Vascular Rinsing and Chilling Carcasses Improves Meat Quality and Food Safety

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1.0 Rinse & Chill® Technology: An Innovative Way for Meat Carcasses to Be Chilled

A novel postmortem process for the meat industry referred to as Rinse & Chill® technology (RCT) is a promising approach to improve product safety and meat quality (color and palatability) while improving economic performance.

RCT was developed and patented by MPSC, Inc. (Hudson, Wisconsin, United States). The system involves inserting a specially designed catheter into the carotid artery of an animal (Figure 1) immediately after exsanguination followed by rinsing (sometimes referred to as “infusion”) with of a chilled isotonic solution containing dilute concentrations of approved common substrates through the cardiovascular system. The vascular system is rinsed at a rate up to 10% of the carcass weight and as a result improves residual blood removal from the carcass. The RCT process lasts approximately 3 to 4 minutes on each beef carcass, and approximately 15 seconds on a lamb carcass. The catheter is then removed, and the carcass continues along the chain as normal.

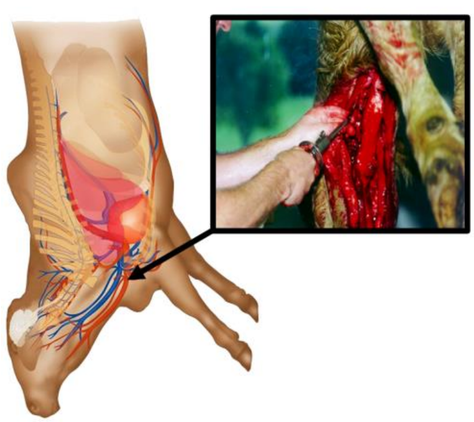


Figure 1. Post-exsanguination vascular infusion through the cardiovascular system.

Vascular RCT of pre-chilled solutions into intact animal carcasses immediately after slaughter is advantageous in terms of lowering the internal temperature and accelerating chilling. The main aims are to enhance blood removal, facilitate carcass chilling, and optimize pH decline, all of which enhance meat quality and safety. Since blood is an excellent media for the survival and growth of microorganisms such as *Escherichia coli* and *Salmonella*, its removal severely impedes the growth of these organisms on the carcass. The technology has matured enough that the benefits of vascular rinsing have become a technical and financial reality for an increasing number of beef and lamb processors.

The technology has been commercially approved and in continuous use since 2000 in the United States and since 1997 in Australia. As of January 2020, 23 plants have implemented RCT among the 5 countries (Australia, US, Canada, New Zealand, Japan) that have evaluated and approved RCT. All plants are operating under sound Sanitation Standard Operation Procedures (SSOP) and a sound Hazard Analysis Critical Control Point (HACCP) program. No food safety issues have been reported associated with the use of this technology.

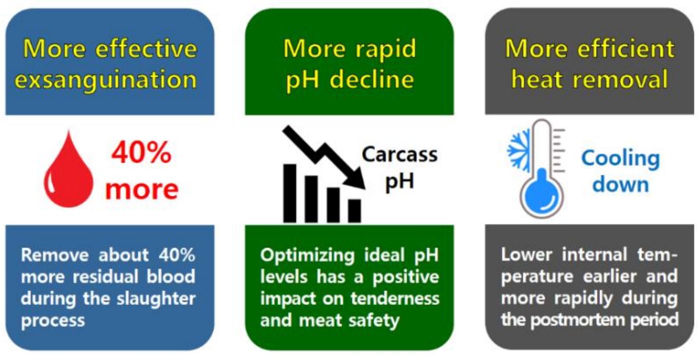
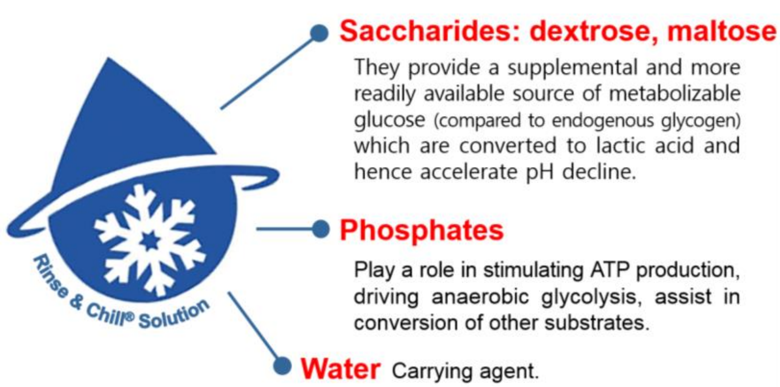


Figure 2. Primary purposes of Rinse & Chill® Technology.

2.0 Rinse & Chill® Technology Associated with the Rinse Solution

The RCT solution consists of approximately 98.5% water and 1.5% of a blend of dextrose, maltose, and phosphates. The saccharides simply provide a source of glucose which is a normal substrate in the muscle used for metabolism. Similarly, various forms of phosphate are found in the muscle to facilitate metabolism. This solution is designed based on the hypothesis below:



All of the ingredients in the RCT solution are approved by the U.S. Food & Drug Administration and are internationally GRAS-listed, common food-grade ingredients. They are classified as substrates and are completely metabolized, leaving no detectable residues.

The RCT solution is prepared daily, filtered, and sanitized by an in-line Ultraviolet (UV) Light System prior to infusion. First, the RCT ingredients are inspected for any contamination, and the incoming water (the carrying agent) is filtered to remove any inadvertent foreign contamination. Throughout these procedures, the chemical, physical, and microbial hazard risks are mitigated, and the risks are further mitigated via regular Cleaning-in-place (CIP) and following Sanitation Standard Operating Procedures.

Although unlikely, if there was an apparatus failure, a real-time Programmable Logic Controller, which monitors and controls the entire RCT process, initiates protocols via instrument feedback, followed by either shut down, or the fault alert on the RCT process to protect the safety of the product and overall RCT system and its sanitary integrity. Therefore, through the combination of all of the processes (SSOP, filtering, UV application, and system controls) the risk of a contaminated RCT solution being infused is greatly mitigated. To further acknowledge the safety of the process, the RCT solution in itself has significant antimicrobial activity.

On the kill floor, an automated process control system weighs each carcass and calculates the amount of rinse required. Appropriate HACCP and sanitary procedures are followed for equipment and operators for each catheter insertion and removal. Once the equipment is installed, there is a full-time, trained and certified RCT technician in every customer facility. They monitor the process and conduct regular tests to confirm that RCT is helping to achieve the highest levels of safety, wholesomeness, and performance.

An RCT system is designed with multiple catheters to meet existing plant production speeds so that multiple rinses can occur simultaneously as carcasses move along the production chain. With such design, there is no production speed too fast for this technology, for example the RCT has already been used at rates of up to 200 carcasses/hr in beef and up to 780 lamb carcasses per hour can be processed. Typically, beef plants using RCT process 200 to 1,200 head per 8 hours shift, and lamb plants process 2,000-6,000.

2.1 Validation Testing of Potential Residues in Meat Associated with the Rinse Solution

An early residue study was performed by the University of Minnesota to determine whether or not there are differences between non-rinsed cattle carcasses and the RCT-processed carcasses in terms of dextrose (glucose) and phosphate (phosphorus). The study was conducted on muscle tissue collected from 216 cattle: 108 controls and 108 Rinsed cattle. High performance liquid chromatography (HPLC) was used for the determination of residues in the longissimus muscles.

The results demonstrated there was no measurable amount of dextrose in any of the samples from the non-rinsed carcasses or the RCT-processed carcasses. No differences between the non-rinsed and the rinsed carcasses were seen as residual glucose levels were below the detection limit of the analytical procedure. In addition, measurable quantities of glucose were not even found in the sample extracts that were concentrated five-fold, while dextrose content was detected in the positive controls. The inability to recover and detect any of the small amount of glucose added by the RCT procedure is not surprising as glucose will rapidly be metabolized to lactic acid, CO_2, and H_2O in the early postmortem (PM) period.

Mean values for phosphorus were as follows: non-rinsed = 2,113 ppm; RCT-processed = 2,079 ppm. The results of phosphorus expressed as phosphate (PO_4) were; non-rinsed = 6,466 ppm; RCT-processed = 6,362 ppm. Although not statistically significant, the RCT-processed samples tended to contain less phosphorus and phosphate than the non-rinsed samples (possibly due to blood removal). In a very comprehensive study by Mateescu et al. (2013), they reported standard deviations of 249 µg/g (Iowa steer beef, n = 309) and 278 µg/g (Iowa cow beef, n = 231). Therefore, with the apparent difference between the non-rinsed beef and the rinsed beef being only 34 µg/g, based on normal biological variability, one would conclude this was not a significant difference.

A recent independent study was conducted to determine the effects of vascular rinsing and chilling temperatures on the quality attributes of meat from cull dairy cows. Carcasses from lean grade, cull dairy cows were conventionally chilled (non-rinsed; n = 12) or RCT processed (n = 28). Immediately after exsanguination at a commercial plant, carcasses were vascularly rinsed with the chilled solution (RCT3; rinse solution, 3°C; n = 13; RCT14; rinse solution, 14°C; n = 15). Longissimus muscles were excised for residue testing. Total phosphorus and sodium were analyzed by an independent certified lab (Deibel Laboratories, Lincolnwood, IL) using inductively coupled plasma optical emission spectrometry (ICP-OES, AOAC 982.14 Modified). Glucose content was conducted by the UW-Madison using a glucose assay kit (GAHK20; Sigma Chemical Co., St. Louis, MO) with the hexokinase method (Kunst et al., 1984).

As documented in the early residue validation work in which meat from RCT carcasses that were vascularly rinsed with the cold solution (3°C), the concentration of residual phosphorus was not different (P>0.05) than the non-rinsed samples (Figure 3a). In addition, the beef from carcasses rinsed at the higher rinse solution temperature (14°C) was also not different than the non-rinsed control. These values are similar to those reported by Mateescu et al. (2013) for conventionally chilled carcasses. They analyzed the phosphorus content of the longissimus muscle and reported 1,742 µg/g in Iowa Angus cow beef and 1,759 µg/g (wet basis) in Iowa Angus steer beef. Furthermore, the concentration of residual sodium was not different (P>0.05) than the non-rinsed control samples and were very similar to those reported by Mateescu et al. (2013) in meat from the same Iowa Angus cow and steer beef (Figure 3b).

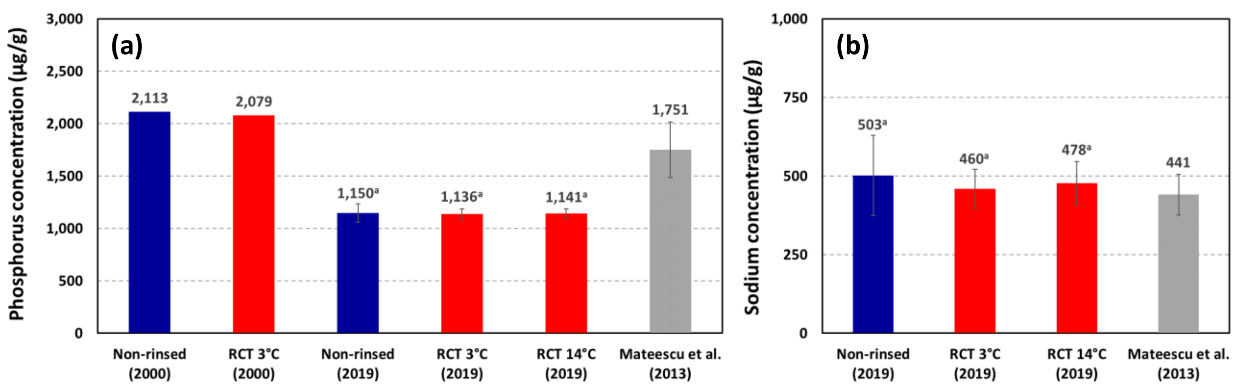


Figure 3. Assessment of residual (a) phosphorus and (b) sodium content (mean ± std. dev., wet basis) in beef longissimus muscle from non-rinsed compared to RCT carcasses (RCT3, 3°C rinse solution, RCT14: 14°C rinse solution). [a]Means from the 2019 study demonstrated no differences (P>0.05, S.E: phosphorous, 19.81; sodium, 27.14) were found between the non-rinsed controls and either of the rinse temperature beef samples. The Mateescu et al. (2013) results represent the average of steer and cow values from conventionally chilled beef.

The residual glucose content in the longissimus muscle from the cull dairy cows was 4.91 µmol/g in the non-rinsed control, 4.56 µmol/g for RCT3, and 4.58 µmol/g for RCT14. The residual glucose content of the samples from the two RCT carcass treatments was not different (P>0.05, Figure 4) than the non-rinsed samples. The level of residual glucose determined in these samples was similar to that reported by Rhoades et al. (2005) in the M. *Sternocephalicus pars mandibularis* which contained 6.54 µmol/g at day 4 postmortem (n = 10, conventionally chilled carcasses).

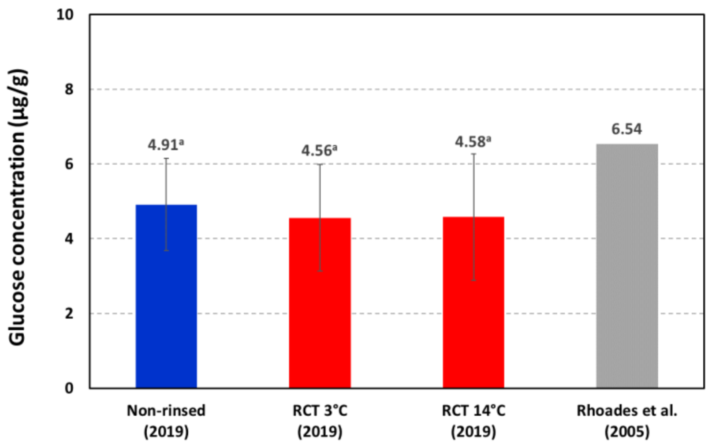


Figure 4. Residual glucose content (mean ± std. dev., wet basis) in the beef longissimus muscle from non-rinsed cull dairy cow carcasses compared to RCT carcasses (RCT3, 3°C rinse solution, RCT14: 14°C rinse solution) [a]Means from the 2019 study are not different (P>0.05, S.E. = 0.39). The Rhoades et al. (2005) results represent the average of cattle values from conventionally chilled beef.

Based on the early validation testing combined with the recent validation work, supports the conclusion there is no difference in residuals between the non-rinsed carcasses and the RCTS-carcasses. At the time of vascular rinsing and early postmortem, prerigor muscle is physiologically active and therefore capable of metabolizing endogenous as well as added sources of glucose. In addition, endogenous phosphate is also involved in normal muscle metabolism. As such, the minor amount of these substances used to rinse out the blood from the vasculature, even if none of them drained from the carcass, would be readily metabolized by the muscle. Moreover, the sodium content was not different between meat from non-rinsed carcasses and meat from RCT carcasses which is pertinent because sodium would not represent a metabolizable substrate.

3.0 How Rinse & Chill® Technology Works: Major Advancements

RCT is a thoroughly tested, safe, effective and proven process where the US experience includes two decades of pilot programs, academic research and several years of commercial trials on a variety of animal types (beef, bison, pork, lamb, and goat). Much of the published scientific research on RCT has been generated by researchers at Michigan State University, the University of Minnesota, Kansas State University, South Dakota State University, and the University of Wisconsin-Madison. In addition, Dr. Claus at the UW-Madison has collaborated with Dr. David Hopkins and his group (Fowler et al., 2017) at the Centre for Red Meat and Sheep Development and Dr. Robyn Warner at the University of Melbourne to add additional information on the applicability of RCT on Australian lamb. Table 1 presents a summary from previous studies which have investigated the effects of post-exsanguination vascular infusion on postmortem metabolic changes and meat quality (tenderness, sensory traits, and color) during the postmortem period.

Table 1. Effects of post-exsanguination vascular infusion on various physical, chemical, and sensory traits.

Animal	Muscle/Cuts*	Effects	Reference
Dairy cows	SS, LL, ST	• 37% reduction in toughness • Improve protein extractability ◻ Non-rinsed: 42.0% ◻ Rinsed: 43.5%	Farouk et al., 1992
Lamb	LL, IS	• Lower carcasses temperature in first 3 h PM ◻ Non-rinsed: 39.7°C (0 h) to 23.1°C (3 h) ◻ Rinsed: 36.6°C (0 h) to 21.7°C (3 h) • Glycolysis complete: Non-rinsed (12~24 h), Rinsed (6 h)	Farouk & Price, 1994
Steer	LL, ST, QF	• 4% higher dressing percentage • Rapid pH decline rate before 24 h PM	Dikeman et al., 2003
Steer	LL, OSM, ISM, PM	• Rapid pH decline rate before 4 h PM • Lighter cherry-red initial color scores in LL and OSM steaks	Hunt et al., 2003
Lamb	LL	• 50% reduction in toughness • Lighter (CIE L*) and yellower (CIE b*) colored muscle	Fowler et al, 2017
Lamb	LL, SM	• Reduce cold shortening up to 5% in rinsed carcasses with electrical stimulation applied before the rinse • Lower pH values during the first 5 h PM	Mickelson et al., 2018
Lean dairy cows	LL, SM	• 2.7% higher dressing percentage • No differences in moisture or fat content between the non-rinsed and rinsed ground beef • Higher CIE a*, higher deoxymyoglobin (DMb), and lower metmyoglobin (MMb) in the rinsed sample on day 7 display ◻ Non-rinsed: CIE a*,13.1; DMb 1.12; MMb,1.11 ◻ Rinsed: CIE a*, 15.8; DMb, 1.29; MMb, 0.94 • Carcass aerobic plate counts: 57% less with RCT	Moreira et al., 2018

Cows	LL	• 20% reduction in toughness	Hite et al., 2019
Market hogs	LL, TB	• Lower pH values during the first 4 h PM • Redder, lighter, greater DMb, and less MMb • Not affect the moisture content when assessed on moisture on a fat-free basis (MFF basis), water holding capacity (WHC), purge, and cook loss	Kethavath et al., 2019
Lean dairy cows (LE), Light dairy cows (LI)	LL	• 56% (LE) and 52% (LI) reduction in toughness, respectively • Longer sarcomere length than non-rinsed □ Non-rinsed: LE 1.44 µm; LI 1.40 µm □ Rinsed: LE, 1.80 µm; LI, 1.80 µm	Moreira et al., 2019
Bison	LL, TB	• 24% reduction in toughness • More red (CIE a*) and greater DMb on day 1 and 4 than the non-rinsed vacuum packaged ground bison	Mickelson & Claus, 2020

***** IS – *Infraspinatus,* ISM – Inside *Semimembranosus*, LL – *Longissimus thoracis et lumborum*, OSM – Outside *Semimembranosus,* PM – *Psoas major*, QF – *Quadriceps femoris*, SM – *Semimembranosus*, SS – *Supraspinatus*, ST – *Semitendinosus*, TB –*Triceps brachii*.

3.1 Blood Removal, Color, Flavor

Blood is the first product obtained at harvest. At the time of blood removal, approximately half of the animal's blood is removed equating to approximately 3.0–3.5% of the animal's live weight in blood (13–16 kg of blood from a 450 kg steer). As described before, the remaining blood in the carcass is the ideal medium for bacteria to grow in and spread. Therefore, it is important to remove as much blood from the carcass as possible during slaughter.

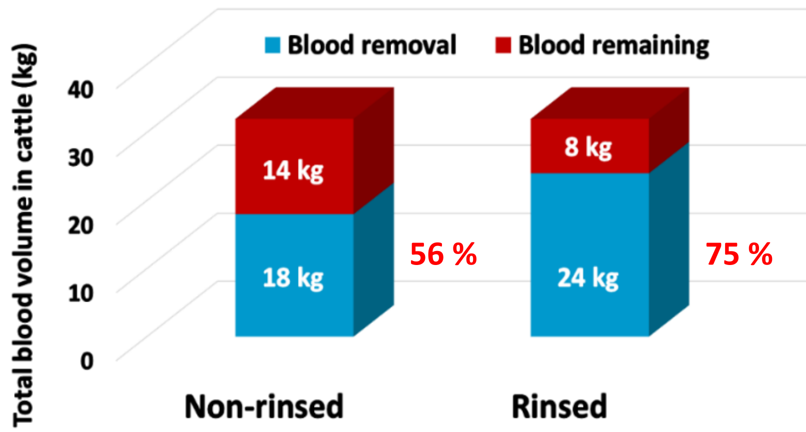
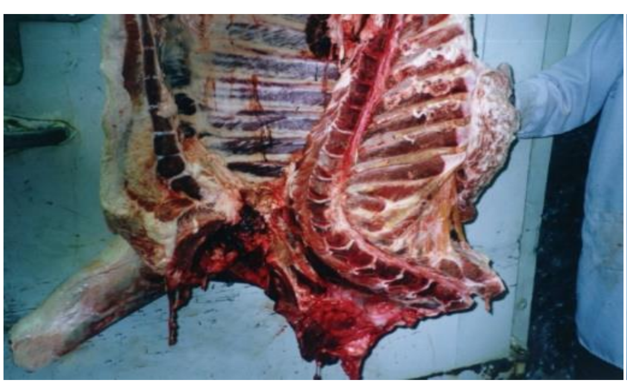
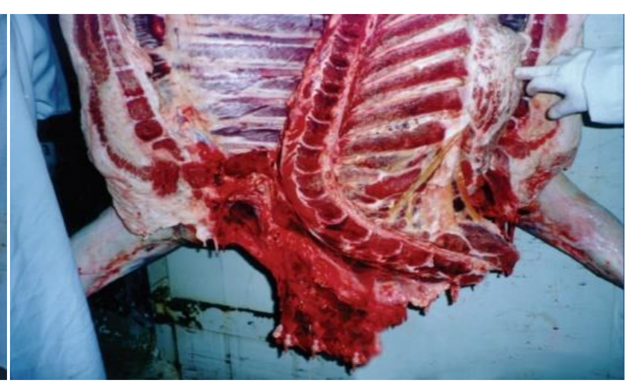


Figure 5. How well RCT contributes to the effectiveness of exsanguination in cattle.

Using a 454 kg (1,000 lb) cattle as an example, there is a total of 32 kg (70 lb) of blood in the animal, which is 7 % of live weight. According to MPSC research, the estimated blood yield in a non-rinsed animal is equivalent to 18 kg (40 lb) fresh blood. Thus, 14 kg (30 lb) would be left in the animal without rinsing. MPSC also confirmed that rinsing an animal through RCT results in 5.6 kg (12 lb) additional blood removed in comparison to the non-rinsed animal, while 8 kg (30 lb) of blood remains (Figure 5). The average blood yields are; non-rinsed = 56% (18 kg or 40 lb); RCT-processed = 75% (24 kg or 51 lb). This means that RCT effectively removes about 40% more residual blood from the carcass. Consequently, this technology positively affects meat color and stability. Numerous studies (Table 1) report increased red color in ground meat and intact steaks and increase levels of oxymyoglobin. Also, a common result was the color of the meat is lighter. Some preliminary results from cull dairy cow studies suggest RCT produces meat that has greater oxygen consumption ability which would be particularly beneficial in meat to be vacuum packaged.



Non-rinsed cattle carcass



RCT-processed cattle carcass

Non-rinsed beef (left) and RCT-processed beef (right)

Non-rinsed lamb (left) and RCT-processed lamb (right)

Additionally, RCT reduces the amount of hemoglobin and non-heme iron that can act as pro-oxidants and have a negative impact on flavor. Previous works reported steaks (*Semitendinosus*) from the non-rinsed cattle had higher cardboard flavor than those from the RCT-processed cattle. Also, cooked ground beef from the RCT-processed cattle had higher beef flavor identity and lower soapy/chemical flavor than those of the non-rinsed cattle (Yancey et al., 2002).

3.2. Chilling Rate, Optimum pH, Tenderness

Carcasses should be chilled to an internal temperature of 7 ºC in the deep round before cutting or dispatch. Although no time is specified in the regulations, with current technology these temperatures can be achieved in 16–24 hours in small carcasses and in less than 48 hours in large carcasses (center of the hind leg). Effective chilling is important to slow microbial proliferation. Extensive research trials have shown that in a conventional chilling system, beef sides, pig carcasses, and lamb carcasses require at least 24, 16, and 10 h, respectively to cool to 7 ºC (Brown et al., 2009).

RCT effectively reduces internal temperatures as much as 5ºC due to the large internal surface of the vascular system and the reduced distance between the muscle and the chilling medium. Early work demonstrated that vascular infusion reduced the time required to achieve deep leg temperatures of 20°C from 2.6 to 1.3 hours, which is a significant time reduction (Brown et al., 2009). Additionally, the infusion of the MPSC solution lowered the temperature by ~2°C compared to non-rinsed carcasses during the early postmortem period (3 h) but also increased the rate of pH decline (Farouk & Price, 1994).

Work done by MPSC at a client plant in 2019 shows that RCT treated beef carcasses chill significantly faster in the deep round muscle. RCT beef carcasses were 8.8°C colder at 18 hours of chill than non-rinsed carcasses (Figure 6).

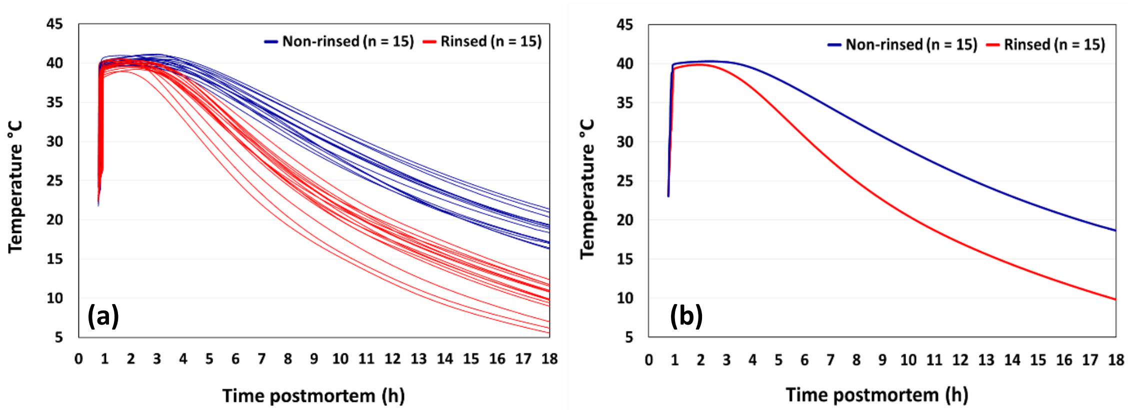


Figure 6. RCT effect on temperature decline (a) individual and (b) average cooling curves in semimembranosus of beef carcasses.

The pre-rigor infusion of the carcass manipulates the rate of glycolysis and thus the pH decline. In a lamb study by Farouk and Price (1994), they reported glycolysis was completed in 6 h compared to 12–24 h for the non-rinsed carcass. More recent studies showed carcasses infused with the MPSC solution exhibited more rapid pH declines during 24 h postmortem on cull dairy cows and before 4 h postmortem on market hogs (Figure 7).

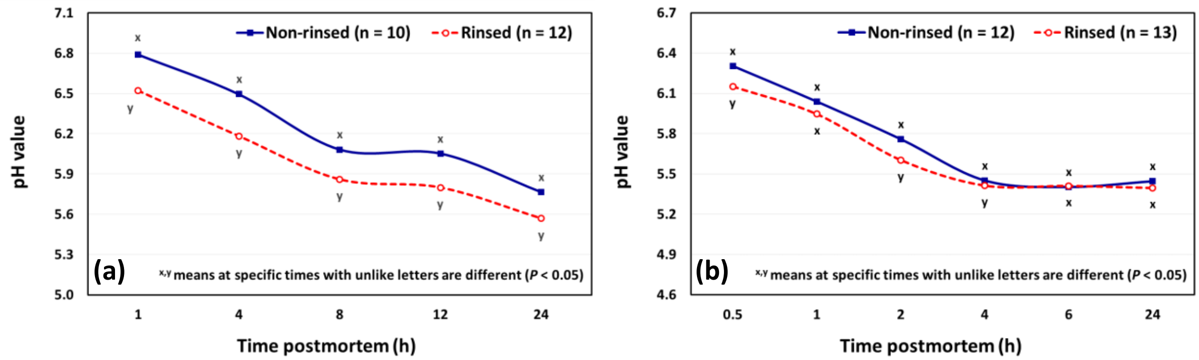


Figure 7. Rate of pH decline in (a) cull dairy cows and (b) market hogs (Kethavath et al., 2019).

The faster pH decline could be explained by the ingredients in the isotonic solution and their effect of glycolytic enzymes. The phosphates likely serve to facilitate stimulating anaerobic metabolism and the saccharides (dextrose, maltose) serve as a source of glucose which under anaerobic conditions lead to the formation of lactic acid. Thus, these compounds likely regulate critical steps in the glycolytic pathway to control the rate and absolute decline in pH.

Shear force trials conducted by Michigan State University (Farouk et al., 1992) found RCT-processed carcasses were significantly more tender. While prime cattle showed improvement, cows showed much greater improvement in tenderness. The trials also showed the improvement in tenderness was realized sooner after processing. The RCT-processed carcasses were significantly more tender than the non-rinsed group at 14 days aging. At 28 days both groups had improved but the non-rinsed group was still less tender than the RCT-processed group at 14 days. It was proposed that the tenderization mechanisms induce by the vascular infusion were caused by (1) the infusion solution enhancing the proteolytic activity process; (2) disruption of the muscle structure caused by the volume and pressure when the infusion solution was introduced into the carcasses; and (3) the phosphate in the infusion solutions may contribute to the solubilization of actomyosin thus improving the meat tenderness. This improvement in meat tenderness was without any negative effect on water holding capacity and protein extractability of the meat. Several recent studies have also reported improvement in tenderness as a result of RCT processing. Based on a reduction in mechanical shear, tenderness was improved by 50% in lamb chops (Fowler et al, 2017), 54% in steaks from cull dairy cows (Moreira et al., 2019), 20% in cow striploin steaks (Hite et al., 2019), and 24% in bison steaks (Mickelson & Claus, 2020).

There is an interesting contrast associated with early postmortem carcass temperature and pH. Known for decades is that a rapid drop in pH while the carcass temperature is still warm can lead to undesirable effects on color (pigment denaturation) and reduction in water holding capacity. These quality problems are more associated with pork but have also been reported in beef. On the other hand, if the carcass is chilled too quickly (<15 °C) while the pH is high (when the muscle still has available energy) cold-induced toughening can occur.

Interestingly, although RCT infuses a cold solution, it appears the more rapid pH decline is capable of preventing cold-induced shortening (Moreira et al., 2019). The process likely induced using up a sufficient amount of energy before calcium was released that would trigger excessive sarcomere shortening. In addition, despite a more rapid pH decline, use of the chilled RCT solution and its effect on efficiently removing heat out of the carcass helps protect the meat pigments from being denaturated as mentioned previously RCT improves the red color stability.

3.3 Antimicrobial Effect

Bacteria potentially can double their populations every twenty minutes. Certain flagellated microorganisms including *Salmonella* also "attach" themselves to the carcass surface in as little as one minute, making them difficult to remove later on. RCT is believed to interfere with bacterial attachment on the carcass surface. So, by dropping pH and temperature sooner and more rapidly, while removing additional blood from the carcass–immediately–as the first step in the slaughtering process, carcasses and by-products have been shown to be microbiologically cleaner and freer of blood.

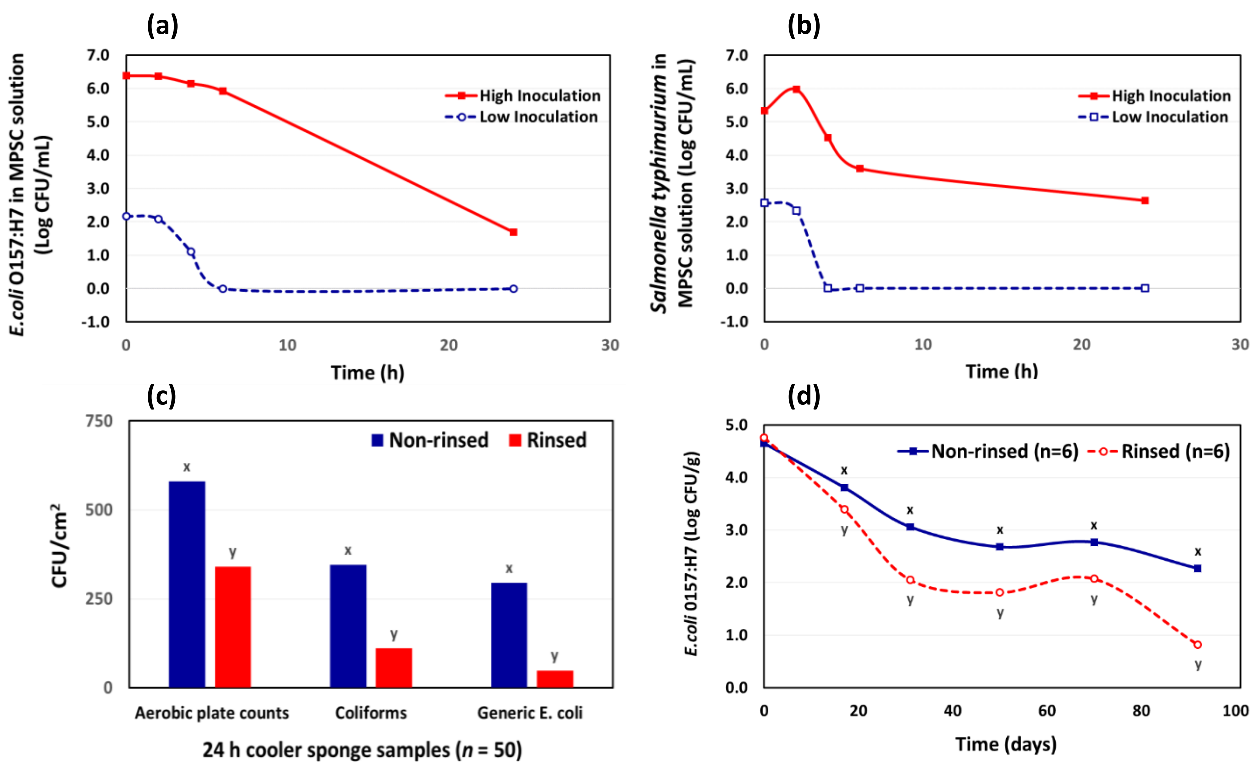


Figure 8. Antimicrobial effect of MPSC rinse solution with two different inoculation levels for 24 hours on (a) *E. coli* O157:H7 and (b) *Salmonella typhimurium,* (c) Microbial status of cattle carcasses after 24 hours in the cooler, (d) Effect of RCT on *E. coli* O157:H7 of vacuum packaged ground beef at 4°C for 0 to 92 days (Feirtag & Pullen, 2003; Feirtag et al., 2002).

Based on in vitro studies performed by the University of Minnesota (Feirtag & Pullen, 2003), by removing metal cations, such as the form of iron found in the blood, certain pathogenic bacteria do not survive. This is especially true for coliform bacteria and *Escherichia coli*. They also reported the RCT solution has antibacterial properties against *Escherichia coli*, *Salmonella typhimurium*, and *Pseudomonas fragi*. The antimicrobial properties of the MPSC solution, when tested by itself, are quite effective in a short amount of time, killing all organisms present within 4–6 hours at low inoculation levels (Figure 8a and 8b). At a high inoculation level, the antimicrobial properties are still present and significantly reduced the number of pathogens.

Aerobic plate counts, a general measurement of microbial cleanliness of carcasses after 24 hours in the cooler, were reduced by more than 41%, coliform bacteria were reduced by more than 67% and *E. coli* were reduced by more than 83% with the RCT (Figure 8c). Additional research indicated that RCT also provided a continuous intervention in the reduction of *Escherichia coli* O157:H7 in vacuum packaged ground beef and the shelf-life of these products were considerably extended (Figure 8d). In a recent study by Moreira et al. (2018), they also confirmed a reduction (57%) in carcass aerobic plate counts.

Furthermore, one of the most common ways that meat becomes contaminated with microbiological pathogens is when the hide is removed. The effort of removing the hide can displace and aerosolize dust and other microscopic contaminants that can land back on the carcass. With RCT, hide removal is easier and fewer pathogens are dispersed.

Researchers at Kansas State University and at the University of Minnesota claimed that the solution (present in the capillaries below the hide) assists in easier hide separation, which reduces contaminating aerosols. With the solution there, the thought is it provides mechanical interference with bacterial attachment.

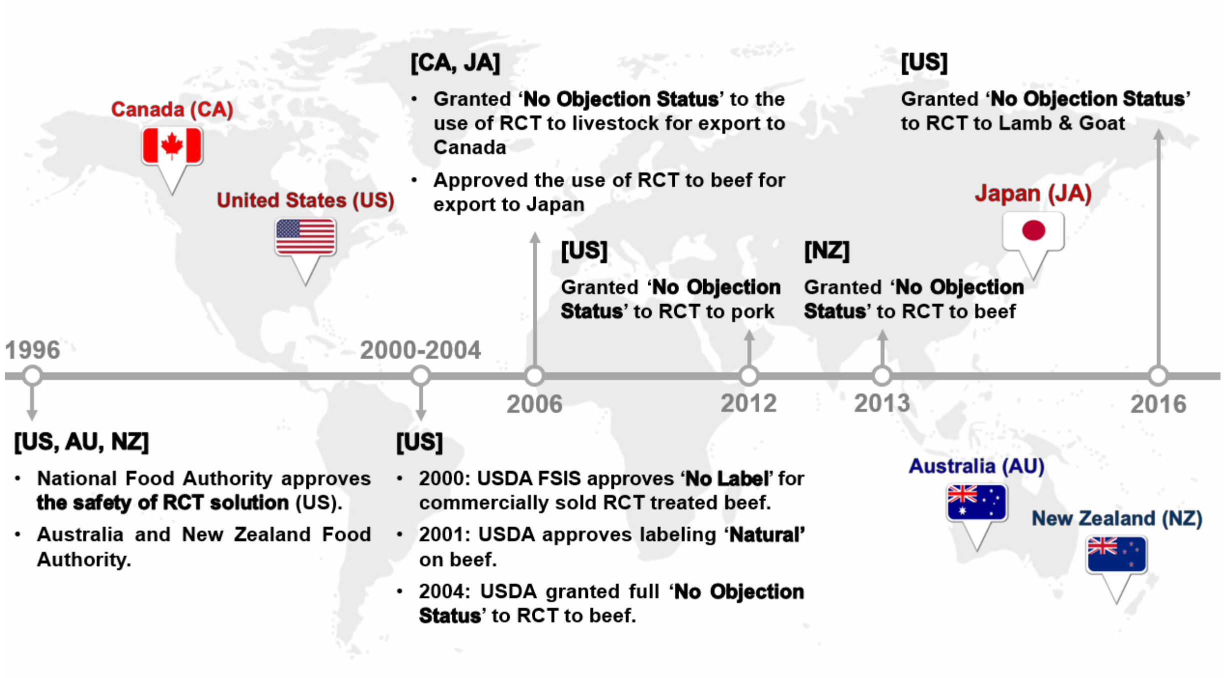
4.0 Retained Moisture Declaration (Labelling) for Meat Products

Many advanced nations require moisture declaration labeling for raw meat products, however, retained water below 0.5% does not need to be declared in the United States. Data from the University of Minnesota (2000) showed the average moisture fat free (MFF) percent of non-rinsed samples was 72.3% whereas the percent in RCT-processed carcasses was 72.64%. The difference of +0.34 % was not scientifically significant. Since there is no significant moisture gain, RCT is compliant with retained moisture regulations in the United States. Recent works have also reported RCT processing in lean dairy cows (Moreira et al., 2018) and market hogs (Kethavath et al., 2019) had no effect on MFF compared to the non-rinsed carcasses. Therefore, meat from RCT processed carcasses do not require any labeling claims associated with moisture. In addition, MPSC has conducted rigorous testing to monitor the moisture level of the meat that underwent RCT in every plant, to ensure that meat produced via RCT meets government requirements in countries including the United States, Canada, Japan, New Zealand, and Australia, which have approved the installation and commercialization of this technology, as well as the import of RCT-processed meat.

5.0 Producing Plant Yields

Vascular infusion has improved dressing percentages to approximately 2–4 % as compared to non-rinsed carcasses (Dikeman et al., 2003; Moreira et al., 2018; Yancey et al., 2002). This advantage is likely associated with less carcass damage during hide removal, in addition to less bloodstaining in the neck area requiring trimming. Processors and boning room operators report beef from RCT is easier to bone, increasing yield by as much as 2% and improving worker safety and ergonomics. Interestingly, meat separates and peels off the bone cleanly.

6.0 The History of Rinse & Chill® Technology Approval (Overseas)



1996: [US] National Food Authority – approves the safety of RCT solution.

1996: [AU] Australia and New Zealand Food Authority (ANZFA).

1997: [AU] Australia Department of Human Service (DHS) approves the safety of RCT solution.

1997: [AU] State by state approvals for domestic operation of RCT and allows first Australian RCT implementation.

2000: [US] USDA FSIS – Approves 'no label' for commercially sold RCT treated beef.

2001: [US] USDA – Approves additional slaughter plants using RCT and approves labeling 'Natural' on beef slaughtered using RCT.

2004: [US] USDA – granted full 'No objection status' to RCT to beef (Includes Commercialization, Importation, and Installation of RCT).

2005: [US] USDA FSIS – Approves the use of RCT to beef for export to the US (Market Access Authorization).

2006: [CA] Health Canada Novel Foods – Granted 'No Objection Status' to the use of RCT to livestock for export to Canada (Market Access Authorization).

2006: [JP] Japan Ministry of Health, Labor and Welfare (MHLW) – Approved the use of RCT to beef for export to Japan (Market Access Authorization).

2012: [US] USDA – Granted 'No Objection Status' to RCT to Pork (Includes Commercialization, Importation, and Installation of RCT).

2013: [NZ] NZ MPI – Granted 'No Objection Status' to RCT to beef (Includes Commercialization, Importation, and Installation of RCT).

2016: [US] USDA – Granted 'No Objection Status' to lamb and goat (Includes Commercialization, Importation, and Installation of RCT).

Conclusion

After decades of extensive research and technological advances, the Rinse & Chill® technology is now providing the global meat industry with an unpresented opportunity to use this process, cost effectively, to remove more blood from carcasses (beef, lamb, bison), optimize pH decline, and facilitate chilling early postmortem in a manner that enhances meat quality (color and tenderness) and has a positive impact on product shelf life and food safety. The rinse solution uses widely recognized and approved food grade ingredients that represent substrates the muscle metabolizes for normal energy production, thus resulting in no detectable differences between conventionally chilled carcasses and carcasses that are vascularly rinsed using the RCT process. Since the carcasses are vascularly rinsed at no more than 10% of the carcass weight with a cold isotonic solution and the solution is allowed to freely drain, meat from this process does not require any labeling requirements for moisture as based on moisture fat free analysis there is less than 0.5% of a difference compared to non-rinsed carcasses. From an economic standpoint, the process has demonstrated benefits in terms of improving dressing percentage and boning yields. Adaptation of this technology has accelerated in the past several years and such growth this expected to continue particularly with engineering advances that enable accommodating larger capacity harvest plants.

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