

# Chilling of Prerigor Meat

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Hot boning has been a topic of discussion for many years. It has also been referred to as hot processing or accelerated processing. This process involves the removal of the edible tissues from the carcass soon after slaughter and prior to chilling. Although research results have suggested many advantages for accelerated processing systems (reduced energy usage, refrigerated space requirements and labor and increased yields and functional characteristics), commercial application has been limited. Currently in the U.S., accelerated processing systems are used in the production of whole-hog sausage, and limited amounts of frozen, prerigor beef are used for further processing. In Europe, several companies are producing beef primal and subprimal cuts with hot boning systems.

With the growth of slaughterer-processor systems for beef in the U.S., hot boning would seem to be a natural progression. If there are so many advantages associated with accelerated processing, why is this technique not being used to a greater extent? Early attempts at hot boning resulted in problems with toughness and shape distortion caused by uncontrolled muscle contraction associated with prerigor excision of muscle. Research has shown that these problems can be controlled by use of postmortem technology such as conditioning of carcasses prior to fabrication, conditioning of cuts prior to chilling or applying electrical stimulation to the carcass (Kastner, 1983). It has been suggested that adoption of this technology by industry has been hindered by concerns about the inability to grade freshly slaughtered beef, how to identify undesirable carcasses, such as dark cutters, and the loss of versatility associated with such a system. However, at the 1981 RMC, Bowling implied that the major deterrent to industrial application of accelerated processing is in the development of commercially feasible chilling systems.

Even though attaining and maintaining a chilled temperature (4°C) are integral parts of conventional beef and pork processing systems, this area has been neglected in much of the accelerated processing research. Few studies have evaluated the effects of chilling temperatures and techniques on the palatability, appearance and shelf life of hot boned products. In particular, commercially feasible chilling systems have not been investigated. There are data that imply that temperature control at various steps in an accelerated processing system determines the magnitude of the advantages

for this system as compared to the conventional processing practices.

For purposes of this paper, the discussion of chilling of prerigor meat has been divided into major product areas: ground products, boneless meat for further processing and primal cuts. This separation was deemed necessary because the chilling requirements and system requirements are different for each product type. In addition to discussing the effects of different chilling treatments on properties of hot processed products, an attempt is also made to address the question of when, in fact, the meat is pre- versus postrigor.

## Ground Products

Temperature control during processing and storage is critical for insuring acceptable shelf life of ground products. High microbial counts on boneless meat associated with increased human and equipment contact, exposure to elevated processing room temperatures and heat from friction during grinding and mixing necessitate that direct temperature control be used.

Conventional processing systems for production of ground meat from chilled, boneless raw materials utilize various types of direct temperature control, either before or after the meat is packaged. Prepackaging temperature control can involve the addition of cryogenic materials (CO<sub>2</sub> or liquid nitrogen) or the use of hard chilled or frozen meat in the formulation. For postpackaging control, packages are subjected to cryogenic tunnels, liquid contact chillers or forced air systems. Patties are normally frozen immediately by use of cryogenic or conveyORIZED blast freezers.

While maintenance of a low temperature increases shelf life, this benefit must be balanced against the cost of achieving the desired low temperature and the lowered volume associated with grinding, mixing and pumping of the cold, dense product. Temperature control is a costly problem in the production of ground products from chilled meat. However, with "hot" meat the problems are magnified since the temperature of raw materials is 25° to 30°C rather than 3° to 6°C as for chilled trimmings.

Comparisons of quality properties of ground beef prepared from hot and cold-boned raw materials have produced varying results, i.e., some show superiority for hot-boned product; some for cold-boned product; and other studies indicate no differences. A careful analysis of these studies suggests that the different chilling and storage procedures used may account for the varied results.

A schematic of chilling systems used for processing of ground beef from hot-boned raw materials is shown in Figure 1. The majority of studies have utilized prepackage chilling by the inclusion of cryogenic materials prior to or after the initial

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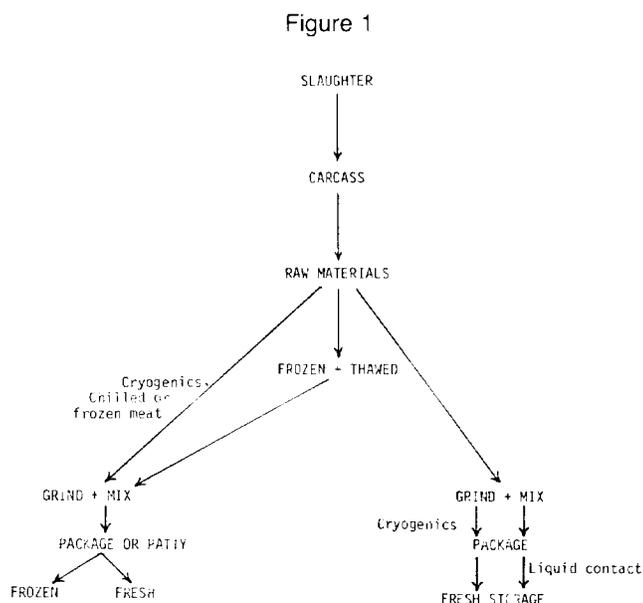


Figure 1. Schematic of chilling systems for ground beef processing from hot boned raw materials.

grind (Cross et al., 1979; Lester, 1979; Emswiler and Kotula, 1979; Nusbaum, 1979; Jacobs and Sebranek, 1980; Wells et al., 1980; Cross and Tennet, 1981; Berry and Stiffler, 1981). When given, these studies indicated that addition of 10% to 20% (weight basis) of CO<sub>2</sub> was required to chill the hot-boned meat to below 5°C. Addition of frozen or chilled meat to the formulation has been utilized to reduce the requirement for cryogenic materials. Contreras et al. (1981) chilled the hot-boned meat overnight at 3°C, froze it, then thawed the meat before producing ground beef. In most studies the processed product was frozen for storage, except for Lester (1979) who maintained the product in the fresh state.

When ground beef was prepared from hot-boned materials that were rapidly chilled, rapidly frozen and cooked from the frozen state (Cross et al., 1979; Nusbaum, 1979; Jacobs and Sebranek, 1980; Wells et al., 1980; Cross and Tennet, 1981; Berry and Stiffler, 1981), cooking loss was less and palatability (juiciness and tenderness) was greater than conventionally processed ground beef. However, when the product was chilled slowly (Contreras et al., 1981) or stored in the fresh state (Lester, 1979; Nusbaum, 1979), the hot-boned product was equivalent or inferior to cold-boned ground meat relative to cooking and palatability traits. These data suggest that rapid chilling, rapid freezing and cooking from the frozen state maintains the muscle in the prerigor state and the product evinces the superior binding properties of prerigor meat (Honikel et al. 1981 a,b). If the product is chilled slowly, stored in the fresh state, or thawed before cooking, the rigor process may be completed and the advantages associated with prerigor meat lost. Based on these conclusions, use of electrical stimulation or conditioning periods prior to boning accelerate muscle pH decline, would lessen the prerigor state, and, thus, would decrease the advantages of hot-boned beef for use in ground beef. Several reports have suggested this may be true (Berry and Stiffler, 1981; West, 1983).

Since a high percentage of the ground beef is distributed in the fresh state, several groups have recently evaluated processing systems for production of ground beef from hot-boned meat which would be similar to those currently used for production of sausage from hot-boned pork. These processes involve postprocessing or postpackaging chilling of the ground beef and storage in the fresh state (Figure 1).

Abu-Bakar and Reagan (1983) compared storage, cooking and palatability characteristics of coarse ground beef prepared by addition of CO<sub>2</sub> to hot-boned meat after grinding, by use of a -2°C brine chiller for chilling of chubs of hot-boned ground beef as by conventional cold-boning methods. Microbiological quality of hot-boned product was superior to that of cold-boned product (approximately one log lower at 21d). However, purge loss and cooking loss tended to be greater for hot-boned than for cold-boned product, which the authors contributed to cold-induced contraction as shown by shorter sarcomere lengths for the hot-boned product.

A recent study by Palma (1983) evaluated the use of glycol vs CO<sub>2</sub> vs conventional procedures for chilling coarse ground and/or chopped beef packaged in 4.5 kg chubs which were stored fresh. Immediately after stuffing, the hot-boned product was 27°C. Two hours after 45 or 60 min of chilling in -11°C glycol, the internal temperature was below 1.7°C. Chubs from treatment groups that were hot boned and glycol chilled immediately after processing had lower microbial counts and less purge over a 24 day storage period than those from the cold-boned or hot-boned plus CO<sub>2</sub> groups. However, the hot-boned glycol-chilled product had a slightly darker lean color, which tended to lower consumer desirability scores during retail display. This darker color was associated with higher pH values found for this product as compared to both CO<sub>2</sub>-chilled and cold-boned products. In all treatment groups where the meat was ground or chopped prior to chilling (Palma, 1983), fat smearing was a problem. This smearing resulted in a very fatty appearance in the product. Preliminary studies in our lab indicated that fat smearing occurred in beef during grinding if the meat was between 10° and 29°C. Above this temperature range, fat smearing did not present a problem.

Based on the preceding discussion on chilling methods for production of ground beef from hot-boned meat, it appears that chilling and storage procedures do affect the advantages associated with hot boning. Further studies are needed comparing the economics of voluminous use of cryogenic materials to other chilling systems and these to conventional processes.

### Meat for Further Processing

Quite often when speakers are discussing hot processing, an advantage often given for this technique is the superior functional characteristics of prerigor meat. There is little doubt that prerigor meat does have superior functional properties when compared to postrigor meat (Hamm, 1960; Acton and Saffle, 1969); however, it is difficult to maintain this prerigor state during storage and use of the product (Hamm, 1978). In addition, it has been questioned whether hot-boned meat from carcasses subjected to pH reducing treatments is, in fact, prerigor (West, 1983).

Little attention has been given to techniques for chilling or

storage of hot-boned meat intended for later processing, particularly large bulk packages such as combo bins. From a microbiological standpoint, Herbert and Smith (1980) recommended that safe handling of hot-boned meat would require chilling of the meat mass to 8°C or below within 4 hr if the meat temperature at boning was 40°C, within 6 hr if the temperature was 30°C and within 9.5 hr if the temperature was 20°C. Their data suggest that some chilling (<30°C) must take place prior to boning to meet these requirements if the meat is placed in -35°C or -20°C freezers in cardboard cartons. Fung et al. (1981) indicated that acceptable shelf life and bacterial quality could be achieved in hot-boned, vacuum-packaged cuts if the temperature was reduced to below 21°C within 9 hrs after processing.

Various questions arise concerning processes for chilling and storage of boneless meat. How much CO<sub>2</sub> would be required to lower the temperature of a combo of hot meat and how is the best method of applying it? Will localized areas of freezing and thawing cause thaw rigor, resulting in greater purge loss? Will box sizes have to be changed to accomplish adequate freezing? What are the costs of these procedures? And finally, will the product have functional characteristics superior or equivalent to cold-boned product? More research is needed to answer these questions. Chilling of large volumes of hot meat is a major problem.

### Primal Cuts

Numerous studies have been reported on the advantages and disadvantages of hot processing of primal cuts as shown in the recent reviews by Kastner (1983) on beef and by Reagan (1983) on pork. These studies have evaluated various contraction prevention techniques, storage times and packaging systems. Unfortunately, few studies have evaluated the effects of chilling methods and their relationship to shelf life and palatability characteristics.

Most studies have involved the chilling of unboxed, hot-boned vacuum-packaged primals in a 0° to 2°C chill cooler, some after a conditioning period at a higher temperature. This would be expected to result in a relatively rapid chill rate, particularly when small cuts are involved. Reviews by Kotula (1981), Kastner (1983) and Reagan (1983) indicate that hot-boned products produced by such systems have acceptable (compared to conventionally cold-boned primals) shelf life and palatability characteristics. However, faster or slower chill rates may alter these results.

Several studies have suggested a relationship between chill rate and contraction prevention techniques relative to palatability, appearance and shelf life characteristics of hot-boned primals. West and Oblinger (1979) showed that cold-induced contraction causing decreased tenderness and increased shape distortion, particularly of multimuscle cuts, occurred when electrically stimulated carcasses were boned immediately after slaughter and the cuts chilled rapidly in a -1°C slush ice bath. This procedure chilled the product to below 4°C internally within 2 hr. However, Zaglul (1981) found that if boning and chilling of cuts in an ice bath were delayed until muscle pH reached 5.8, cold shortening and shape distortion were not problems.

Effects of chilling rate on microbiological and storage characteristics also have been reported. Fung et al. (1981)

indicated that a slow chill rate created by the boxing of hot-boned, vacuum-packaged primals and chilling of these boxed primals at 2.2°C resulted in unacceptable microbial quality. Zaglul (1981) reported similar findings in that hot-boned primals boxed prior to chilling at 0° to 2°C had greater purge loss and higher microbial counts than did cold-boned controls. Recently, Oblinger (1983) in his review of the microbiology of hot-boned beef concluded that adequate and prompt chilling of hot-boned meat was a critical point in the overall process.

Similar findings have been presented for hot processed pork primals and subprimals (Reagan, 1983). Wynne (1980) reported that brine (-1°C) chilling of hot-boned, vacuum-packaged pork loins resulted in greater purge loss during storage than did slower chilling rates achieved in a conventional chill cooler. Palatability was not affected. Recently, extremely rapid chilling of hot-boned pork loins and shoulders in a cryogenic tunnel was found to essentially double purge loss when compared to values for cold-boned primals. (J. O. Reagan, 1983, unpublished data, Univ. GA). This occurred even though the carcasses had been conditioned at 17°C for 3 hr prior to boning.

Based on the present knowledge of chilling requirements for hot boning systems, several requirements for a commercial processing system can be suggested:

1. Do not chill the cuts rapidly until the muscle pH is 5.8 or below. This prevents cold shortening.
2. Chill the packages prior to boxing. This will prevent slow chilling and the resultant purge and microbial problems. In addition, shape distortion due to gravity and stacking effects will be reduced.
3. Chill systems should be rapid, automated and continuous with packaging. This eliminates excessive handling of cuts, long storage times and high space requirements.

Commercial use of hot boning technology for production of vacuum-packaged primals is restricted presently to Denmark and Finland. These operations generally involve conditioning of cuts at 7° to 12°C for 4 to 24 hr prior to rapid chilling and boxing. (Buchter, 1982). In addition, cuts are aged for 5 to 14 days to insure adequate tenderness prior to distribution. From the standpoint of the U.S. industry, this would be a labor, time and space-extensive approach. A semi-continuous process would more closely fit the volume and scale of U.S. processors. This could be realized by use of modern chilling practices, such as cryogenic tunnels, liquid contact systems, conveyORIZED forced air chillers or a counter-current conveyORIZED system (Henrickson, 1981). However, little data are available on use of these systems.

A recent study in our lab attempted to combine various concepts of hot boning into a continuous system (Gardner-Carimi, 1983). Based on a report by Zaglul (1981) who showed that muscle pH decline was faster with double stimulation (2X, 20 min apart) than with a single stimulation, carcasses were stimulated with low voltage (45 v RMS) during bleeding and with high voltage (550 v) after splitting. With this procedure, the loin pH was at 5.8 within 60 to 90 min postmortem. The tenderloins, strip loins, bone-in ribs and top

rounds were removed, vacuum packaged and chilled in either  $-4^{\circ}\text{C}$  propylene glycol for 45 min (no crust freezing) or  $-11^{\circ}\text{C}$  glycol for 30 min (crust freezing). Cuts were then boxed and stored at  $-1^{\circ}$  to  $1^{\circ}\text{C}$  for up to 28 days. Control sides similarly stimulated were chilled for 48 hr at  $-1^{\circ}$  to  $1^{\circ}\text{C}$  and fabricated, and the cuts vacuum packaged, boxed and stored. Chill rates for boxed, hot-boned, glycol-chilled primals were slightly faster for the small cuts and slightly slower for the larger primals than those achieved in the respective control cuts remaining in the carcass. Few major differences in storage, retail display or shear force values were apparent among treatments. Distortion of subcutaneous fat layers was apparent in hot-boned primals. This was thought to occur during vacuum packaging since the fat is soft and easily formed. Thus, it appears that with a few minor adjustments, a continuous hot processing system may be possible. More data are needed on the economics of such systems.

### Summary

Chilling systems for hot-boned meat have been neglected in many research studies. This is particularly true for chilling systems which have commercial applications. Chilling rates and storage conditions were shown to be important determinates of quality for ground products, meat for further processing and primals produced by hot processing procedures. Studies incorporating commercially feasible chilling systems were discussed.

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