A System For Assuring Pork Quality

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SYSTEM FOR ASSURING PORK QUALITY

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INTRODUCTION

The purpose of this revised document is to review the science behind some of the factors that affect the quality of fresh pork. The factors include on-farm, in transport, in-plant and post-plant considerations. It has been estimated that the producer and the packer each contribute about half to potential quality deterioration in fresh pork. Also, it should be noted that pigs, carcasses, or pork products can either sustain or degrade the inherent genetically quality. Only enhancement, further processing, or aging that can improve the quality.

With development of this support material, recommendations will be established for producers and packers relative to adjustments that should be considered to improve the quality of pork products for all customers including further processors, retail, foodservice, and export and, ultimately, for all consumers.

QUALITY CONTROL POINT 1: GENETIC INPUTS

CHOICE OF BREEDS

The NPPC Terminal Line Study (1995) and the results of twelve years of National Barrow Show data (1991-2001) demonstrate large differences between breeds in regard to meat quality traits. In general, Berkshires are far superior to any other breed for overall muscle quality, but they suffer in carcase and performance traits. The breed that has the best combination of other economically important traits and has good values for muscle quality is the Duroc breed. Candek-Potoker et al. (1996) as quoted in D’Souza and Mullan (2001) reported that pork from Duroc pigs not only had higher marbling levels but also better color and texture compared to Large White and Landrace pigs. In another study D’Souza and Mullan (2002) found that while Durocs had greater levels of intramuscular fat, they had lower levels of backfat. In fact both of these breeds (Berkshires and Durocs) are classified as good for pork quality. The breeds that are average for pork quality include Spots, Poland China, Yorkshires and Hampshires (rn+rn+). The breeds classified as having poor meat quality include Landrace and Mullan (2001) reported that pork from Duroc pigs not only had higher marbling levels but also better color and texture compared to Large White and Landrace pigs. In another study D’Souza and Mullan (2002) found that while Durocs had greater levels of intramuscular fat, they had lower levels of backfat. In fact both of these breeds (Berkshires and Durocs) are classified as good for pork quality. The breeds that are average for pork quality include Spots, Poland China, Yorkshires and Hampshires (rn+rn+). The breeds classified as having poor meat quality include Landrace and Hampshires (RN-). Le Niendre and Terlouw (2000) stated that Durocs react greater to stress during slaughter but that this is not necessarily translated in terms of changes in meat quality.

RECOMMENDATION: All commercial market hogs should have at least some percentage of Durocs (+/or Berkshires), or other hybrids or synthetic lines, with commercially proven pork quality performance to help enhance the opportunity to produce higher quality pork products.

CHOICE OF SIRES WITHIN BREED

Recent analysis of the National Barrow Show data by sire line within breed demonstrates a great deal of variation within breed for pork loin quality as defined by color, pH, intramuscular fat, tenderness and cooking loss (Goodvin, 1998). Expected Progeny Differences (EPD’s) have been calculated for the major sire lines within eight breeds (Goodvin, 1994, 1996). In order to maximize quality and minimize quality defects, the U.S. pork industry must take an aggressive stance toward exploiting some of these breeds and sire lines within breeds which are known to have exceptional pork quality, without sacrificing some of the other economically important traits.

RECOMMENDATION: Request pork quality information and/or quality EPD status on all sire purchases from individuals or companies. Furthermore, the breeding stock companies and breed associations should begin to provide this type of pork quality information to their customers. Traits of interest are loin color, loin intramuscular fat, and drip loss. Ultimate loin pH (24-hour) is a predictor of quality that is also of interest.

RYR 1 or HALOTHANE (Stress) GENE

There is a plethora of data that categorically supports the conclusion that this gene, even in the carrier state, contributes to poor meat quality (Wittman et al., 1993; Scmitten, 1993; Peschke et al., 1993, Guebabez et al., 1995, and McPhee and Trout, 1995 as cited by S. Hermisch, 1998; Luxford, 1995 as cited by Warner, 1998; Rempel et al., 1995; Gispert et al. and Henckel, 1995). Channon et al. also looked at handling and stunning method to conclude that stress genotype was the major factor influencing meat quality. This negative effect which manifests itself in lower 45 minute pH, lighter color, and greater drip loss percentage is the reason that NPPC producer delegates took the national position in 1996 opposing to the presence of even one copy of this gene in market hogs in the U.S. The negative effects of this gene seem to be further exacerbated by selection for lean growth. Breeds or lines selected for lean growth have pronounced negative effects of the stress gene (McPhee and Trout, 1995). This becomes especially important as the U.S. pork industry moves to leaner hogs.

RECOMMENDATION: Require that all breeding stock purchases be certified stress free gene. All commercial producers should certify that they do not or will not knowingly market hogs with the halothane gene.

NAPOLE (RN) GENE

This gene is prevalent in the Hampshire breed (Miller, 1998). Meat from Hampshires is characterized by having a lower ultimate (48 hr) pH together with a higher cooking loss (Monin and Sellier, 1985), a higher water content, a lower protein content (Fjelkner-Modig and Tornberg, 1986; Wassmuth et al., 1991), and a higher glycogen content (Monin and Sellier, 1985). Presumably, these effects are due to the Napole gene. Heterozygous RN pigs’ drip loss and cooking loss were 21% and 12% greater, respectively, while the Napole ham yield was 7% lower, compared with the homozygous non carriers (Lundstrom et al., 1996). In spite of the negative impact of this gene on technological quality, it appears to have positive or no contribution to eating quality. The RN carriers have a lower shear force (increased tenderness) and a stronger taste and smell (Lundstrom et al., 1996) and improved juiciness (Lundstrom et al., 1998). Indeed, the NPPC Terminal Line Study (1995) showed that Hampshires have more tender and juicy meat after cooking than a variety of genotypes. Because of the negative impact of this gene on processing quality, several breeding companies have limited or eliminated use of the Hampshire breed from their programs. Furthermore, Przybylski et al. (2000) showed that when the halothane gene is present, it deepens and intensifies the effect of the RN gene.

RECOMMENDATION: Work should proceed to isolate the RN (Napole) gene and further clarify its positive and negative impacts.
LOIN INTRAMUSCULAR (IM) FAT

Several studies have shown the positive contribution of IM fat on eating quality of pork. Wood et al. (1994) listed the possible role of IM fat on tenderness, juiciness, and flavor of fresh pork. DeVries et al. (1988) suggested a threshold level of 2.5-3% IM fat as optimum for eating satisfaction. Results of NPPC’s Consumer Preference Studies (1995) demonstrated a linear preference for IM fat in terms of juiciness, tenderness, and flavor up to 61% IM fat. Recently, a recessive major gene has been detected for IM fat (H-FABP gene). This could eventually lead to DNA tests that would allow better and easier control of the marbling level of U.S. pork. The new NPB pork quality targets set the level of IM fat that the industry should be striving for at 2-4%.

RECOMMENDATION: Continue to utilize breeds and sires that will contribute positively to marbling without increasing fat in other deposits (subcutaneous, abdominal, and intermuscular).

FIBER TYPE

Greaser et al. (2001) stated that results to date suggest that meat quality is related to fiber type and most specifically to the proportion of Type Iib fibers. Klont et al., 2001, quoted the following in his paper: The impact of muscle fiber type composition on lean quality is even less understood, although the relative high volume of Type Iib fibers was related to poor meat quality (Sosnicki, 1987; Brocks et al., 1998; Fiedler et al., 1999). For instance, PIC/Purdue University research showed that the abundance of Type Iib myosin is negatively related to pH at 45 minutes post-mortem (r=−.50 in Hal gene positive and carrier pigs, and negatively related to pH at 24 hours post-mortem in the Hal gene negative population (r=−.50) (Gerrard, personal communication). It was also reported that Type Iib fiber percentage was negatively related to pH at 30-minutes post-mortem, negatively to pH at 24 hours post-mortem, positively to glycolytic potential, and positively to color lightness (Essen-Gustavsson and Fjekje-Mødg, 1985; Lefaucheur et al., 1995; Ruusunen et al., 1996; Larzul et al., 1997). Published heritabilities (h) of muscle fiber traits are moderately high: i.e. h of Type I fiber CSA = .59; h of Type I fiber percentage = .46; h of Type Iib fiber percentage = .58 (Larzul et al., 1997). Published genetic correlations (rg) indicate that Type I and Type Iib fiber percentages are negatively related (rg=−.85; Gerrard and Sosnicki, 1997; Larzul et al., 1997). This particular genetic correlation indicates that breeding for higher percentage of Type I fibers would decrease the proportion of Type Iib fibers, thus directionally improving meat quality without negatively affecting Type Iia and IIx percentage (rg=+.16) or mean fiber CSA (rg=+.15). This approach would enable selection for fast lean tissue growth rate without negatively affecting meat quality (Larzul et al., 1997; Klont et al., 1998).

RECOMMENDATION: Encourage consideration of the use of fiber typing of genetic seedstock for improvements in leanness and pork quality.

DNA TECHNOLOGY

Evidence is accumulating that current and new breeding goal traits may involve a relatively small number of genes with relatively large effects (known as major genes). Modern DNA technologies provide an opportunity to exploit major genes which offer a very promising future for improvement of pork quality (deVries et al., 1998). Some of the genes referred to above fit in the meat quality improvement category (halothane, Napole, and IM fat gene). Klont et al. (2001) stated that the use of DNA markers in breeding programs will also help to reduce variation in carcass composition and meat quality traits. In addition, the exploitation of new markers (both physiological and DNA) in combination with controlled environmental conditions will allow for customization of breeding programs and, therefore, pig/carcass differentiation for specific markets. Ciobanu et al. (2002) and Fields et al. (2002) have demonstrated the possibilities of new DNA markers for calpastatin and for glycogen content, respectively.

RECOMMENDATION: Utilize the new valuable genetic tools in traditional selection programs. As these DNA tests become more readily available, commercial producers need to ask for assurance that their breeding stock suppliers are utilizing all the pork quality tools at their disposal.

QUALITY CONTROL POINT 2: NUTRITIONAL INPUTS

VITAMIN & MINERAL SUPPLEMENTATION

There is a substantial body of data relative to the effects of certain vitamins and minerals on pork quality. Feeding of Vitamin E to pigs offsets lipid oxidation in pork chops packed in high oxygen atmospheres (Jensen et al., 1998). Lipid oxidation is a main factor in determining quality and shelf life of these products. Dietary vitamin E has been found to decrease drip loss (Asghar et al., 1991) and to improve color stability of raw chill-stored pork chops (Monahan et al., 1992).

RECOMMENDATION: Vitamin E is proven beneficial to pork quality but may be economically prohibitive. More information is needed.

Vitamin D has a positive effect on tenderness in beef but recent research with hogs failed to show any advantage in pork quality (Enright et al., 1998 and Beitz, 1998). The addition of high levels of L-carnitine (vitamin Bt) has been reported to reduce the paleness of pork (Sardi et al., 1996; as cited by Mordenti and Marchetti, 1996). The addition of niacin (vitamin PP) at high levels may increase muscle glycogen content. These two vitamins need further study before recommendations can be made.

Magnesium supplementation is a viable option for improving pork quality (Kuhn et al., 1981) and reducing the incidence of PSE (Schaefe et al., 1993; Otten et al., 1992). D’Souza et al. (1998) confirmed that 40 g of magnesium aspartate/pig/day for five days improves meat quality (reduced drip loss and improved color and muscle pH) and reduces the incidence of PSE pork in stressed and unstressed pigs. Dietary supplementation using inorganic Mg sources such as magnesium sulfate and magnesium chloride (DSouza et al., 1999) and magnesium mica (Apple et al., 2000) have also been shown to reduce drip loss, improve color and reduce the incidence of PSE pork.

RECOMMENDATION: Adding magnesium to the diets of finishing hogs for five days prior to slaughter has been shown to be beneficial to quality and should be considered.

Roberts et al. (2002) found that a manganese amino acid complex at the inclusion rate of 350 ppm improved color and resulted in less lipid oxidation but had no effect on drip loss in retail packaged pork. More work is needed on the effects of manganese before a recommendation can be made.

AMINO ACID LEVELS PRE-MARKET

Ball (1988) showed that adding 5 mg of tryptophan/kg to the diet of finishing pigs for five days pre-slaughter resulted in a reduction in the incidence and severity of PSE. In addition, tryptophan treated pigs are markedly less aggressive when mixed in unfamiliar surroundings (Warner et al., 1990 as cited by Pethick et al. 1998). Cisneros et al. (1988) demonstrated that feeding a diet deficient in lysine (.48% lysine) for five weeks prior to slaughter can result in a two percentage point increase in intramuscular fat in pork. NPPC consumer preference studies have shown a significant impact of intramuscular fat on juiciness, flavor, and overall acceptability of pork.

RECOMMENDATION: Restricting amino acids in the diet in late finishing can double IM fat levels, but is not recommended due to other negative consequences: poorer performance and lower meat quality.
**DIETARY FAT SOURCES AND LEVELS**

The major issues relating to fat quality are soft fat, yellow fat, oxidative rancidity, and the impact of pork fat on human health (Ellis et al., 1998). The industry faces a dichotomy relative to fat in pork. The processing segment would prefer fat rich in saturated fatty acids, whereas consumers and health professionals would prefer unsaturated fatty acids. Hertzman et al. (1988) showed that there were high correlations between fatty acids in the diet and in the carcass, with diets high in unsaturated fatty acids resulting in softer fat. There is also potential to alter the composition of intramuscular fat by dietary means although not to the same extent as subcutaneous fat (Marchello et al., 1983). Raising the dietary concentration of unsaturated fatty acids may increase meat tenderness but may adversely affect fat quality. Pork flavor intensity is positively correlated with the concentration of saturated fatty acids in muscle tissue and negatively correlated with the concentration of unsaturated fatty acids. Oxidative processes to which unsaturated fatty acids are particularly susceptible, can adversely affect the quality attributes of meat for human consumption, contributing to rancidity and warmed-over flavor (Gray et al., 1996). However, Corino et al. (2001) found that addition of 3% fat for long terms had no effect on the meat quality or sensory characteristics of heavy pig loins. A potential new idea for altering the fatty acid composition of pork is through use of conjugated linoleic acid (CLA). Thiel et al. (1998) showed that belly hardness increased linearly as the concentration of CLA in the diet increased, along with added improvements in daily gain, feed efficiency and carcass fat levels. CLA is also a potent antioxidant and anticarcinogen. Its effects on pork quality are less clear. There have been reports of no impact on pork quality (Dunshea & Ostrowska, 1999), increased marbling levels (Wiegand et al., 2000; Carroll et al., 1999) or poorer eating quality (D’Souza et al., 2001) for pork from CLA fed pigs, as compared to controls. Joo et al. (2002) reported increased water holding capacity, increased intramuscular fat and improved color stability from feeding CLA.

**RECOMMENDATION:** Moderate the use of fat in the diet controlling the amount of unsaturated fat added. Also, consideration should be given to the use of CLA for its effects on belly hardness.

**AD LIB FEEDING**

Work done by Warkup et al. (1990) and by Ellis et al. (1996) suggest a small but significant improvement in tenderness and juiciness from ad libitum feeding. Wood (1993) agreed, stating that ad lib feeding results in more tender meat to increased marbling fat concentration increased muscle protein deposition rate. Tarrant (1998) also showed that feeding high energy diets, especially in the latter stages of growth, can elevate the rate of protein synthesis and degradation which may accelerate post mortem proteolysis and improve the tenderness of pork (as cited by D’Souza and Mullan, 2001)

**RECOMMENDATION:** Continue the U.S. practice of full feeding finishing hogs to maximize quality of the product.

**DIETARY STARCH**

A recent study by Anderson et al. (1998) demonstrated that pigs fed a diet in which the starch content was limited for a period of about three weeks had higher pH values 24 hours post mortem and darker meat than the controls. In another study (Rosenvold et al., 2001), it was found that strategic feeding of diets low in starch can reduce muscle glycogen stores to an extent that results in lower drip loss and darker but less tender meat. Leheska et al. (2002) found no differences in any meat quality attributes with feeding of an ultra high protein/low carbohydrate diet prior to slaughter.

**RECOMMENDATION:** Further studies are necessary to support or refute the value or costs of starch feeding with typical U.S. rations. No producer recommendation is apparent at this time.

**METABOLIC MODIFIERS**

Porcine somatotropin (PST) is not yet approved in the U.S. This compound can result in profound improvements in performance and carcass composition. However, the best one can hope for in terms of product quality is no change (Beerman et al., 1988; Prusa et al., 1989; McKee et al., 1988; Bryan et al., 1999). Indeed, some research has shown a negative effect on eating quality of pork, from pigs that were subject to PST administration (Boles, 1989; D’Souza, 2002; Solomon et al., 1990). Chromium is another product that has been found to have positive effects on performance and carcass composition (Page et al., 1993) but may have positive (Matthews et al., 1999) or negative (O’Quinn et al., 1998) effects on pork quality. D’Souza (2001) suggested these differences may be due to the source of chromium. It suggested that more work needs to be done to elucidate these results. Betaine is an active methyl donor with a lipotropic effect (Barak et al., 1993 as cited by D’Souza and Mullan, 2001). This energy sparing compound has significant impacts on carcass fat (Cadogan et al., 1993; Henman, 1995; Dunshea and Walton, 1995 as cited by D’Souza and Mullan, 2001). It also has been shown to improve water holding capacity and color (Matthews et al., 2001a; Matthews et al., 2001b). Ractopamine is a beta agonist that increases the protein deposition rate in pigs. Stoller et al. (2002) stated that ractopamine treatment had no significant effect on muscle quality assessments, sensory attributes or instrument measures of palatability.

**RECOMMENDATION:** Because PST is not yet approved for use in the U.S., no recommendation is evident. However, with demonstration of economic return from the performance and carcass benefits, positive consideration should be given to using betaine and chromium for the potential pork quality benefits. Use of ractopamine is dependent on its value for performance and carcass traits with little value to pork quality. Its use should be predicated on adapting handling systems for minimum stress and gentle handling on the farm, in transport and at the plant.

**FEED WITHDRAWAL**

Numerous studies have shown the positive effects of withdrawing feed from market hogs for 12-18 hours prior to slaughter. It is important that actual time off feed be calculated, because lengthy feed withdrawal periods may begin to negatively impact carcass weight. Hyun et al. (1997) investigated eating behavior of market hogs and found that pigs consumed relatively little feed between 6 P.M. and 6 A.M. Therefore, hogs loaded for transport to market at 5 A.M. may well have 11 hours of feed withdrawal. Add the transport time and the rest time in lairage, and the time off feed is adequate to accomplish the advantages. These include less deaths in transport, easier moving hogs, less contamination during evisceration, and less waste for the plant to handle in addition to the feed cost savings that the producer experiences (Eikelboom et al., 1981 and Gispert et al., 1996).

There is one study that indicated that feed withdrawal improves meat color and water holding capacity. Murray et al. (2001) found a slight darkening of pork with no other meat quality effects with overnight feed withdrawal. However, Ellis et al. (1998) cited two studies by Bidner (1998) from which he suggested that genotype and animal handling factors interact to determine the response in pork quality to feed withdrawal. There had been some concern that withdrawing feed prior to market was exacerbating salmonella shedding. A study by Isaacson et al. (1999), however, refuted this claim and suggested that feed withdrawal may actually reduce the incidence of pigs that are actively shedding Salmonella.

**RECOMMENDATION:** Ensure that total feed withdrawal time from last consumption until slaughter is between 12 and 18 hours, with access to water.
QUALITY CONTROL POINT 3: ON-FARM HOG HANDLING

HEALTH/STRESS HOG HANDLING

Pigs left in dark, quiet rooms are more easily startled than pigs in well-lit pens with exposure to human activity (Grandin, 1986). Also, pigs should be allowed to move from their pens at least twice during the finishing period. This will reduce the stress of loading but may not be practical. However, the caretaker should walk the pens of finishing pigs daily to accustom them to human activity. Hemsworth et al. (2001) concluded that the correlations between stockperson behavior, plasma lactate and glucose, and muscle lightness reflect increased muscle glycogenolysis presumably associated with an increase in handling stress prior to slaughter. Such results indicate the opportunity to manipulate the behavior of stockpeople prior to slaughter to improve meat quality. Empowering the handler by improving his/her knowledge on the behavior and biology of the pig will have a permanent positive impact on the attitude that she or he will have towards the animals (Hemsworth, et al., 2001). Pigs should be moved with minimal force. If an aid is required, cutting boards and slappers should be used. Electric prods should be avoided (Grandin, 1989; Guise and Penny, 1989; Kilgour and Dalton, 1984 as cited by Berg, 1998). If electric prods must be used, they should be used only in cases of an emergency and only by trained handlers. D’Souza et al. (1998) concluded that negative handling of pigs prior to slaughter using an electric goad had a detrimental effect on pork quality as measured by lower muscle pH, paler pork, higher percent drip loss and a higher occurrence of PSE pork. D’Souza (2001) conducted a study on commercial farms and in plants and concluded that the use of electric prodders resulted in lower muscle pH, increased surface exudate, and paler color. Pigs should never be prodded in highly sensitive areas such as the eyes, nose, anus, etc. Every individual handling market hogs on the farm should be required to watch the NPB videos on “Handling of Hogs on the Farm”. Sick, injured or severely stressed pigs must be isolated from other pigs.

RECOMMENDATION: View the NPB “Handling” videos; eliminate or significantly curtail the use of electric prods; accustom pigs to human activity during the finishing period; separate health stressed pigs from healthy pigs; empower stockpersons by teaching them handling affects the welfare of the animals in their care and the resulting meat quality.

SLAUGHTER WEIGHT

As breeds and lines of pigs are selected for high lean growth efficiency, they become later maturing. These new genetics can maintain feed efficiency and leanness at heavier slaughter weights. At these heavier weights, the product is likely to have higher pork quality ratings due to juiciness, flavor and tenderness (Kim et al., 2002). From their studies, Hugo et al. (1999) concluded that technological properties of intramuscular fat improve with increased slaughter weight.

RECOMMENDATION: Depending on the genetic lines used, carry finishing pigs to maximum practical market weights to maximize product quality.

FACILITY CONSTRUCTION

Pig handling facilities should be designed to promote easy handling. Finishing buildings should have a three-foot wide alley allowing pigs to walk side by side. Pigs should not experience injury or distress during handling or loading. Load pigs in small groups of five or six. Level floors are recommended and ramps should have a slope of less than 20°. All ramps should have a non-slip surface. Dual ramp designs with solid outside walls and a transparent middle partition allow for easier and less stressful loading (Grandin, 1997). Reverse the flow of ventilation so that air is not blowing in pigs’ faces as they exit the building.

RECOMMENDATION: Provide facilities that offer the least resistance and stress for pigs during handling and loading. Dual ramp designs should be constructed into the loading facilities.

QUALITY CONTROL POINT 4: TRANSPORTING HOGS

TRUCKER QUALITY ASSURANCE (TQA)

Channon (2001) cited Martoccia et al. (1995) to state that pig transport was the most influential pre-slaughter factor that influences pork quality. Transportation involves factors that increase stress in pigs such as unfamiliar noises and odors, deprivation of food and water, crowding, vibrations and changes in acceleration, and extremes of temperature. Whether the producer hauls his own hogs to market or whether (s)he hires the hauling, all truckers must be required to become Certified Quality Truckers by taking the course and passing the exam in the Trucker Quality Assurance program. It is the responsibility of producers to assure that their trucker has become certified and adheres to the recommendations of the TQA program.

RECOMMENDATION: Producers are responsible for the proper handling of their hogs in transport to market even if the hauling is hired. Require all truckers to become certified in the National Pork Board’s Trucker Quality Assurance program.

ELECTRIC PRODS

D’Souza et al. (1998) demonstrated the negative effects of electric prods on pork quality. Electric prods should be eliminated for loading or unloading hogs. Many packers have dramatically reduced and/or forbidden the use of electric prods on their premises. If situations require their use, they should be severely curtailed and used only sparingly by trained handlers. In his study of commercial farms and abattoirs, D’Souza (2001) made the observation that the major factors affecting pig movement requiring the use of electric prodders were the steep angle of loading/unloading ramps, lack of anti-slip cleats on ramps, and inadequate skills of truck drivers.

RECOMMENDATION: Eliminate (or significantly curtail) all use of electric prods for loading and unloading hogs.

TRUCK/TRAILER TYPE

Possum belly semi-trailers are popular because they hold more market weight hogs than flat-floor trailers and they can double as cattle trailers, while flat-floor trailers only have one deck for cattle transport. These potbellied trucks are very questionable when it comes to loading and unloading hogs, particularly in certain weather and with certain types of genetics. They usually require more time in removing pigs from the lower and upper decks and most often, they require the use of electric prods. The newer pot belly trailers have gentler slopes on the inside ramps and are more conducive to loading and unloading than the older version of these trailers were. Pigs find vibration very aversive according to Stephens et al. (1985). Trailers should be equipped with air shocks to minimize the discomfort to pigs.

RECOMMENDATION: Only hire haulers who have flat-floor trailers (or at least have more modern pot belly trailers). Commercial producers who do their own hauling should transition from potbellied trailers to flat-floor trailers to enhance pork quality and reduce the number of deaths in transport. Use only trailers with air shocks to haul market hogs.

LOAD SIZE

Space allowance should be such that hogs can lie down and stand up in their natural position. Stacking density should be 4.2 square feet for a 250-lb. pig which equates to 190 pigs for a standard double-deck flat-floor trailer (Sosnicki et al., 1998). Hauling 200 pigs on these trailers may result in double the number of DOA’s.

RECOMMENDATION: Haul no more than 190 head in 48 foot X 102 inch standard double-deck, flat-floor trailers.
WEATHER EXTREMES

Extremes in weather should be considered when hauling hogs to market. During extremely hot and/or humid weather, pigs should have access to cooling wind which means that the truck should not be allowed to sit idle for any extended periods of time. Pigs should be unloaded immediately upon arrival at the plant. Water sprays should be considered for these extreme periods. Trailers should be lined with wet sand or wet shavings when temperatures exceed 15°C (60°F). Grandin (1998) recommends pigs be scheduled for delivery at the packing plant at night or early in the morning during these hot weather extremes. For extremely cold weather, the trailer should be enclosed and some type of bedding should be used.

RECOMMENDATION: Give special consideration to market hogs during times of weather extremes. Adjust the transport vehicle to lessen the impact of the weather on the transport subjects.

TRANSPORT TIMES

Channon (2001) stated that it is difficult to draw definite conclusions about the effect of transport time or distance on muscle glycogen content and ultimate pH due to the many factors involved in the transport process, e.g. loading density, temperature at the time of transportation, genotype of pigs, transport time, the number of stops during transport, and the length of time since last fed. In the U.S., pigs are transported varying distances and times, but there is very little data available about the effect of transport on quality. It may be more critical to pay attention to such factors as load size and weather extremes, especially for long hauls. With adequate consideration of these factors, long hauls may be less stressful than short hauls as the pigs have a chance to rest.

RECOMMENDATION: Make sure that extra attention is given to load size and other factors on short and long hauls.

QUALITY CONTROL POINT 5: PRE-SLAUGHTER HANDLING

FACILITY CONSTRUCTION

Holding pen sizes differ among plants. Hogs should have enough room to walk to waterers and move freely. Alleys should be wide with no obstructions that can cause bruising. Corners should be rounded and well lit with no shadows that can cause pigs to balk. Floors should be clean with a non-slick surface.

RECOMMENDATION: Give special attention to holding facilities to reduce stress and lessen the detrimental effects on meat quality.

WATER SPRAYS

The use of water sprays and misting systems to cool pigs in hot environmental conditions affect pig behavior in holding pens, especially when used intermittently to maximize evaporative cooling, according to Weeding et al. (1993) as cited by Barton Gade (1998). Long and Tarrant (1990) found that showering pigs with cool water during the summer actually reduces the incidence of PSE carcasses. Channon (2001) stated that showering pigs with water not only reduces the effects of heat stress suffered during transport and/or in lairage but also tends to wash away the individual body odors and make pigs more acceptable to each other. Long and Tarrant (1990) also showed that showering caused a reduction in deep loin temperature at 40 minutes post mortem. Water sprays should not cause the pigs to shiver which means that pigs should not be showered during the coldest winter months.

RECOMMENDATION: Provide water sprays in the holding pens during hot weather to reduce stereotypical behavior and calm the pigs as they prepare to enter the stunning chute.

ELECTRIC PRODS

Berg (1998) cited several studies (Grandin, 1989; Guise and Penny, 1989; and Kilgour and Dalton, 1984) to conclude that electric prods should be avoided during this period critical to meat quality. In addition, Fauciiano et al. (1997) recorded a 50% decrease in the carcass blemish score by avoiding the use of electric goads within the raceway prior to the stunning restraining conveyor. They also found that the use of electric prods resulted in greater stress, higher skin damage scores and elevated incidences of PSE and blood splash. Pethick et al. (1998) stated that acute stress before or at stunning may result in an accelerated muscle pH decline while the carcass temperature is still high, resulting in PSE pork. Shafer et al. (2000) stated that pre-mortem stress leads to an early post mortem pH drop at higher body temperature. Post mortem stress also results in higher drip loss and an early, severe post mortem drop in the Py value, which is highly correlated to drip loss. D’Souza (2001) observed that electric prods are required in situations where unloading ramps are too steep, there is a lack of anti-slip cleats on ramps, and the raceways leading to the stunners are inadequate.

RECOMMENDATION: Eliminate the use of electric prods in the holding facility and prior to stunning.

REST (LAIRAGE) TIMES

The required resting time is highly dependent upon the transport time, environmental conditions and genetic makeup of the pigs. Berg (1998) stated that it was generally accepted that time spent in lairage allows a stressed animal time to recover from the stress of loading, transport, and unloading, reduce the incidence of PSE meat. Pigs should be rested 2 to 4 hours before entering the stunning area (Grandin, 1994). Aslany and Barton Gade (2001) published results showing that there was no influence of lairage time on pork quality in low stress handling of pigs in cooler temperatures, but when the experiment was repeated in warmer temperatures, shorter lairage times led to higher loin muscle temperatures immediately post mortem. It is important to note that there is mounting evidence that two hours is satisfactory for pigs to become infected with Salmonella in packing plant pens. While work is ongoing, there may be good reason to limit lairage times from one to two hours to obtain the necessary rest time for the pigs, without compromising their Salmonella status. (Hurd et al., 2001)

RECOMMENDATION: Rest all pigs for two hours before exsanguination to allow for transport recovery.

PRE-STUN HANDLING

Rough handling of pigs in the stunning chute during the last few minutes before exsanguination will increase the occurrence of PSE meat, even in pigs not carrying the stress gene (Tarrant, 1989). van der Wal et al. (1997) presented data to support the hypothesis that stress immediately prior to slaughter affects meat quality more than stress experienced earlier on. Pigs do not possess the instinct to walk in single-file (Grandin, 1994). A dual chute with solid sides and a see-through partition is recommended. If the chain speed is greater than 500 head per hour, the restraining system should be split into a dual system. The two biggest stressors pre-slaughter are isolation and restraint. The dual system helps alleviate the isolation problem but not the restraint issue. Troeger and Woltersdorf (1989) showed that restraint as that seen in V-belt restrainers causes increases in adrenaline and noradrenaline as compared to pigs electrically stunned while standing on the floor. The angle and width of the V-shaped conveyor must be specified for a particular weight range of pigs. Troeger (1989) also stated that pigs led in a single line without any mutual visual contact before exsanguination will increase the occurrence of PSE meat, even in pigs not carrying the stress gene (Tarrant, 1989). van der Wal et al. (1997) presented data to support the hypothesis that stress immediately prior to slaughter affects meat quality more than stress experienced earlier on. Pigs do not possess the instinct to walk in single-file (Grandin, 1994). A dual chute with solid sides and a see-through partition is recommended. If the chain speed is greater than 500 head per hour, the restraining system should be split into a dual system. The two biggest stressors pre-slaughter are isolation and restraint. The dual system helps alleviate the isolation problem but not the restraint issue. Troeger and Woltersdorf (1989) showed that restraint as that seen in V-belt restrainers causes increases in adrenaline and noradrenaline as compared to pigs electrically stunned while standing on the floor. The angle and width of the V-shaped conveyor must be specified for a particular weight range of pigs. Troeger (1989) also stated that pigs led in a single line without any mutual visual contact and with frequent interaction with humans had increased concentrations of catecholamines in their blood and increased body temperatures. In addition the muscle acidification rate is faster than normal as a result of fear and excitation. Henckel et al. (1997) concluded that a low pH within one hour post-mortem does not signify a faster rate of pH fall but a lower pH at exsanguination. The pH level at sticking is a function of pre-slaughter
handing. Some of the new work with batch stunning of pigs with CO₂, with no restraint has shown a very positive effect on meat quality (personal observation).

RECOMMENDATION: The two greatest stressors on pigs just prior to slaughter are isolation and restraint. Implement a dual system for moving pigs to the restrainer for electrical stunning or into the chamber for CO₂ stunning to reduce isolation. Systems that can alleviate the stress of restraint should be investigated. All workers in this area need to be thoroughly trained on the effects of stress on subsequent pork quality.

QUALITY CONTROL POINT 6: STUN & EARLY POSTMORTEM STUNNING SYSTEM

Throughout the world, the two systems most popular for rendering an animal insensible include electrical stunning and CO₂ stunning. None of the two methods is ideal and both have some advantages and disadvantages. But both of the methods are internationally recognized as humane and acceptable (Holst, 2001). Although both have been in use for some period of time, pork quality effects have brought some new issues to bear in the discussion of the best system to use.

Electrical

With electrical stunning, packers experience a certain percentage of broken backs and shoulders, blood splash, bruising, and meat quality defects, all of which relate to vigorous muscle contractions upon stunning (Simmons, 1998). Berghaus and Troeger (1998) maintain that Coulomb (ampere X seconds) is the important factor in having an effective stun without the associated meat quality deterioration. Voltage and ohms of resistance affect amperage delivered. A constant amp system measures the resistance of the pig to reduce variation. Simmons (1998) investigated high frequency stunning and concluded that this method alleviates many of the broken bone and blood splash problems associated with electrical stunning and provides an improvement in the quality of meat. On the contrary, this method results in greater kicking activity in the post-stun pig which is of great concern to packers from a worker safety perspective. Recent work by Daly (2002) has shown that the combination of head only stunning using high frequency stunning coupled with low frequency stunning causing cardiac arrest with a breast plate has very positive results. The carcasses had all the positive pork quality benefits without the excessive kicking. This system is now being commercialized in the U.S.

Carbon Dioxide

In explaining why Denmark has switched to CO₂ stunning, Barton Gade et al. (1992) stated that the improvement in meat quality (reduction in blood splashing and PSE meat and elimination of fractures) more than outweighs the extra running costs of CO₂ stunning. Silveira et al. (1998), Henckel (1998), and Channon et al. (1998 & 2002) confirmed the positive effects of CO₂ stunning on pork quality compared to electrical stunning. In fact, Velarde et al. (2001) reduced PSE incidence from 35.6% to 4.5% with CO₂ stunning compared to electrical. Moreover, they stated that electrical stunning increased significantly the incidence of petechiae (defined as fiery pinpoint bleeding in the fat or surrounding tissue) in the loins, shoulders and hams and ecchymosis (defined as larger blood areas in the muscle tissue) in the loins and hams. These are very positive pork quality effects of CO₂ stunning but Troeger and Woltesdorf (1991) showed that CO₂ will not prevent the incidence of PSE meat in stress positive pigs. In fact, these halothane positive pigs seem to be more sensitive to changes in the concentration of CO₂, and may suffer more than halothane negative pigs.

RECOMMENDATION: Implement a documented process to address all meat quality effects of the handling and stunning operation including operator training, electrical parameters or gas concentrations, periodic changing of all electrical wiring and switches, handling procedures, etc. Consideration should be given to the use of carbon dioxide stunning for its obvious improvements in pork quality.

STUN TO STICK INTERVAL

Grandin (1994, as cited by Berg, 1998) recommends bleeding pigs within 10 seconds after stunning. Some plants can accomplish this within 6 seconds after stunning while other plants take as long as 45 seconds or more. The industry average is about 25 to 35 seconds (Meisinger, personal observation). Shorter intervals help to minimize blood splash due to reductions in blood pressure and help to remove heat quickly thereby reducing the opportunity for PSE formation.

RECOMMENDATION: Make adjustments to reduce the stun to stick interval to less than ten seconds.

HORIZONTAL VS. VERTICAL STICKING/BLEEDING

Berg (1998) stated that many U.S. plants apply a horizontal stick before the pig is shackled as a means of reducing the stun to stick interval. This will improve meat quality by reducing bruising and prevent struggling after stunning (Ellert, 1997, as cited by Berg, 1998).

RECOMMENDATION: Install horizontal systems for sticking and bleeding to reduce the stun to stick interval and to minimize postmortem body convulsions.

BLEED TIME

It had been suggested that a minimum time of five minutes be allowed for carcass bleeding before scalding (Sosnicki, 1998). However, a new study by Gardner et al. (2002) shows that 99.2% of the blood is removed by three minutes post-sticking. In addition, they found that with a ten-minute dwell time (the time between stunning and scalding), there was a significant negative effect on tenderness as compared to a five minute dwell time. With this knowledge, packers can shorten their bleed chains and cut valuable minutes from the evisceration process.

RECOMMENDATION: Allow sufficient time for adequate bleeding of carcasses but reduce this time to no more than five minutes.

SCALD TEMP/TIME OR SKIN TIME

van der Wal et al. (1993, as cited by Berg, 1998) showed that scalding carcasses at 60°C for 5.5 to 7.5 minutes gave satisfactory dehairing results except during hard hair season. Gardner et al. (2002) showed that scald times of eight versus five minutes did not affect temperature or pH of the longissimus or semimembranosus muscles. Two other papers cited by Berg (1998) suggested an improvement in pork quality with skinning rather than scalding (Ellert, 1998 and Troeger, 1987).

RECOMMENDATION: Document the process for addressing the scald time and temperature and the impact on carcass temperature.

TIME ON BUFFER RAILS

Many plants routinely use buffer rails to hang carcasses to be used to “fill holes” in the line. In effect these carcasses are being incubated in the warm temperature conditions that exist there. Almost any carcasses can be made to become PSE with incubation. (Floyd McKeth, personal communication). This is a very important consideration and requires training of employees in that part of the plant about the very negative effects of this practice on pork quality.

RECOMMENDATION: While buffer rails are a necessary economic consideration, limit the time any individual carcass is left to hang on these rails to no more than 10 minutes.
QUALITY CONTROL POINT 7: EVISCERATION

EVISCERATION TIME

Delays in carcass processing rates have been previously shown to result in paler meat (Eldridge et al., 1993). Eilert (1997, as cited by Berg, 1998) suggested that an ideal plant would have carcasses off the slaughter floor within 20 to 25 minutes. The industry range is from 30 minutes to one hour (Meisinger, personal observation).

RECOMMENDATION: Reduce the time from stick to chill to no more than 30 minutes.

SPLITTING ACCURACY

Whether splitting is done manually or automatically, the accuracy of the split affects quality and value of the resultant product. Mis-splits can significantly reduce the value of two of the most highly valued items on the carcass, the loin and tenderloin.

RECOMMENDATION: Implement a procedure for monitoring and reducing the incidence of off-split carcasses and the effects on product quality.

Fecal contamination of carcasses can be significantly reduced by requiring that all pigs have a period of feed withdrawal before slaughtering and by using highly trained individuals to do the opening and evisceration procedures.

RECOMMENDATION: Encourage a system of feed withdrawal with hog suppliers and implement a procedure for training of employees for these critical areas of opening and gutting.

TRIMMING

Most packers are experts at trimming carcasses for defects and doing it rapidly and accurately. Unfortunately, not many of these defects are recorded for communication with producer suppliers. Some of the reasons for trim loss are packer caused but many are due to conditions of the pigs over which the producer has control. Many of these conditions could be alleviated if the pork producer had knowledge of the problem and the cause. There are now systems available for capturing this veterinary data on carcasses and on viscera for better communication back to producers.

RECOMMENDATION: Consider a system that captures veterinary data on-line for transfer to producers.

MEASURING CARCASS COMPOSITION

Virtually all market hogs in the U.S. are measured to estimate the lean composition of the carcass. Devices include a simple ruler, optical probes, ultrasound applications (hand-held devices and Autofom), carcass imaging systems, and total body electrical conductivity. Each of these has its own set of advantages and limitations, but collectively, this technology has catapulted the lean composition of U.S. market hogs into dramatic improvement over the past several years. The new Fat-Free Lean Index is based upon the largest and best database of information available to the industry. For reporting purposes and for their own grading and evaluation programs, all packers should utilize these new equations.

RECOMMENDATION: Strive for more accuracy in measuring and reporting composition of carcasses. Use the FFLI equations as the standard for the industry.

QUALITY CONTROL POINT 8: CARCASS CHILLING

CHILLING SYSTEM

The purpose of any chilling system is to remove the heat from the carcass as quickly as possible after slaughter. This affects pork quality and is important to retarding microbial growth. Some of the chilling systems in use in the U.S. include conventional, forced-air systems, moderate to extreme blast chilling, and spray chilling. The popularity of the blast chill systems in the U.S. relates to the reduction in PSE with these systems. However, this reduction in PSE is only apparent in some carcasses. Van Laack and Smulders (1997) cited Offer (1991) when they pointed out that the effect of chilling on PSE conditions is strongly dependent upon the rate of pH decline. In fact, they went on to say that tenderness differences due to cold shortening might also be due to the rate of pH decline. Berg (1998) concluded that pH at two hours post mortem coupled with a temperature measurement at one minute was most effective in predicting the ultimate quality of the product. They found this two hour pH measurement to be best in the explanation of variation in drip loss which is in contrast to the general acceptance of pH2h as an indicator of drip in pork from populations containing the Halothane gene.

RECOMMENDATION: Continue to develop devices and procedures for accurate measurement or prediction of pork quality on line. Develop systems to communicate quality estimates. Have pork producer suppliers make information available about any changes they make in genetics, handling or nutrition that may affect their running average quality.

MEASURING PORK QUALITY

Because the quality of fresh pork continues to change dramatically for hours and subtly for days, the industry will not likely ever measure pork quality on-line on individual carcasses. However, certain measures will be used to estimate quality variation between carcasses, lots, suppliers, or genetic lines. On-line measures of defraction at different wavelengths with fiber optic, measurement of electrical bioimpedance using spectroscopy (Gobantes, et al., 2001), measurement in the mid-IR range with infrared spectroscopy (Pedersen and Engelsen, 2001), and/or measurement of pH for the estimate of acceptable or unacceptable quality may become commonplace in the future. The use of pH alone for individual carcasses contains many opportunities for error. There is a great deal of variation over time with pH measurements that it is difficult to establish a plant base for this characteristic. In addition, pH measured on the slaughter line has a very low correlation with ultimate quality. pH measured at 24 hours is somewhat more reliable but only for group averages with no comparisons over time and only to predict drip loss. Channon et al. (2001) stated that the measurement of pH was poorly related to pork eating quality (tender-ness, juiciness, flavor and overall liking) of loin steaks grilled to a medium/ well done degree of doneness. This study suggested that, in addition to ultimate pH, other meat quality attributes may be required to provide industry with a useful model for sorting pork into different eating quality classes.

Recent work at the Danish Meat Research Institute has shown that a few, critical pH and temperature measurements early post mortem are sufficient to explain variation in drip loss in pork chops. Schafer et al. (2001) concluded that pH at two hours post mortem coupled with a temperature measurement at one minute was most effective in predicting the ultimate quality of the product. They found this two hour pH measurement to be best in the explanation of variation in drip loss which is in contrast to the general acceptance of pH2h as an indicator of drip in pork from populations containing the Halothane gene.

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RECOMMENDATION: Develop and utilize systems with the goal of removing the heat from the carcass as quickly as possible without compromising tenderness. Also, support work should be on the interactions of completed chilling systems with pork quality, handling, and genetics (leaness) of the carcasses.

CHILL TIME/TEMPERATURE

Chill time is simply a function of internal temperature of the thick portions of the carcass. The internal muscle temperature should be at approximately 36° to 40°F at 24 hours post mortem. Following is a chart representing the recommended chilling rates of loins:

<table>
<thead>
<tr>
<th>Time Postmortem</th>
<th>Temperature (°C)</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Death</td>
<td>39° C</td>
<td>102° F</td>
</tr>
<tr>
<td>1 hour postmortem</td>
<td>35-37° C</td>
<td>95-98° F</td>
</tr>
<tr>
<td>2 hours postmortem</td>
<td>30-32° C</td>
<td>86-90° F</td>
</tr>
<tr>
<td>3 hours postmortem</td>
<td>26-28° C</td>
<td>79-82° F</td>
</tr>
<tr>
<td>5 hours postmortem</td>
<td>22-24° C</td>
<td>72-75° F</td>
</tr>
<tr>
<td>6 hours postmortem</td>
<td>20° C</td>
<td>68° F</td>
</tr>
<tr>
<td>10 hours postmortem</td>
<td>12° C</td>
<td>54° F</td>
</tr>
<tr>
<td>16 hours postmortem</td>
<td>8° C</td>
<td>46° F</td>
</tr>
<tr>
<td>20 hours postmortem</td>
<td>5-7° C</td>
<td>41-44° F</td>
</tr>
</tbody>
</table>

Honikel 1999

RECOMMENDATION: Space carcasses to allow adequate air movement during chilling. Achieve a temperature in the thickest part of the ham of below 86° F as quickly post mortem as possible >50° F within 12 hours post mortem. Assuming a 24-hour chill, deep ham temperatures should be less than 40° F as the carcass enters fabrication.

CARCASS SUSPENSION

The typical method used for suspension of carcasses in the U.S.A. is by passing a gambrel behind the Achilles tendon. However, work in Australia has shown that aitchbone hanging results in a highly significant difference in tenderness after cooking. According to Channon (2001), this method is commercially practiced in the UK as part of their program to improve the tenderness of pork. This practice requires that carcasses be rehung after evisceration, which requires more labor and more room in the cooler. In addition, the resulting cuts take on unconventional shapes due to aitchbone hanging, the affect on retail cuts needs to be considered.

RECOMMENDATION: Consider the aitchbone method of carcass suspension to achieve an extra level of tenderness in the loin and ham.

QUALITY CONTROL POINT 9: FABRICATION

WORKMANSHIP

Economic losses from poor workmanship should be avoided. Slashes and miscuts result in loss of value. Excessive trim reduces value of valuable cuts. To some, quality is defined as “adherence to specifications”. Special attention should be given to monitoring adherence to specifications in cutting, trimming and boxing product for shipment from the fabrication area.

RECOMMENDATION: Implement sound procedures and continuous monitoring for assuring quality of fresh pork in the fabrication area.

QUALITY CONTROL POINT 10: FURTHER PROCESSING OF FRESH PORK

ENHANCEMENT OF FRESH PORK

“ENHANCEMENT OF FRESH PORK” is the process of adding non-meat ingredients to fresh pork, to improve the eating quality (juiciness, tenderness, and flavor of the pork) of the final product. Enhancement typically consists of a solution of water, sodium phosphates, salt, sodium lactate, and varying flavoring agents injected into the muscle (Miller, 2001). There are many different levels of pump being utilized in the industry by various packers. This practice has become very popular because of its effect on pork quality. Very little information about this practice exists in public data banks. However, McKeith (personal correspondence) has shown that quality of the raw material is critical to the success of this procedure. In fact, Miller (2001) said that enhancement is not a method to improve low quality pork, but is a method being used by the pork industry to improve the overall quality of fresh pork in the retail case. This technique is especially useful for protecting pork from the temperature abuse that is typical when most U.S. consumers cook fresh pork.

RECOMMENDATION: Support research work to evaluate different levels, ingredients, and various quality levels of raw materials to use in the enhancement of fresh pork.

IRRADIATION OF FRESH PORK

Murano et al. (1995) concluded that irradiation did not affect the quality of fresh pork, but vacuum packaging may offer some advantages by minimizing the occurrence of lipid oxidation immediately after irradiation. However, Ahn et al. (2001) stated that volatile compounds responsible for off-odor in irradiated meat are produced by the impact of radiation on protein and lipid molecules and are distinctly different from those characteristics of lipid oxidation (warmed-over flavor) in oxidized meat. They found that irradiation increased the production of sulfur-containing volatiles, regardless of packaging conditions. Most of these volatiles escaped during storage under aerobic packaging conditions. Irradiation and storage of meat in vacuum packaging may be desirable for long-term storage but may reduce the acceptance of irradiated meat because of the sustaining off-odor volatiles. Ahn et al. (2001) stated that significant amounts of cholesterol oxidation products (COPs) can be formed if irradiation, cooking, and storage in aerobic packaging are combined. However, their work demonstrated that irradiation had no effect on the content of COPs in cooked pork. After 7 days of storage, aerobically packaged pork produced 10- to 15-fold higher amounts of total COPs than the vacuum-packaged pork. They concluded that packaging was far more important than irradiation in the formation of COPs and lipid oxidation in cooked meat.

RECOMMENDATION: Conduct further work to elucidate the impacts and relationships of irradiation on fresh and in cooked pork with different packaging systems in terms of pork quality.

FREEZING & THAWING OF FRESH PORK

It is the general opinion that fast rates of freezing are associated with less drip during thawing (Lawrie, 1991). Steier and Borup (1995) found that the rate of freezing, defined as the time it takes the temperature of a product to decrease from 5° C to a core temperature of -12° C, has a great impact on the quality. Hvid and Darre (2001) also found a significant difference in thawing loss, depending on the freezing process and time. Both of these studies showed that quicker freezing times were associated with less thawing loss, probably due to the smaller ice crystals formed during quicker freezing. Length of frozen storage time also affects pork quality. Honkavaara (1995) demonstrated that compared to fresh pork, almost half of the water holding capacity of pork trimmings was lost after six months’ storage.
RECOMMENDATION: When freezing fresh pork, always use methods that bring the internal temperature down quickly. Do not store pork in the frozen state for excessive periods of time.

QUALITY CONTROL POINT 11: PACKAGING

AGING OF PORK

Channon (2001) referenced three sources to conclude that some of the desirable eating quality characteristics of pork, particularly tenderness, increase with post slaughter storage at 32-40° F. The improvements in tenderness due to aging are rapid in the first 1-2 days; then continue at a slower pace and plateau at around 6 days post-slaughter (Dransfield et al., 1980). This is in contrast to data from a study by Okumura et al. (1999) which showed that aroma, taste intensities, and tenderness of pork loins gradually increased during storage and was largest at 20 days post mortem. The improvements in tenderness seen with aging are believed to occur because of the degradation of some of the key structural proteins by endogenous enzymes when meat is aged (Koohmaraie et al., 1995) although these effects are greater for lamb and beef than for pork (Koohmaraie et al., 1991). Wood et al. (1996) found that aging pork for 10 days post-slaughter had a greater effect than both genotype and feed level in improving tenderness. Moya et al. (2001) found that the aging of pork meats produced a general increase in all free amino acid concentrations which are known to be important in flavor development. Kristensen and Purslow (2001) presented data to confirm that water holding capacity of pork eventually increases during aging but only after a decrease during the first 2-7 days post-mortem. Studies have also shown that the improvements in tenderness associated with aging of pork are not applicable to PSE pork (D’Souza and Mullan, 2001).

RECOMMENDATION: Because pork products continue the aging process during packaged storage, shipment, and display, all pork should be allowed this normal aging process for periods of up to ten days after slaughter.

PACKAGING

Vacuum packaging of fresh pork provides for an extended shelf life. Modified atmosphere packaging improves meat color and shelf life stability over that of conventionally overwrapped (aerobic) packages (Farber, 1993; Sorheim, 1996). The increased shelf life of MAP systems is achieved by carbon dioxide in the package headspace gases. The MAP systems have advantages over vacuum packages because the greater headspace allows use of greater amounts of carbon dioxide and usually results in less purge. If, however, carbon dioxide levels are too high (over 40%) surface discoloration/browning of fresh meat can occur. Consequently, MAP systems typically utilize 20% to 30% carbon dioxide (Sebranek and Krause, 2001). These investigators also found that low levels of carbon monoxide (0.5%) in a MAP system achieved a dramatically stable, bright-red color over an extended storage period. In addition, lipid oxidation was suppressed, as compared to overwrap-package treatments.

RECOMMENDATION: Consider Modified Atmosphere Packaging (MAP) as a technique to extend shelf life and improve quality.

QUALITY CONTROL POINT 12: COOKING EFFECTS ON PORK QUALITY

COOKING PROCEDURE

Aaslyng (2002) showed that the cooking procedure influences the sensory profile, depending on the raw meat quality. She surmised that for flavor evaluation, pan frying is optimal, while for small texture variations, oven cooking is optimal.

END POINT TEMPERATURE

Aaslyng (2002) concluded that the effects of end point temperature depend on raw meat quality. For roasted flavors, she pointed out that end point temperatures of 176° F are best for roasted flavors, 149° F for other flavors, and 167° F for texture.

COOKING LOSS & JUICINESS

Aaslyng (2002) stated that water holding capacity and pH influences cooking loss but there seems to be a threshold value or an area of influence. Intramuscular fat also influences cooking loss. She concluded that the rate of increase in cooking loss depends on the cooking procedure and raw meat quality. The correlations between cooking loss and juiciness depend upon raw meat quality as well.
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