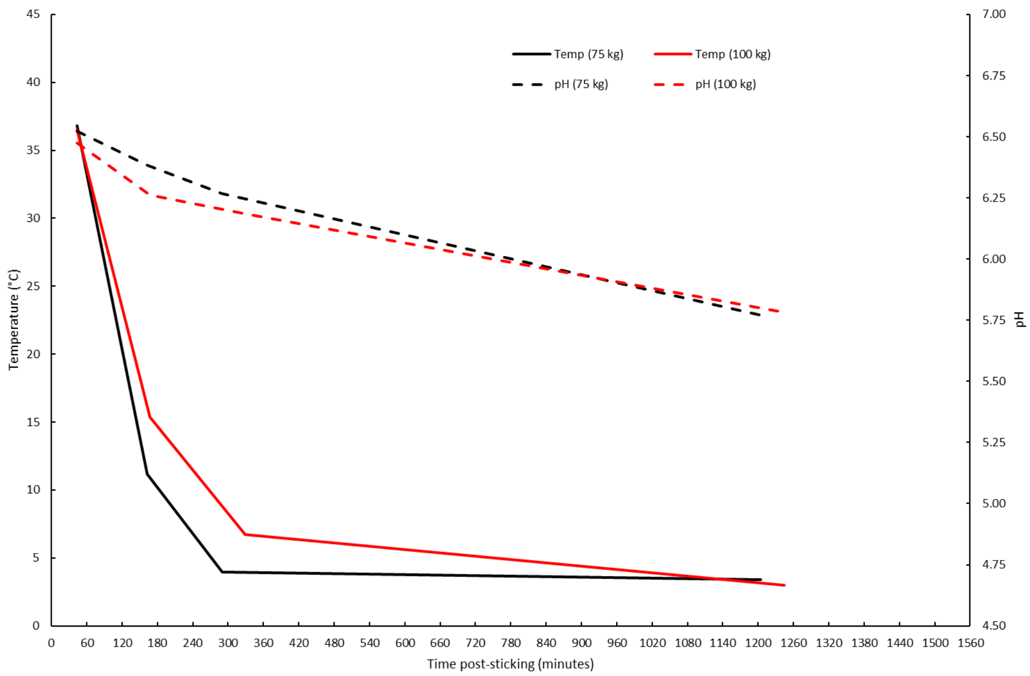

Figure 3. Loin pH and temperature profiles of carcases of different carcase weight (75 kg (black); 100 kg (red)) stunned utilising a back-loading group CO_2 stunner and chilled using a quick chill tunnel and equalisation chiller system.

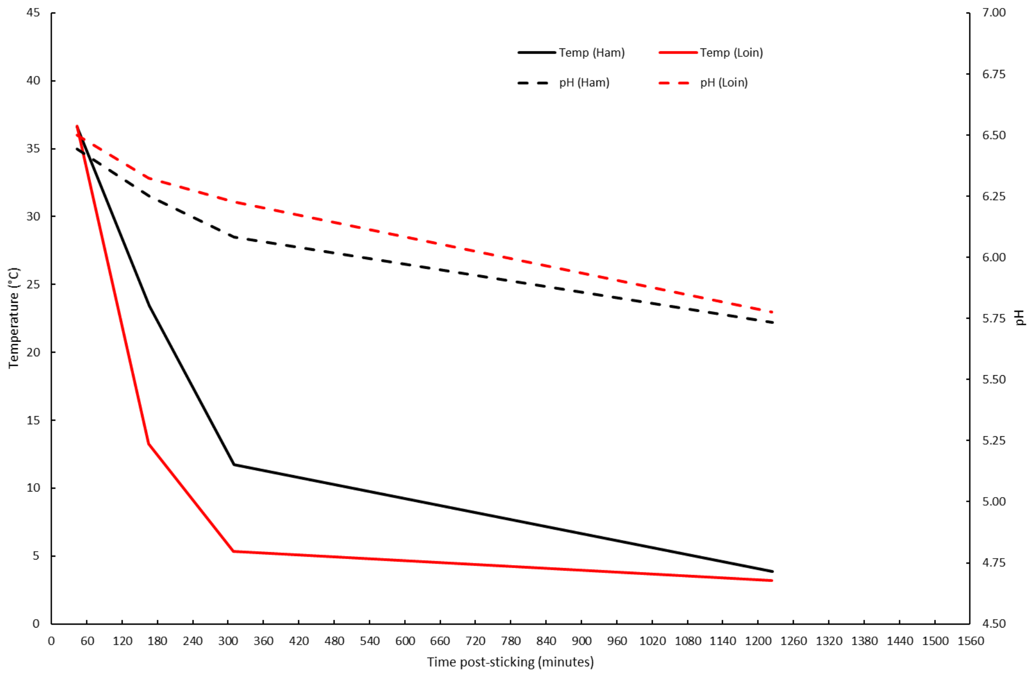

Figure 4. pH and temperature profiles of loin (red) and ham (black) muscles of carcases stunned utilising a back-loading group CO_2 stunner and chilled using a quick chill tunnel and equalisation chiller system.

Comparing indicative data collected under the previous stunning and chiller setup and management (single-file, side-loading CO_2 stunner) and conventional chilling to data derived from a back-loading group CO_2 stunner with carcases cooled under either conventional chilling or through quick chill and equalisation (Table 1) supports the findings of Matthews *et al.* (2019), which showed the benefits of group stunning are apparent only when combined with accelerated chilling systems.

Table 1. Comparison of ultimate pH of carcases stunned utilising a side-loading single-file CO_2 stunner or a back-loading group CO_2 stunner and chilled under conventional chilling or by using a quick chill tunnel and equalisation chiller system.

Stunner…	**Single-file**		**Group**			
Chill profile…	**Conventional**		**Conventional**		**Quick Chill**	
	pH	**T**	**pH**	**T**	**pH**	**T**
Mean	5.43	2.2	5.61	1.1	5.78	3.1
SE	0.015	0.03	0.022	0.04	0.021	0.08
MIN	5.26	1.5	5.36	0.8	5.59	1.8
MAX	5.68	2.8	5.84	1.5	5.99	3.6

4. Discussion

The implementation of a quick chill and equalisation chilling system, in combination with a back-loading CO_2 stunner has resulted in an improvement in the ultimate pH of pork carcases and a change to the rate of pH decline.

The two systems, stunning and chilling, are additive in nature. Improvements were seen when conventionally chilled carcases were stunned using a back-loading group stunner, with an additional increase in ultimate pH observed when group stunned pigs were chilled in the quick chill system.

An often-overlooked advantage of this system is that each carcase is chilled optimally. Unlike conventional chilling where carcases are loaded into a chiller over a period of time and therefore subject to the conditions of the chiller open entry, each carcases enters the quick chill tunnel at the same amount of time post-slaughter, is held at those lower temperatures for the same amount of time and enters the equalisation chillers after the same amount of time. This will reduce the variation in carcase quality.

Differences in temperature and pH declines between heavy and light carcases shows that further improvements could be made in carcase quality through differentially chilling carcase types. However, the nature and size of the Australian pig industry, market requirements and the realities of operating service kill abattoirs is likely to make this further differentiation difficult.

5. Implications & Recommendations

This project shows that the improvements seen in ultimate pH, and therefore meat quality, that are achieved when single-file stunners are replaced with group-stunning systems can be further enhanced through the implementation of a chilling system that utilises a combination of quick chill and equalisation.

Whilst a change in chilling systems is a large capital expense, the advantages of carcases entering the ideal chilling profile, when they should, at the exit of the kill floor enables the production of consistent high-quality carcases. Processors without these systems, should utilise chiller and inventory management to minimise any deviation from best practice.

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