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R. L. HENRICKSON

THE USE OF HOT MEAT IN MEAT PRODUCTS

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INTRODUCTION

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The well-known biochemical and biophysical changes occurring in muscles in its conversion to meat will be re-emphasized. After death, most of the changes in muscle occur in the nonprotein nitrogen and glycogen fractions. However some profound changes also occur in the muscle fiber components during *rigor mortis*. These important biochemical and biophysical changes are complete in about 24 hours after slaughter at cold storage temperature. When the blood supply to the muscle has terminated, the ATP level is maintained by the breakdown of creatine phosphate which serve to phosphorylate ADP to ATP. One theory

suggests that calcium ions are released from the muscle fiber sarcoplasmic reticulum or mitochondria [10]. The ions activate the adenosine triphosphate (ATP) to adenosine diphosphate (ADP). The fiber need for ATP initiates the breakdown of glycogen to lactate and hydrogen ions. As a result of glycolysis, and catabolized creatine phosphate, some ADP is phosphorylized to ATP until either all the glycogen is depleted or the glycolytic enzymes are inactivated by a low pH. On termination of glycolysis, the remaining ATP and ADP is transformed to inosine monophosphate (IMP). This loss of ATP causes the muscle proteins actin and myosin to associate forming the actomyosin complex. As this association takes place, meat is considered to be in rigor [47]. When the pH falls as a result of lactic acid formation, the water holding capacity (WHC) is greatly decreased [25].

The anaerobic conversion of glycogen to lactic acid causes a rapid decline of ATP followed by the parallel loss of muscle fiber extensibility. Thus, the acid formation which invariably occurs in the conversion of muscle to meat provides some quality advantages, as well as disadvantages. A low pH (5.4) is desirable for a bright lean color, bacterial control, and cure color development, but it causes a reduction in water-holding capacity and in the retention of water soluble nutrients. Therefore, it seems logical and desirable for the processor to take full advantage of these biochemical and biophysical changes in the heat processing of meat to achieve quality products, as well as the conservation of energy.

Present knowledge of *pre-rigor* muscle and the processes of *rigor mortis* suggests that a rapid heat treatment of *pre-rigor* muscle would inactivate the enzymes before much progress toward *rigor* could proceed. The resulting cooked product would have a high water-holding capacity, and be more tender than meat heated *post-rigor*. The color of the cooked product should be no different than would be expected in *post-rigor* meat. A brief study using one bovine muscle indicated that meat quality can be achieved through controlled heating of *pre-rigor* muscle [9]. Deep fat fried *pre-rigor* steakes were found to be more tender than *post-rigor* fried steaks [60]. Thus, it seems that time after death, heating rate, and the degree of doneness are all critical features in the preparation of *pre-rigor* muscle to arrest the *rigor* process.

The application of an electrical stimulus to bovine muscle increases the *post-mortem* glycolysis of muscle which initiates the onset of *rigor mortis* at an earlier time sequence. Therefore, induction of electrical current through the bovine muscle shortly after death permits an early fabrication of the carcass to boneless cuts prior to chilling. This accelerated processing technology has encouraged earlier cutting and the incorporating of "hot" meat into manufactured products.

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would include lower microbial contamination, reduced heating time, less labor cost, and lower energy requirements for each heating process. The objective of this paper is to assemble and present information on the use of "hot" meat in the manufacture of meat products.

MUSCLES AND MUSCLE SYSTEM

The published research on "hot" boning of the bovine carcass suggested that hot boning of block beef is feasible [68, 39, 30, 69, 41, 81, 62, 44]. The importance of seaming muscles to reduce drip loss from the raw tissues was found to be important [32]. Early sectioning of lamb carcass was also found to be feasible [45, 46]. "Hot" cut pork muscle was reported equal in overall quality to the conventionally prepared cuts [47, 29]. Cured pork products were also found to have acceptable quality [47]. Seven pork muscles from the hot carcass were excised and exposed to a temperature of 0°C [53]. Marsh [53] found that the muscle varied as to their tenderness response. This tenderness difference was caused by the individual muscles response toward the development of *rigor mortis*. With this preponderance of evidence, it appears that the meat industry could well afford to consider more efficient alternate methods of processing the human meat supply, particularly now since electrical stimulation has become so well-accepted. *Pre-rigor* muscles and/or muscle systems vacuum packaged and then cooled, provided some quality advantages [39, 68, 69]. By applying a vacuum package, meat is less subject to bacterial contamination and can be boxed for storage or shipment. Freezing of vacuum packaged muscles from electrically stimulated carcasses, removed 1 hour *post-mortem*, shoud be delayed to avoid tenderness variation [12]. Cross and Tennent [12] suggested that further work will be required to identify precisely how rapidly the temperature can be reduced.

COOKING *PRE-RIGOR* MUSCLE

Concern for processing costs has increased the need for more efficient systems of food preparation. One approach has been to centralize food preparation so as to reduce the need for equipment and energy. This has led to pre-cooked meat.

Pre-cooked meat items have become popular for institutional feeding and in "deli" markets. Some of these meat items are roasts, steaks, ground beef, luncheon meat, canned stew, hamburger patties and TV dinners. Studies have shown that meat cooked immediately after *rigor mortis* is relatively tough, but meat cooked *pre-rigor* is relatively tender [55, 64, 60, 15, 52, 80, 9].

If the heat treatment is extremely rapid and extended far enough, enzyme denaturation would occur before significant progress toward rigor could take place [54]. Present knowledge of the rigor process suggests that meat cooked *pre-rigor* would not only be tender but would possess a high water-holding capacity. Some concern for shape of the roast was expressed [9, 65]. Treatment of the meat prior to cooking and the heating method would seem to be important criteria for the pre-cooking of *pre-rigor* meat. Heat *rigor* nodes in all the cooked, hot boned tissues were observed, but they were more frequently observed in the tissues heated by microwaves [60, 56]. Thus, it appears that microwave cookery is too rapid while oven cookery is too slow. The optimum heating temperature rate, and cooking end-point are areas for further research.

GROUND BEEF

The demand for ground beef has become very extensive as a result of convenient eating establishment and the varied uses which the consumer has made of this meat item. The present U.S. consumption is approximately 18.2 kg per capita with an expected 25% increase in the next 5 years.

Meat for grinding has, in the past, been produced from cow beef. In plants where hot boning is practiced, without electrical stimulation, the carcass is boned on the rail as an extension of the slaughter line. In most cases boning is initiated within 1 hour after bleeding. It takes approximately 15 minutes to free the skeleton of tissues. The individual muscle pieces are moved by conveyor, to the point of packaging or grinding. *Pre-rigor* beef was used for frozen ground beef patties [37]. They found the shrink during freezing, rancidity development, and lightness of color were basically the same as for *post-rigor* prepared patties. The *pre-rigor* patties had a higher pH, reduced cooking loss and greater acceptability by consumers for: tenderness, juiciness, and overall palatability. These data along with others indicated that the use of *pre-rigor* ground beef patties could result in a saving of time and energy to processors [33]. An evaluation of patties for microbial content showed that *pre-rigor* processing may permit slightly more aerobic microorganisms [37]. However, they were unable to recover any *Salmonella* and the *Staphylococci* levels were the same as for cold boned. The shelf life of hot-boned ground beef from carcasses which had received electrical stimulation was prolonged by 3 days [63]. Raccach and Henrickson [63] were unable to detect *Clostridium prerfringens*, *Salmonella*, or *Coliform*, but found *Staphylococcus aureus* at a level of 10 cells per gram.

The bacteriological traits of *pre-rigor* pork sausage were evaluated and associated with organoleptic traits [42]. Lin et al. [42] found *pre-rigor*

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The bacteriological traits of *pre-rigor* pork sausage were evaluated and associated with organoleptic traits [42]. Lin et al. [42] found *pre-rigor* sausage to have a higher bacterial count, higher taste panel score, but a lower cooking loss than *post-rigor* sausage. All sausages were palatable through 21 days storage at 2°C and 56 days at −22°C.

SAUSAGE

Pre-rigor meat is well-known for its ability to emulsify fat [77, 1, 13]. However, its usefulness is limited by the short period for which it retains this desirable property [24]. The high water-holding capacity of *pre-rigor* meat was attributed to its higher pH, and the presence of ATP. The emulsifying property was also preserved by freezing, mincing or by pre-blending meat with salt (NaCl) and ice [24]. Acton and Saffle [1] indicated that *pre-rigor* beef had 34% more extractable protein than *post-rigor* meat.

Hot meat that is coarsely ground or chopped, salted with 2-4% sodium chloride (NaCl) within 2 hours *post-mortem* and held under refrigeration (0°C) will retain its water-holding capacity for 3 days. Water-binding and fat emulsification ability of this product for sausage manufacture is almost as good as hot meat. Other researches noted that salting of *pre-rigor* meat preserved the high water-holding property although it accelerated the breakdown of ATP [25, 26]. The combined affect of high ATP levels, high pH, and added salt causes such a swelling of the fibrillar proteins that no association of actin and myosin takes place so that rigor cannot occur in the fiber fragments even after a complete breakdown of ATP. Therefore, the water-holding capacity does not decrease [27].

"Hot" meat is not readily available to the sausage maker because they do not have slaughtering facilities. However one can maintain the high water-holding capacity by rapid freezing the hot meat at −20°C or lower. Freezing at this temperature stops the enzymatic breakdown of ATP and glycogen. In order to utilize this product, the sausage manufacturer must process meat in its frozen state without thawing. Some have suggested that the meat be coarsely ground in the *pre-rigor* state and frozen in a thin layer (1-2 inches thick) at −40°C with storage at at −20°C [28]. The frozen meat should then be added to the chopper in the frozen state with salt and water. The remaining steps are as conventionally accomplished. Sausages from such unsalted *pre-rigor* frozen meat will have a high WHC and make a better sausage than *post-rigor* nonfrozen meat. One can preserve the high WHC of "hot" beef for months in the frozen state. Thus, the ability to preserve high WHC of *pre-rigor* beef by rapid freezing of ground salted or unsalted beef, before the complete breakdown of ATP, is available to the sausage manufacturer. Care should be taken to keep the *pre-rigor* salted and unsalted meat at

−20°C to prevent the breakdown of ATP. Due to the influence of temperature on ATP and lactate, it has been suggested that it is better to salt the beef before freezing rather than during the preparation of the sausage emulsion [35]. Pre-blended meats for use in sausage manufacture will provide increased extraction of soluble proteins during comminution, increased fat emulsifying ability of the extracted protein, a more desirable color formation, and will permit product analysis for sausage fomulation.

RESTRUCTURED MEAT

Commercial interest in restructured raw meat has increased largely due to the rapid expansion of the fast food industry. Forming of loafs, rolls, pork chops and beef steaks has been made feasible by the use of a hydrolic meat press which utilizes a wide variety of shapes. Most of the reported research with raw reshaped meat has been concerned with ground or flaked products [23, 17, 49, 57]. Binding properties of meat have been well-studied and reported. Myosin was shown to be the most capable of the three major muscle proteins (myosin, actomyosin, sarcoplasmic) for developing an adequate bind strength [43, 18, 70, 19, 66, 58]. Extracts of myosin is best achieved with the aid of 2% salt and 0.5% phosphate [61]. Crude myosin extracted from *pre-rigor* muscle has a greater binding strength than that extracted from *post-rigor* muscle [78]. Hot boned meat rolls had a high cooking yield and possessed good binding strength. Huffman et al. [36] found that the binding strength and cooking yield was higher for salt-phosphate meat than meat treated with only salt [36]. An increased mixing time provided little effect on the binding strength. Vacuum mixing of *pre-rigor* meat provided a greater yield of crude myosin than *post-rigor* meat [74]. A difference between hot-boned and cold-boned beef in regard to shear force, flavor, juiciness, tenderness and panel acceptability has been established and substantiated [69, 68, 39]. Thus, it seems that beef rolls or loaves can be prepared from low-cost beef muscle parts that are not well-suited for roasts or steaks. Restructered pork chops prepared from *pre-rigor* meat possessed a more desirable eating quality than chops from *post-rigor* muscle [36]. Color of the restructured chops was less desirable than the regular pork loin chop.

CURED MEAT

Very little research has been reported on the curing of *pre-rigor* meat. Cured "hot" bellies found to be shorter but wider than regular bellies [48]. Pressing the cured slab partially reduced the length and width difference.

Even though this shape difference existed, all other quality advantages favored the hot curing method. Bacons can be cured and smoked and be ready for sale within 15 hours after slaughter. Ham cured and smoked in the *pre-rigor* state was acceptable in tenderness, juiciness and flavor [47]. The pre-chill cured ham muscle had a more stable cured meat color as evidenced by a greater quantity of extractable nitrosopigment after 54 hours display [29, 3, 59, 50]. The rate of cure penetration was faster in *pre-rigor* meat than in *post-rigor* meat [3]. While curing *pre-rigor* ham muscle in a vacuum tumbler, it was found that the pickle absorption was more uniform [74]. Taste panel scores and Warner-Bratzles shear values indicated that the hot cured and smoked ham was significantly more tender than *post-rigor* ham [47]. This was to be expected since the pH and ATP levels were still high, thus providing a high water-holding capacity. The feasibility of using *pre-rigor* pork in the production of cured products such as ham, bacon and loins seems to be well established.

A study of the bacterial populations in hot cured and smoked ham revealed no significant bacteriological problem [51]. The ready-to-eat ham was quite comparable to the conventionally processed ham. Since the spoilage of cured meat depends upon the level and types of initial viable bacterial numbers and their resistance to treatment, competition, and ability to grow under the conditions of storage, "hot" cured ready-to-eat ham has advantages over the conventional method of ham curing [5]. Accelerated processing could be equally as effective as normal procedures in reducing "in-process" contamination [11]. When curing corned beef the cure penetrates individual muscles at different rates [8]. The color of each muscle, even though good, varied due to the inherent pigment. Beef cured "hot" held more water than the meat cured *post-rigor* and was found to have more juice. Beef cured under vacuum was more shelf stable than beef cured without vacuum.

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WYKORZYSTANIE CIEPŁEGO MIĘSA W PRODUKTACH MIĘSNYCH

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S t r e s z c z e n i e

Wykorzystanie mięsa ciepłego w różnych produktach kulinarnych ma wielkie potencjalne znaczenie. Obecnie, kiedy elektryczna stymulacja zyskała uznanie w praktyce, będzie więcej możliwości dalszego ulepszania wydajności w przetwórstwie. Ustalenie biochemicznych i biofizycznych właściwości przekształcania mięśni w mięso będzie również zwiększać wykorzystanie mięśni w stanie przedstężeniowym. Producenci kiełbas — kierownicy rzeźni będą musieli współpracować w celu wyzyskania wszystkich korzyści z produktów mięsnych uprzednio kutrowanych. Zakłady wytwarzające wyposażenie są zainteresowane w konstrukcji i badaniu nowych maszyn do formowania, kształtowania i plasterkowania mięsa ciepłego. Obróbka termiczna mięsa ciepłego daje dużą potencjalną oszczędność energii, jednak z założeniem zaakceptowanej jakości produktu. Peklowanie mięsa ciepłego ma również wielkie możliwości, ponieważ produkty te peklowane z zastosowaniem próżni mogą mieć przedłużony okres składowania.