THE INFLUENCE OF PRE-CHILL PROCESSING ON PORK PRODUCTS

By

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INTRODUCTION

The processing of pork products to a finished form prior to initial chilling appears to have many advantages over the present techniques utilized in pork processing. Present industry methods require the products to remain in the packinghouse from two days to two weeks depending on the various steps in fabrication. Pre-chill processing methods could be used to reduce to a minimum the costly fabrication steps involved with carcass chilling, curing, smoking, and final chilling found in conventional processing.

Many of the basic chemical and physical changes which occur in pork muscle post mortem have been reported in recent years. Considerable knowledge about the influence of additives incorporated into the cured and smoked product is now available. Little attention has been paid to the application of this information to improvement of handling techniques, and reduction of time required for production of the product. Cured products could be prepared more efficiently if the chilling of the carcass, which is followed by heating of the product to a level higher than the original temperature of the carcass, was eliminated. Similarly, the long curing periods following pumping and prior to smoking could be eliminated or reduced to a minimum. Fresh cuts could be chilled more rapidly, if excess fat and bone were removed prior to chilling. This thesis is concerned with the application of some of this knowledge concerning pre-chill processing to the present methods used in the meat

packing industry.

Additional literature reported from the study of which the thesis is a part include Mandigo and Henrickson (1966a), Mandigo and Henrickson (1966b), Moore et al. (1966), Barbe et al. (1966), and Smith et al. (1966).

REVIEW OF LITERATURE

Many physiological and biochemical changes occur in meat that influence the quality of the final product. A few of these changes will be discussed in this review. The influence of the various curing additives will be discussed along with the effects of smoking, heating, and the chemistry of cured meat pigments.

Structure and Function of Muscle

The contractile structure of striated muscle, including the overlapping filaments containing the two principle structural proteins actin and myosin, has been discussed by Huxley and Hanson (1959). Filaments of actin extend to the Z-line, the boundry of the sarcomere, and slide in and out of the A-band, composed of myosin filaments. If a cross section through this area of overlapping were made, each myosin filament would be surrounded by six filaments of actin. Changes in the length of the sarcomere were seen when the actin and myosin filaments slide past each other and the complex, actomyosin, was formed by cross bridges from the myosin to the actin.

Bendall (1951) found creatine phosphate content high immediately post mortem. It decreased rapidly to less than 20% at a pH 6.6, and before there was any appreciable loss in ATP. He stated that the disappearance of ATP, once started, was lost at a steady rate until less

than 30% remained. During the delay phase, the breakdown was balanced by resynthesis, and during the rapid phase the reserve of glycogen was almost exhausted. During this phase, resynthesis was unable to keep up with the breakdown.

The main chemical changes after death in the muscle according to Briskey (1959) were the production of lactic acid from anaerobic glycolysis, and the breakdown of creatine phosphate, which served as mechanisms for resynthesis of ATP from ADP. One and one-half molecules of ATP were resynthesized for every molecule of lactic acid formed. This balance between resynthesis and breakdown depended upon creatine phosphate. The balance was lost when the store of creatine phosphate was depleted, according to Bendall (1951) and Lawrie (1953). Dephosphorylation exceeded the rephosphorylation so that the actual ATP level began to fall.

Briskey (1959) stated that the initial pH was dependent upon the severity of the death struggle and depletion of glycogen. The ultimate pH appeared to be dependent upon the level of feeding prior to death and the degree of fatigue before death.

Rigor Mortis

Rigor mortis and physiological contraction were postulated to be the same by Bendall (1951). Work by Marsh (1954) confirmed this as a slow and irreversible physiological contraction. Partmann (1963) indicated that the mechanisms were the same in both cases. Briskey et al. (1962) developed an apparatus that enabled them to study rigor mortis under different conditions. Onset of rigor mortis was found to vary from two minutes to eight hours in their study. The striking differences

seen in the course of rigor mortis were attributed to: (a) variation in membrane resistance against autolytic processes or acidification; (b) deviations in post mortem release of calcium and other ions by muscle proteins; and (c) differences in the relation between the velocity of glycolytic ATP resynthesis and its breakdown.

Thaw rigor has been found to exist in muscles frozen before rigor mortis and then thawed. Perry (1950) showed that rigor mortis will take place once thawing had commenced. Considerable exudation of fluids and shortening of fibers were found in thaw rigor. Bendall (1951) reported that this marked exudation was caused by a very high rate of ATP breakdown on thawing.

Cured Meats

"The art of preserving meats by curing in common salt, with or without smoking, is one which has been practiced from remote antiquity", Kerr et al. (1926). They also indicated that the first commercial tests involving the direct use of nitrites in the curing mix was carried out in 1923. Fields and Dunker (1952) surveyed the methods commonly used throughout the packing industry, and discussed the various methods. They indicated that each of the curing adjuncts used in the modern, rapid processed ham involved a specific function.

Water-

Water comprised 60 to 95% of the total weight of foods and was by far the dominant constituent of foods according to Garner (1966). Changes in the water content or water distribution lead to significant changes in food products. Garner (1966) stated that the water holding capacity of meat was influenced by almost all processing operations

after slaughter including transport, storage, grinding, salting, curing, heating, freezing, and thawing. Hamm (1960) found that all treatments affected the inter-action between muscle solids and water. In a later paper, Hamm (1963) stated that water was immobilized within the meshes of the protein network.

Frazier (1958) explained available moisture as it affects bacteria in foods, and indicated that the activity of water would be in equilibrium with the relative humidity of the atmosphere about the food. Water must be from an approved public supply to be acceptable according to U.S.D.A. (1965) for use in the meat industry. In addition, if private sources of water are used, bacterial surveys should be taken at least every six months. According to the U.S.D.A. (1960) water should be clean, ample, and potable with adequate facilities for distribution and protection against contamination.

Salt-

Salt has been classified as an effective dehydrating agent in the curing of meat, and as such, will cause the meat to become dry and hard, thus decreasing the rate or microbial growth (Brady et al., 1949; and Callow, 1956). Wood (1966) stated that the preservation of meat by salt depended on the salt reaching all parts of the meat, fatty tissue, and bone. Consideration must be given to the diffusion of curing agents into the muscular tissue and the diffusion of water from the tissue. Salt diffusion through the tissue was the rate-determining function which was largely governed by the concentration gradient and the temperature. Initially there was an outward flow of water, proteins and other materials, but this was soon reversed. The slower the diffusion, the greater would be the outward flow due to osmosis and changes in the

protein structure (Callow, 1956; and Wood, 1966). Inward diffusion could be increased by: (a) immersion of the muscular tissue in weak brine solutions, (b) the close microstructure of the tissue, and (c) by the use of solid salt (Callow, 1956). Solid salt and strong brine solutions caused precipitation of the surface proteins, minimizing the flow of protein but not water. Callow (1956) stated that over 80% of the water could be expressed in uncured muscle, while after curing only 40% could be expressed. A probable explanation of this effect was that the muscle fiber swelled up and held the water much like a minature gel system.

Further evidence by Grant and Gibbons (1948) indicated that saltiness of bacon increased during storage, which indicated that the chloride ion was bound to the muscle constituent. White and Cook (1940) indicated that considerable variation was encountered in the salt content at various locations across the surface of a Wiltshire ham slice, and that greater uniformity was obtained when the number of injections was increased.

Sugar-

Sugar and molasses have been considered useful in imparting a desirable flavor to cured meat while at the same time reducing the hardening effect of the salt (Warner, 1938; Ziegler and Miller, 1938; and Brady et al., 1949). Greenwood et al. (1940) stated that prior to that time, the sole role of the sugars was thought to be one of added flavor. They found that reducing sugars produced significant changes in the presence of bacteria. Dextrose and levulose were readily reduced by bacteria. These reducing sugars produced color changes of the blood pigments more readily than sugars less metabolized by the bacteria. They stated that these sugars appeared to exert no influence on the blood

pigments in the absence of the microorganisms.

Kraybill (1953) found that sugar was not present in most cured products in sufficient amounts to impart a sweet taste, but it may serve to soften the brashness of the salt. He found bacon to be one of the exceptions. He proposed that sugars played an important role in the curing by maintaining acid and reducing conditions which were favorable to the development and retention of good color.

The use of excessive amounts of corn sugar and other reducing sugars has been stressed by several authors in reports on the dark colors obtained during cooking and the lowered pH values obtained which would oxidize the nitric-oxide hemoglobin (Greenwood et al., 1940; Urbain and Jensen, 1940; and Urbain, 1944). Additional use for sugars with respect to the ultimate cured and smoked product has been reported by Wismer-Pedersen (1959a). He found that feeding sugar increased bacon yields and improved the keeping quality of the bacon. In another study, Wismer-Pedersen (1959b) stated that this increase in yields could be reflected in the accumulation of sugars in the meat.

Nitrate and Nitrite-

Nitrates have been employed mainly as an additional source of nitrite after conversion by nitrase bacteria. U.S.D.A. (1926) first authorized the use of nitrites in meat subject to other meat inspection regulations. Jensen and Hess (1941) found nitrate in small quantities would prevent the incidence of bone-marrow sours. White and Gibbons (1941) found both the total number of organisms and number capable of reducing nitrate to nitrite were significantly correlated with the nitrite content. They stated that increased nitrite content observed in their study and in previous studies at temperatures below 55°C could be

attributed primarily to the bacterial growth and not enzymes or other constituents of the bacon.

Increased nitrite content also increased the stability of the red components of color in a study by Winkler et al. (1940b). Hanley et al. (1955a) found with elevated temperatures in the presence of nitrite, there was decreased time required to develop the cured pink color. When this temperature was sufficiently high, the protein was denatured and there appeared an increase in the color stability.

White et al. (1940) found a decreased nitrite content when temperatures were above 55°C and attributed this to direct loss, oxidation, or reactions with the meat constituents. Few changes were found in the nitrite and bacterial contents of brine when transported up to one week in a study by Cook et al. (1940). Cook and White (1940) found the nitrite content of the cured meat to increase with the pH, and the moisture content decreased as the chloride content increased.

Ascorbate-

The primary use for ascorbate and ascorbic acid in meat has been to aid in developing and maintaining the cured meat color (Watts and Lehmann, 1952; Bauernfeind et al., 1954; and Mills et al., 1958). The Meat Inspection Division of the U.S.D.A. (1956) approved the use of ascorbic acid and its derivatives in the processing of comminuted meat products, in the curing pickle of all pork products, and as a protective solution on the exposed slice of prepackaged luncheon meats.

Mills et al. (1958) and Mills and Wilson (1959) stated that sodium iso-ascorbate was closely related to ascorbic acid and sodium ascorbate. They further found that vitamin C activity of ascorbic acid was greater than that of the sodium ascorbate, but otherwise it had much the same

reaction characteristics that have been found in ascorbates and ascorbic acid. Maintainence of the color of cured meat was attributed to the reducing ability of the ascorbates which maintained the reduced state of the cured pigments.

Deeper red colors were found in hams pumped with a brine containing ascorbic acid in a study by Henrickson et al. (1956). During a five day storage period, those slices treated with the ascorbic acid did not fade as rapidly as their controls. Sodium ascorbate used in pork curing was not as effective as the ascorbic acid in retarding fading. Mullins et al.(1957) found sodium ascorbate and/or sodium hexametaphosphate were not beneficial in preventing discoloration since no residual ascorbate could be found in the product.

Watts (1956) found that a combination of ascorbic acid and certain commercial liquid smokes acted as powerful antioxidants even though the ascorbates might act in accelerating rancidity.

Phosphates-

Work by Bendall (1954) into the effect of polyphosphates in meat indicated that the cooked volume of meat in a 1% sodium chloride solution was only about 75% of the original volume of the fresh meat. This could be increased to approximately 80% in the presence of phosphate compounds, with the exception of pyrophosphates, in which case there was an increase to about 95%. He stated that the exerted effect of the pyrophosphates in a 1% solution of sodium chloride was at least that exerted by sodium chloride of a similar ionic strength. He suggested that the contractile protein actomyosin was split into its components and that there was a partial conversion of these from their gel form to the sol form. Claimed improvement in texture could be attributed to the increase

in water due to swelling on addition of the phosphates (Bendall, 1954; and Swift and Ellis, 1956). Wismer-Pedersen (1959c) found meat color to be considerably improved when sodium tripolyphosphates were added to the cure.

Heating and Smoking-

Callow (1956) stated that smoking not only dried the sides but introduced flavors and imparted certain colors. Wilson (1960) found that modern smokehouses were designed primarily to attain close control of the heating function, with the actual function of smoking given a secondary consideration. Heating periods of 12 to 24 hours were required for bacon in a study reported by Draudt (1963). The actual smoking was carried out in only a part of this time, usually 2 to 8 hours. He stated that smoke was commercially produced in the United States by essentially three methods: (a) burning dry sawdust, (b) burning damp sawdust, and (c) by friction. Draudt (1963) went on to conclude that the functions of smoke also included preservation, which included some antioxidant action; bacteriostatic and bacteriocidal actions; as well as providing a protective film on the surface of the smoked product. Most workers stated that the flavor of the smoke applied to the product was primarily of a phenol nature, and several indices of smoke applied rely upon total phenolic content (Draudt, 1963).

The results of Wierbicki et al. (1957) indicated that the muscle proteins were denatured when temperatures reached 40°C and the denaturation was usually completed at 70°C. The amount of moisture lost usually increased with the increasing temperature. In the presence of heat, nitrosomyoglobin reacted with nitric oxide to form nitrosohemochrome (A.M.I.F., 1960).

Work by Johnson and Bull (1952) in attempting to develop an accelerated cure determined that the most optimum smoking temperature was 48.9°C. For a 55° brine, 24 hours smoking at 48.8°C gave the best results in another study which they conducted. Continuous methods of smoking have received considerable attention in the last few years. Smoking in as few as three minutes in bacon using a rod-type infra-red heating unit was found satisfactory by Hanley et al. (1955a). In their work, bacon was heated in as few as 25 minutes, thus making total smokehouse time about 30 minutes.

Electrostatic deposition of smoke has been another method of rapid application of smoke to products (Hanley et al., 1955a). Equipment for electrostatic smoking has been discussed by Hanley et al. (1955b).

Cured Meat Color

The typical cured color (Hornsey, 1964) has been shown to be due to the combination of myoglobin, the natural pigment of fresh meat, with nitric oxide derived from nitrite either added as such, or produced by curing bacteria from nitrate. The resulting compound nitrosomyoglobin (nitric oxide myoglobin) has been shown to be the natural coloring material of cured meats, and variation in its distribution, concentration, and stability should be the main interest of the modern cured meat processor.

Ramsbottom et al. (1951) studied fading in meats and stated that the bright color occurred when freshly-cut meat surfaces were exposed to air for a short time. The oxygen of the air combined with the tissue myoglobin to produce a bright-colored pigment, oxymyoglobin. This color must be developed and maintained for the best display of fresh meat. If

transparent wrapping materials were used which were not permeable to oxygen, a dark color soon developed because of the reduction of oxymyoglobin. Contrasted with fresh meat, those that were cured, smoked, and table-ready presented a different problem. The best display color of processed meat has been shown to be the bright pink or red observed immediately after cutting. Unfortunately, this bright attractive color changed rapidly to grey and brown under light. This color change was the result of oxidation of the pink nitric oxide myoglobin and nitric oxide myochrome which had been produced during the processing of the meat. This oxidation proceeded slowly in the absence of light. Light acted to catalyze the reaction, and discoloration was proportional to light intensity in his study.

Variation in discoloration falls into three categories according to Hornsey (1964): (a) variation of natural pigments, (b) natural pigment color faults induced during and after processing, and (c) color faults due to metallic and bacterial contamination. If otherwise normal cured meat was found to possess an abnormally high or low content of total pigments, this was not a processing fault according to Hornsey (1964). This could be directly attributed to an individual pig which was deficient or over-abundant in muscle pigments. This then gives the first two categories of pigment variation, which frequently occur: (a) normal pale muscles, and (b) deep colored or "beefy" muscles. Thus a slice of ham which shows a cross-section of several muscles, can show a third category of natural variation, two-toning. This again has been seen as a very commonly occuring fault, traceable to the original pig and not to any variation induced by processing. Freshly killed animals contain a variable amount of glycogen in their muscles. After death, glycogen has

been transformed to lactic acid, which has been shown to be the largest single factor governing the ultimate pH.

Hornsey (1964) found that the conversion of pigments to the cured meat form was approximately the same for all muscles, and that it increased mainly with temperature. Reducing conditions and pH were found to play a more minor but important role. He found the critical temperature zone responsible for the higher rates of pigment conversion were between 130 and 180°F. This range was also the temperature range at which coagulation of proteins, and pigments took place. Cook and Chadderton (1940) had results indicating that the pH of the bacon was affected by the pH of the pump pickle, and decreased with time in the cure, although it increased with the age of the cure.

The interacting effects of time and temperature on color after heating were studied by Winkler and Hopkins (1940), they found that at 40 and 50°C, total intensity of color increased. At 60 and 70°C there was no definite trend in the color development, and at 80°C there was a reduction, with the maximum intensity occurring at 70°C. Seasonal difference in color development was studied by Winkler et al. (1941). They found no definite differences could be attributed to this effect. In two additional studies (Winkler et al., 1940a; and Winkler et al., 1940b) no correlation between salt, nitrate, and moisture content or pH of the meat and its stability were found.

Woodcock and White (1943) indicated that the presence of 50 ppm of nitrite in the meat appeared to be sufficient for complete cured color formation. They found that nitrate had little effect on the cured color of bacon, and the change in color was due to the formation of methemoglobin. The effect of microorganism growth on the color development has

been known and Greenwood et al. (1940) stated that these changes in color could be correlated to growth of the microorganisms which could utilize the sugars, yielding acid products.

Wismer-Pedersen (1959c) found that ham from pigs fed sugar was, on the average, paler in color than ham from fasted pigs. The meat color was considerably improved by the addition of tripolyphosphates to the cure. The color stability seemed not as good in the hams from the pigs fed sugar as from those fasted. Stability and shelf life of canned comminuted meats reported by Silliker et al. (1958) were shown to be the combination of the effect of nitrite, salt, thermal injury, and low indigenous spore loads in the products.

The effect of different processes on the conversion of pigments would be the extent of the denaturation induced by the process (Hornsey, 1964): (a) after normal maturation 30 to 50% conversion, (b) after smoking (dependent on temperature) increases to 50 to 75% conversion, and (c) after cooking (dependent on temperature) increases to 65 to 90% conversion. This assumed that sufficient nitrite was available for conversion to proceed. Fading has usually been accepted as being due to an initial light activated dissociation of the nitrosomyoglobin followed by oxidation by atmospheric oxygen to metmyoglobin.

Metmyoglobin has been shown to be a brownish pigment when concentrated, but when reasonably diluted as in pork muscle, and against red surroundings of the rest of the meat, it appeared as a ginger to olive green discoloration. Hornsey (1964) found the eye noticed the absence of red when the nitrosomyoglobin fell below 30 ppm, whereas 50 ppm would still cover up the color of even 50 ppm of the oxidized pigment. Underprocessing (heat) gave rise to a decreased stability to light.

Meat case illumination was found by Ramsbottom et al. (1951) to vary from 10-200 ft.-c. with the average in the self-service stores of about 60 ft.-c. They found that meat varied in color retention, "Cool White Deluxe" and "Soft White" gave the best rendition of color. Fading of color in meat was proportional to exposure, with the intensity and time of exposure influencing total exposure. They also found that deterioration of color and flavor were both the result of oxidation of the pigment nitric oxide myoglobin. Winkler (1959) found in the absence of air, there was a linear relationship between moisture loss and color change, irrespective of temperature.

Hornsey (1956) developed a selective extraction method for the nitric oxide heme acetone complex by the use of an acetone/water solvent. Other meat pigments were not extracted under the conditions employed. He found the acetone/ water ratio was critical, with maximum extraction being obtained with a ratio of 4:1, with allowance being made for the amount of moisture in the sample. After filtration, the optical density was measured spectrophotometrically. When hydrochloric acid was included in the solvent, total pigments were extracted. A more detailed procedure used in this study is presented in the Appendices. Estimation of the stability of the cooked, cured meat has been made using the methods of Hornsey (1957), where the fading could be measured.

Pre-Chill Processing

Weiner (1964) studied the influence of pumping brine into ham immediately after slaughter and removal of the ham from the carcass on the yields and quality factors. Treated hams were pumped and removed from the carcasses and cured for 16 days prior to heating, while the controls

were cured for 14 days. The loins were wrapped in freezer paper and frozen at -10° and -20°F for 48 hours, thawed and evaluated for various quality attributes. He found that there was no significant difference in percent cured weight of the hams. Significantly lower cooking loss and drip were obtained for the treated hams. Hamm (1959) prevented the rapid loss of water holding capacity after slaughter by salting the meat during the first hour after slaughter. He stated that this effect was due to the influence of the chloride ions, as the salt cross linkages between peptide chains may be split off by binding of these chloride ions, thus more charged groups became available for water binding. Weiner (1964) concluded that the increased water holding capacity would mean that the treated hams would have increased ability to hold fast its own or added water during the application of heat. He found that the treated hams were significantly more tender than the controls.

Kamstra and Saffle (1959) found that sodium hexametaphosphate injected into the hams within 14 minutes after slaughter increased tenderness. They felt that the salts combined with the calcium ions as they became free, thereby preventing the calcium ions from inhibiting the relaxing factor. Significantly higher shear value for the loins treated by freezing was found and this was attributed to thaw rigor by Weiner (1964). He found no significant difference in the ether extractable fat content of the treated and control hams. Pietrazek (1964) discussed the operations of a commercial packer producing whole hog sausage using hot boned pork carcasses and rapidly chilling of the partially prepared fresh pork sausage.

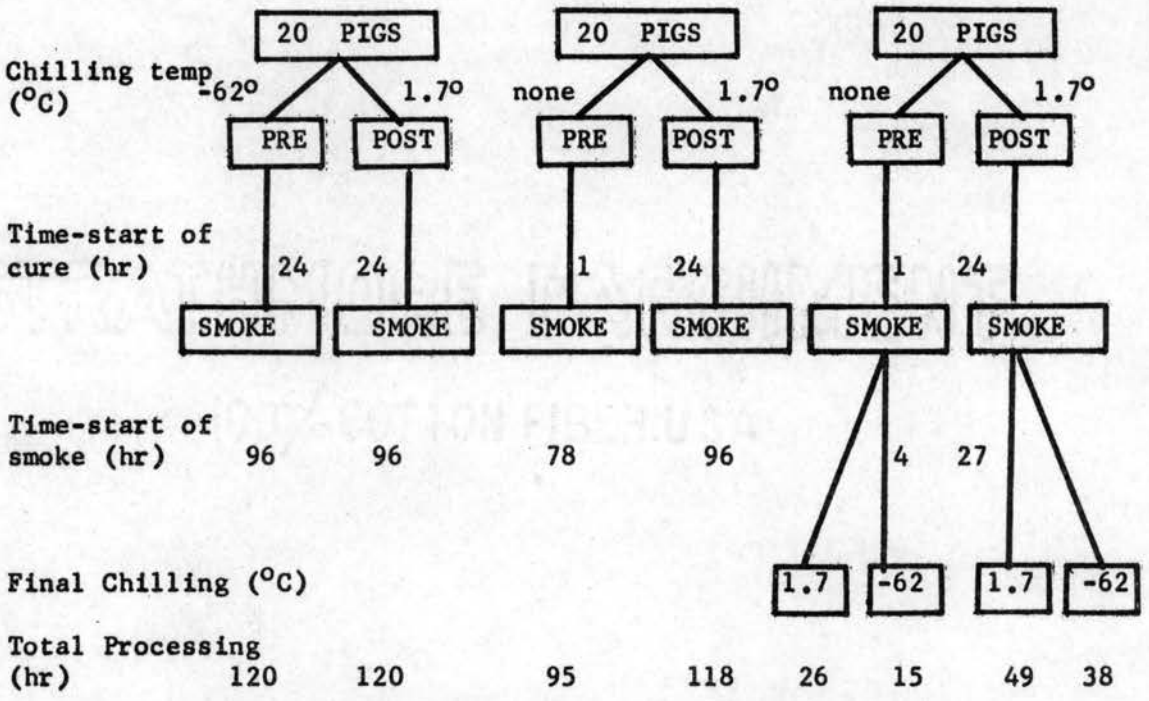
Mullins et al. (1957) found the percent trimmed ham weight to the carcass weight was remarkedly uniform within grades of hog carcasses

(r= .99). They used this method to determine the amount of brine to pump into the ham which remained on the carcass immediately after slaughter. They found it feasible to inject the hot ham through the use of the femoral artery, before cutting the ham from the carcass. Hams injected while hot were slightly more uniform in color than paired hams injected after being chilled.

Carpenter et al. (1963) found tenderness scores of bacon significantly improved with a decrease in age and weight and with an increase in intra-muscular fat content of the longissimus dorsi. Juiciness scores were not associated with the carcass weight, age, or intramuscular fat content of the longissimus dorsi. The bellies shrank approximately 13% during the curing, smoking, and skinning process. The mean values of the percent separable lean from the bacon of 227 carcasses was 31.71%.

MATERIALS AND METHODS

Four groups of 20 barrows each (Figure 1) were obtained from the Oklahoma Agricultural Experiment Station herd. Experiment I was conducted in January and February of 1964, Experiments II and III in August of 1964, and Experiment IV in August of 1965. The barrows in each experiment were of similar breeding, age, and weighed approximately 91 kg when slaughtered. The pigs were delivered to the Meat Laboratory approximately 15 hours prior to slaughter. Feed and water were withheld overnight. The animals were slaughtered according to the procedures established at the laboratory and according to the methods and practices currently used in the industry. Following bleeding, scalding, dehairing, and eviscerating, the carcasses were split and washed prior to assignment to processing treatment. After random assignment of the first carcass in each experiment, the sides were alternately assigned to pre-chill and post-chill processing treatment. Pre-chill processing was defined as completing some or all of the fabrication steps prior to the initial chilling of the cuts. Completed form implied that all processing had been completed and the products were ready to leave the packinghouse. Pre-chill processing involved removal of the wholesale cuts and processing within 30 minutes post-slaughter. Post-chill processing (the controls) involved a 24 hour chilling period prior to any wholesale cutting and processing. The cutting procedure used followed that described at the Reciprocal Meat Conference (Cole *et al.*, 1952).



a/ Each experiment contained 20 pigs.

Figure 1. Experimental Design and Time Elapse from Slaughter

In each of the four experiments, the fresh cuts were removed immediately post-slaughter. The loins were trimmed of fat and rapidly chilled. Chilling temperatures were -62°C until the center internal temperature reached 10°C at which time the loins were removed from the air-blast chamber and placed on shelves in a cooler at 1.7°C and allowed to temper (Expts. I, II, and III). In the final experiment the rapid chilling temperature for the fresh pork cuts was -20°C. While the outer surfaces of the fresh cuts were frozen, the cuts were not frozen solid.

With respect to the cured and smoked meats, the following experimental procedures were followed:

Experiment I- The hams and bellies were removed from the carcass according to conventional methods employed in the packing industry. The hams were defatted, boned, rolled, tied, and placed in stockinettes. The pre-chill processed hams were then placed in a -62°C air-blast chamber until the internal temperature reached 10°C, then removed and placed on a tempering shelf at 1.7°C. The post-chill processed hams were chilled on the carcass in a cooler at 1.7°C. Twenty-four hours post-slaughter, the hams were pumped to 110% of green weight with a curing brine (67° brine- salt, sugar, nitrate, nitrite, and phosphates), placed in a cover brine, and cured at 1.7°C for three days. After curing, the hams were soaked for one hour in fresh water (15°C), drained, placed in the smokehouse, smoked for 10 hours at 60°C, fully cooked for two hours at an internal temperature of 68°C, washed, and chilled at 1.7°C.

Bellies with the skin-on were placed in the air-blast chamber (-62°C) until the internal temperature reached 10°C, then removed and placed on a tempering shelf at 1.7°C. The post-chill processed bellies were chilled on the carcass in a cooler at 1.7°C. Twenty-four hours

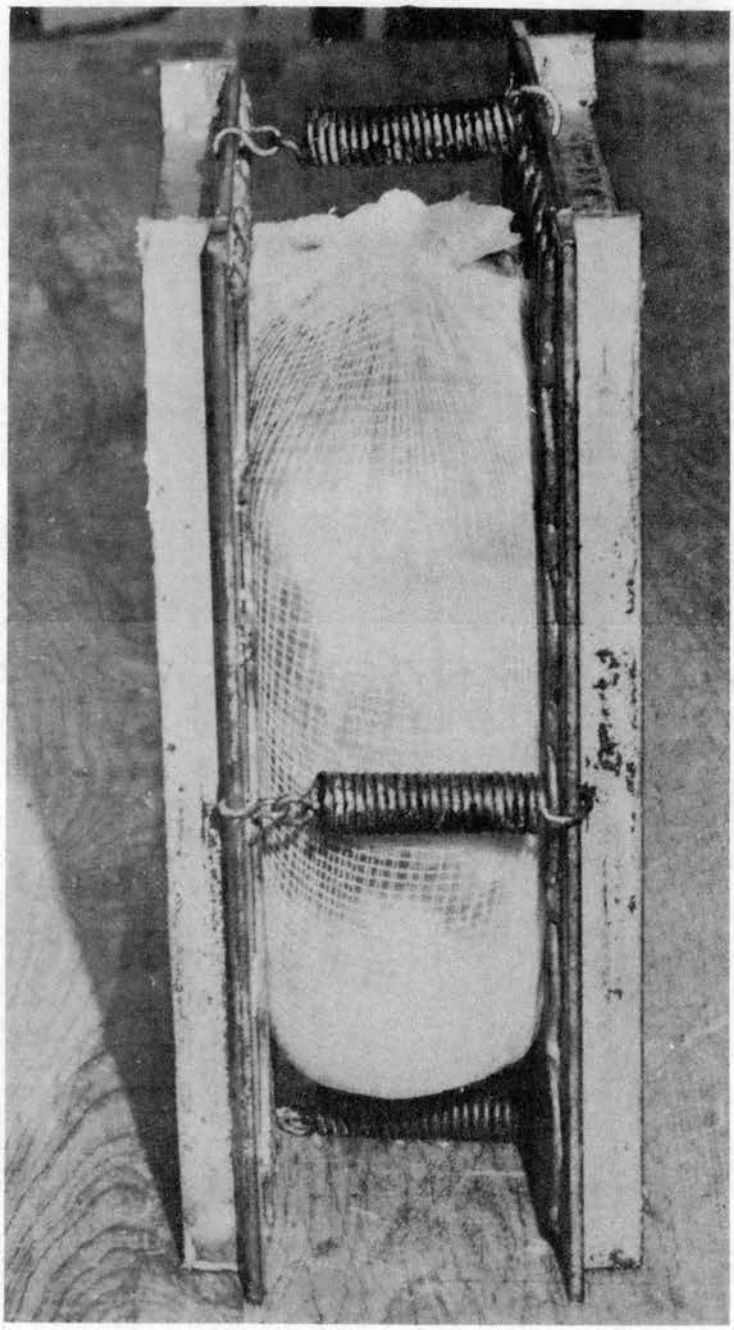
post-slaughter, the bellies were pumped to 110% of green weight, cured for three days, smoked the same as the hams except they were removed after eight hours, washed and chilled at 1.7°C.

Experiment II- Hams (internal temperature 32-38°C) were removed directly from the hot carcass, pumped to 110% of green weight (70° brine- salt, sugar, nitrate, nitrite, and phosphates), defatted, boned, and placed in a fibrous casing. Conventional chilling was used for the control ham. The hams were then placed in a cold cover brine (1.7°C) for three days, soaked in fresh water for one hour, drained, and placed into molds. The hams were smoked for eight hours (54°C) and fully cooked (68°C, for 2 hours), washed, and chilled at 1.7°C.

Bellies (internal temperature 32-38°C) were removed directly from the hot carcass, pumped to 110% of green weight and placed in a cover brine for three days. After the three day period, the bellies were soaked for one hour and smoked for eight hours at 54°C, washed, chilled at 1.7°C.

Experiments III and IV- Hams were removed from the hot carcass (internal temperature 32-38°C), defatted, pumped to 110% of green weight (85° brine- salt, sugar, nitrate, nitrite, phosphates, and ascorbates), boned, and inserted in fibrous casings, placed directly into forming molds (Plate I), and smoked. Smoking procedures were the same as in Expt. II. In the third experiment, after smoking, chilling was at two temperatures: 1.7° or -62°C. In the -62°C treatment, the hams were chilled until the internal temperature reached 10°C, followed by tempering at the regular chilling temperature (1.7°C) along with the controls. In Expt. IV, the hams were chilled at 1.7°C. Bellies were processed the same as in Expt. II.

PLATE I. HAM IN MOLD PRIOR TO SMOKING.



Sampling and Testing

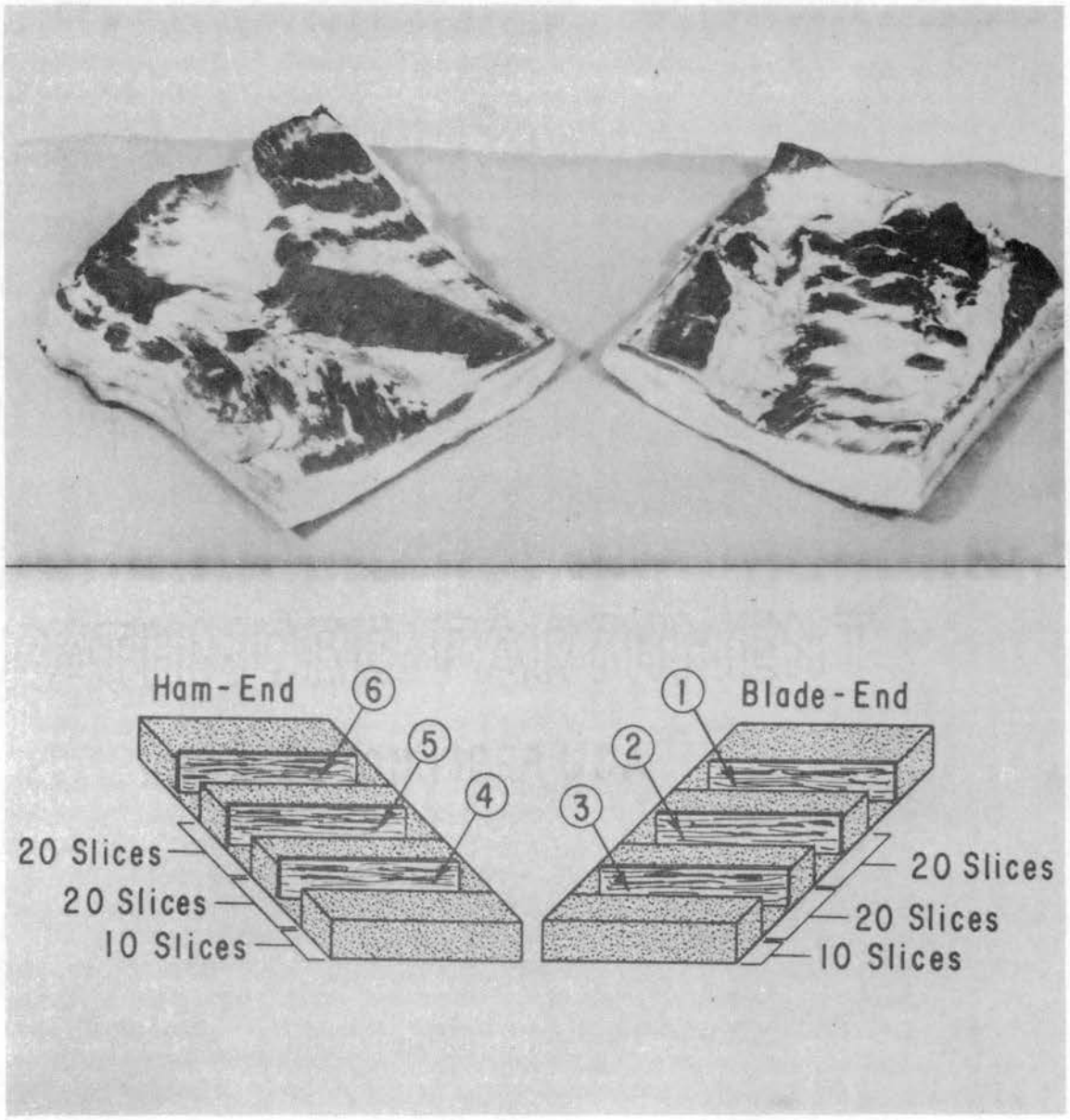
Ham- Each ham was divided into halves and a 1/2-inch slice removed from each half for testing. Warner-Bratzler shear values were determined on 3/4-inch cores from the semimembranosus muscle.

Bacon- Following chilling and storage, Expts. II, III, and IV bellies were formed using a commercial bacon press and sliced for further evaluation. Number of complete slices, weight of complete slices, and weight of the trimmings were obtained. Six slices of bacon from each slab were removed and frozen for detailed study (Plate II). Sampling was accomplished by dividing the belly into two halves. Slicing was initiated from this mid-line and progressed toward the two ends. The six sample slices were in effect sampled 20 slices apart. Slice thickness approximated 2.5 mm. Bellies in Expt. I were not pressed, but sampled for evaluation.

Acetate tracings were made of each of the six slices from each belly in Expts. I, II, and III. Tracing of the total area, lean area, and fat area by difference was accomplished by using a compensating polar planimeter. Following tracing of each slice, the slices were physically separated into lean and fat components and weighed to determine percent composition.

Loin- Following chilling, the full cut, trimmed loins were sectioned between the 10th and 11th ribs to allow loin-eye tracings to be made for the producer of the animals. A six inch loin section posterior to the 11th rib was removed from each loin and frozen for later study (Moore et al., 1966). Three-inch portions of the loin were weighed to the nearest 0.1 gm while frozen and allowed to thaw in a 1.7°C

PIATE II. SAMPLING LOCATION OF BACON.

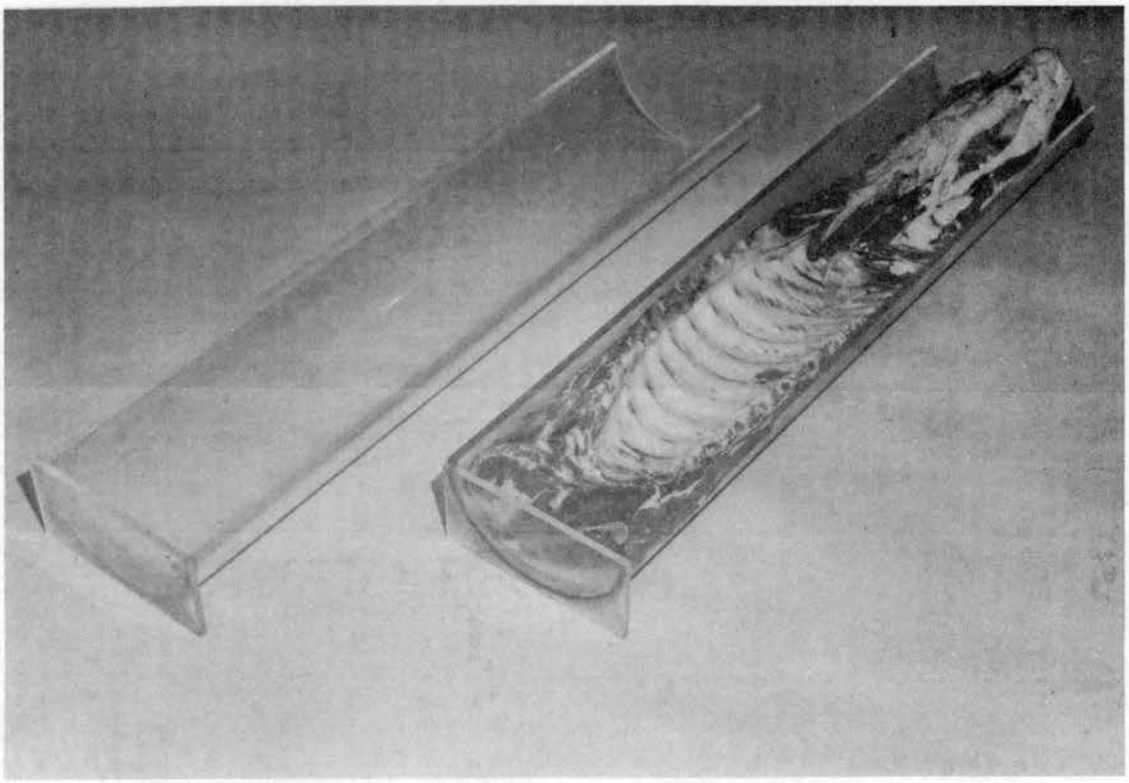


cooler overnight. The following day the thawed pieces were blotted dry and reweighed to obtain thaw loss. The temperature of the natural gas oven was 177°C. Four loin pieces were placed on their chine in a pyrex baking dish and heated. A recording potentiometer was employed to measure the internal temperature at the center of each loin piece. When the internal temperature of 76.7°C was reached, the loin pieces were removed from the oven and permitted to cool at room temperature. The pork loin pieces were covered and placed in the cooler overnight. Cooking loss was determined by weight difference based on the frozen weight. Shear value was determined the same as for ham. Loins in Expt. IV were chilled in plastic molds (Plate III) to eliminate the rough, cloudy fat surface seen in the earlier work.

Data on the pre-chill and post-chill loins were obtained from this study as well as the study by Moore et al. (1966). Thaw loss, cooking loss, total moisture loss and tenderness measurements were obtained.

Cured Color Stability- A two-inch center slice was removed from the hams and wrapped immediately to avoid contact with light. The slice paralleled the microbial survey sample reported by Barbe et al. (1966). Working in a darkened cooler (red photography lamp only), temperature 1.7°C, the ham samples were unwrapped, and all smoked surfaces were removed. The remaining ham was ground through a 1/4-inch grinder plate (Dormeyer home mixer-grinder). A ten gm aliquot of the ground ham was then weighed into 9 cm petri plates without tops. Four plates of each of the nine display intervals were weighed out, two plates each for nitroso-pigments and two for total pigments (Hornsey, 1956; and Hornsey, 1957). Time intervals studied included 0, 1/2, 1, 2, 3, 4, 5, 6, and 24 hours. Each morning at 10:00 am the 24-hour samples were removed

PIATE III. LOINS IN PIEXIGIASS MOIDS.



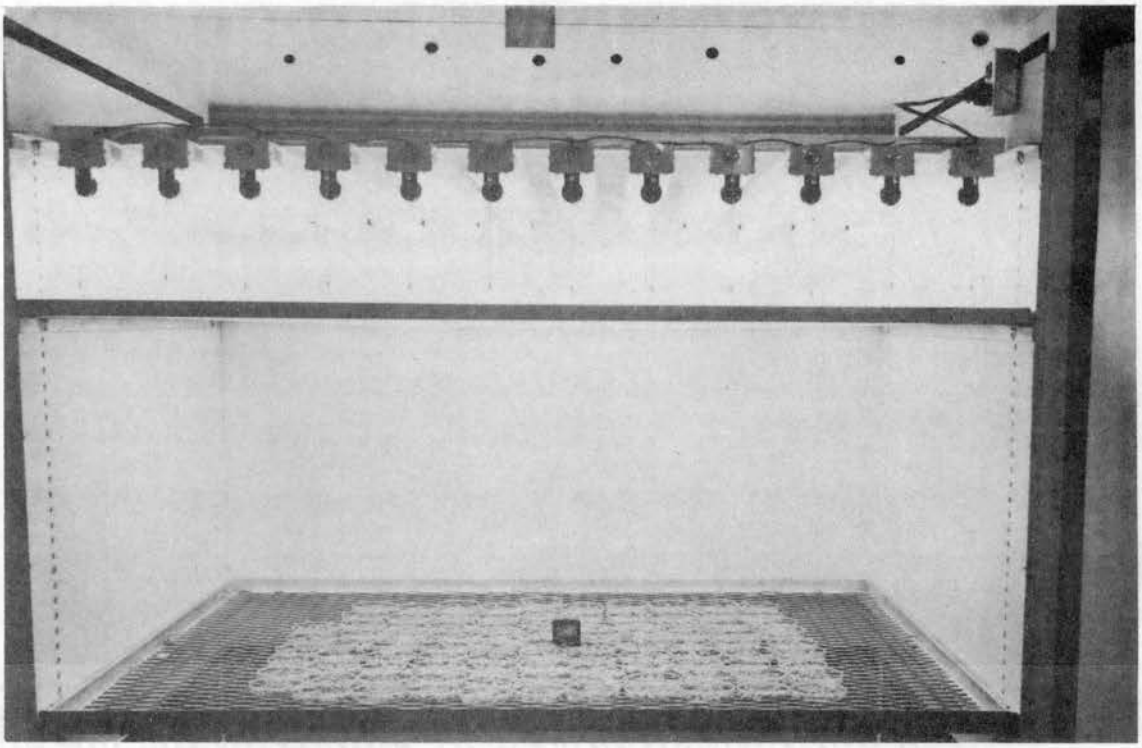
from the cabinet from the previous days samples and the new samples were introduced.

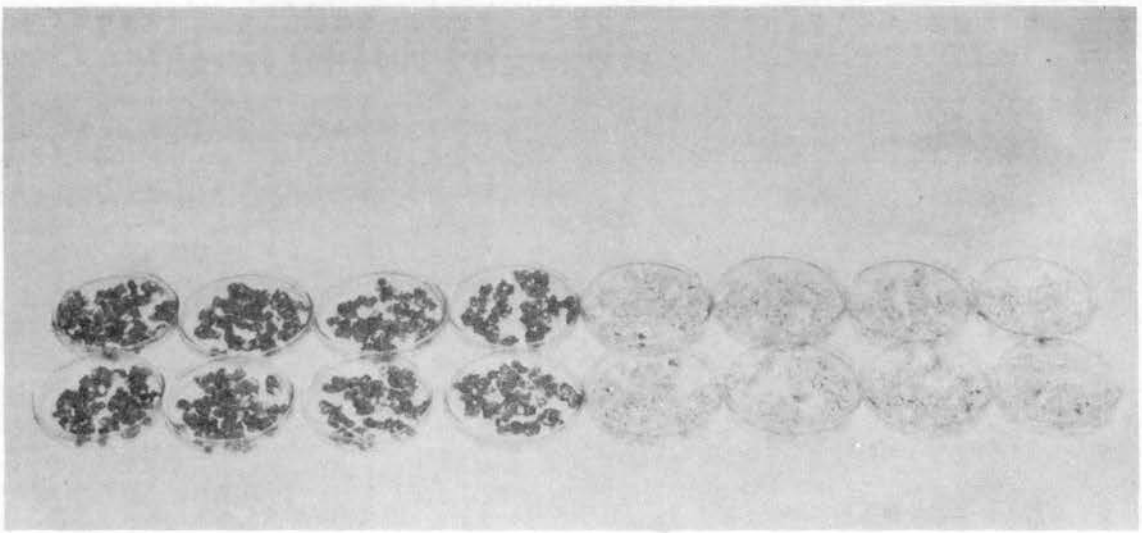
Following removal to the darkened room, the samples were carefully transferred to 125 erlenmeyer flasks attached to a mechanical shaker. Solvent (43 ml) was added and the mixtures shaken for 10 minutes. The mixtures were then filtered twice through qualitative filter paper into 50 ml erlenmeyer flasks and read on a Bausch & Lomb Spectronic 20 spectrophotometer. For the nitroso-pigments the wavelength was set at 540 mμ and for the total pigments, 512 and 640 mμ . The solvents were 4:1 ratio composed of 40 ml of acetone, 3 ml of distilled water, and 7 ml of water derived from the meat sample for the nitroso-pigments. In the case of total pigments, the solvent contained 3 ml concentrated hydrochloric acid in place of the 3 ml of distilled water.

A light exposure cabinet was designed (Plate IV) to study the stability of the cured meat color. An adjustable height 51 x 62" galvanized 1 and 1/4" expanded metal shelf was positioned 42" from the floor in a 1.7°C cooler and housed within walls constructed of 5/8" plywood painted flat white. A white opaque plexiglass baffle was mounted 68" from the floor and a bank of lights 76" from the floor. Twelve fluorescent 40-watt Deluxe Cool White tubes were used, spaced 5" apart within the cabinet. Ceiling was located 88" from the floor with a 3" space between the ceiling and the top of the walls to allow for air flow. Air flow was found to be 15-25 fpm in this experiment using an Alnor type 8500, thermo-anemometer (Alnor Inst. Co., Chicago, Ill.). Light level was maintained at 200 ft.-c. by use of a rheostat after selecting proper shelf height.

Proximate Analyses- Total moisture and ether extractable fat con-

PIATE IV. COLOR STABILITY CABINET. HAM SAMPIES EXPOSED FOR ZERO AND 24 HOURS.





tent were determined using adapted A.O.A.C. (1950) procedures currently in use in the Meat Laboratory. Additional analyses of ham in Expt. IV included salt content, by the method of Kamm et al. (1964), and nitrite according to the methods of the A.O.A.S. (1952).

Statistical Analyses- Comparisons of pre- and post-chill processing techniques were made using the "t" test (Snedecor, 1946). Means and their standard errors were calculated.

RESULTS AND DISCUSSION

Ham- The effect of the processing method on the yield of the various components of the ham has been summarized in Table I for the four experiments. Because of the pliable state of the hot carcass, some carcass movement was encountered when removing the ham. The muscles of the hot ham tended to form in a natural standing position of the pig, while the chilled ham muscles were stretched and held rigidly in an unnatural position as a result of chilling. The form of the ham in the cold or post-chill processed carcass was primarily due to the solidification of the tissues in a fixed position. Rigor mortis had progressed to near completition in the post-chill muscle. Rigor mortis was in the early stages of development, or had yet to occur in the pre-chill muscle. Briskey et al. (1962) stated that rigor mortis occurred in as little as two minutes and up to eight hours following slaughter. The internal temperature of the pre-chill carcass was 32 to 38°C at the time of cutting.

Failure to extend the ham shank during removal was felt to be the cause of the significantly greater ($P<.01$) bone trim in the first experiment. Correction in the bone weight was observed when in the subsequent experiments, greater care was exercised by extending the shank of the pre-chill sides at the time of cutting. A significantly different pre-chill unprocessed weight was found in the last two experiments. The increased lean and fat trim weight found in Expts. III and IV resulted

from the loose and pliable flank region on the pre-chill carcass. More of the pliable flank tissue remained on the pre-chill ham.

TABLE I. EFFECT OF PROCESSING METHOD ON THE YIELD AND LOSS OF HAM COMPONENTS.

Item		Expt.	Mean		Std. error of mean
			Pre-	Post-	
Unprocessed ham	kg	I	7.72	7.57	0.08
		II	7.62	7.63	0.08
		III	7.59*	7.20	0.10
		IV	7.98**	7.52	0.06
Boneless ham	kg	I	4.28	4.33	0.05
		II	4.48	4.51	0.08
		III	4.54	4.51	0.09
		IV	4.54	4.33	0.08
Lean trim	kg	I	0.30	0.33	0.02
		II	0.51	0.48	0.03
		III	0.55*	0.63	0.02
		IV	0.54*	0.66	0.02
Fat trim	kg	I	2.24	2.13	0.06
		II	2.46	2.23	0.08
		III	2.38*	2.21	0.05
		IV	2.53**	2.17	0.07
Bone trim	kg	I	0.87**	0.79	0.01
		II	0.85	0.81	0.02
		III	0.82	0.77	0.02
		IV	0.80	0.75	0.02
Finished ham	kg	I	3.50	3.37	0.05
		II	3.38	3.85	0.06
		III	3.76	3.53	0.10
		IV	3.65	3.56	0.08
Processing loss	%	I	18.39*	22.41	1.02
		II	13.26	14.82	1.23
		III	17.45	17.53	1.25
		IV	19.64	20.54	0.70

* $P < .05$.
** $P < .01$.

In Expt. IV, the use of a rotary powered breaking saw was probably the cause for increased differences seen in the unprocessed weight and the lean and fat trim weights, compared to the use of a hand saw in the first

three experiments. The significant increase in the amount of fat removed from the pre-chill ham could also be attributed to the ease at which the hot fat was separated from the lean tissue.

The percent weight loss during the smoking and chilling periods was significantly less ($P < .05$) in the pre-chill processed ham from Expt. I (Table I). The difference between the pre- and post-chill processed ham for Expts. II, III, and IV was non-significant, but losses tended to be less in the pre-chill processed ham. Even though the smoking and chilling phases of the processing were essentially the same for Expts. II and III, weight losses were greater for the ham from the third experiment when compared to that in the second experiment. These hams received the three-hour cure and were smoked directly after pumping and trimming. Ham processed with the three-hour brine and smoked immediately did not have the same opportunity for cure equalization as ham given the three-day cover cure. Consequently, the total moisture loss during smoking was greater in ham cured for only three-hours. This could be altered by pumping the ham to more than 110% of green weight.

The higher, although non-significant differences seen in the total processing loss of Expt. IV ham were also reflected in the amount of moisture remaining in the ham after complete processing (Table II). Warner-Bratzler shear value was determined on 3/4-inch cores taken from 1/2-inch slices. In Table II, the pre-chill processed ham in the first experiment was found to be significantly ($P < .05$) more tender as measured by the shear value (3.66 compared to 4.19 kg, pre- and post-chill, respectively). This difference was probably due to the method of handling, chilling the pre-chill ham prior to curing. The difference between pre- and post-chill processed ham in tenderness was non-significant in the

last three experiments. Weiner (1964) found rapid processed ham more tender than the controls.

TABLE II. INFLUENCE OF PROCESSING METHOD ON SHEAR FORCE VALUE AND CHEMICAL COMPOSITION OF HAM.

Item		Expt.	Mean		Std. error of mean
			Pre-	Post	
Shear value	kg	I	3.66*	4.19	0.17
		II	2.38	2.60	0.17
		III	2.42	2.45	0.18
		IV	3.89	3.86	0.12
Moisture	%	I	66.37	65.01	0.61
		II	69.70	70.72	0.45
		III	69.11	70.34	0.44
		IV	65.75	66.49	0.76
Salt	%	IV	1.57	1.37	0.07
Nitrite	mg/gm meat	IV	0.021	0.021	0.002
Ether Extract	%	IV	10.55	10.10	0.84

* $P < .05$.

The percent moisture of the ham sample was determined (A.O.A.C., 1950). The means and their standard errors can be seen in Table II. No significant difference was found in the moisture content of the ham. Lower moisture content in the first experiment along with the high shear value was primarily attributed to the method of processing. The ham from Expts. II and III was cured and smoked in a fibrous casing and was not subjected to the drying effect as in Expt. I. In the fourth experiment, the lower moisture content and higher shear value was attributed to the greater shrink observed (Table I), caused by more rapid heating following the smoking period. As such, the ham remained longer at the higher temperature.

The salt content of the ham was determined in conjunction with the color stability study (Expt. IV). Pre-chill processed ham contained

more salt than the post-chill ham, although the difference was found to be non-significant (1.57 and 1.37%, respectively). The nitrite content, also determined for the color study, was found to be the same in both pre- and post-chill processed ham (Table II). Marbling or intramuscular fat, as reflected by ether extract, was not influenced by the two treatments. These results were similar to those found by Weiner (1964). The yield of ham was essentially the same in all experiments as was the shear value of the pre- and post-chill processed ham. Processing of ham to a finished or completed form prior to the initial chilling appears feasible from the results of this study.

Bacon- With a few exceptions, the differences in most measures studied between the pre- and post-chill processed bacon were non-significant. The weight of the unprocessed belly (green belly) was found to be significantly ($P < .05$) heavier for the pre-chill bellies in the first experiment (6.76 and 6.47 kg, respectively). This difference was attributed to the failure of the operator to physically hold the pre-chill carcass the same as the post-chill carcass during the removal of the ham, thus effecting a larger belly from the pre-chill sides. Adjustments in removal of the wholesale cuts in subsequent experiments reduced this difference. Adjustment of the skinning machine (Townsend model 26) in the fourth experiment partially corrected the difference seen in the skin-off weight. The pre-chill bellies were skinned immediately after slaughter, while the skin was soft, pliable, and contained more moisture than the cold bellies.

No significant differences were found for the pumped weight or the cold smoked weight, with one exception. In Expt. II, a significantly heavier ($P < .05$) pre-chill belly was found after final chilling of the

TABLE III. THE EFFECT OF PROCESSING METHOD ON VARIOUS BACON YIELDS.

Item		Expt.	Mean		Std. error of mean
			Pre-	Post-	
Belly unprocessed	kg	I	6.76*	6.47	0.08
		II	6.52	6.21	0.15
		III	6.53	6.09	0.11
		IV	6.84	6.58	0.13
Skin-off wt.	kg	I	1/	1/	1/
		II	5.60**	5.06	0.10
		III	5.36**	4.92	0.08
		IV	5.66	5.65	0.14
Pumped wt.	kg	I	1/	1/	1/
		II	6.18	6.14	0.12
		III	6.08	5.77	0.16
		IV	6.78	6.40	0.14
Cold smoked wt.	kg	I	6.06	6.05	0.08
		II	4.86*	4.59	0.09
		III	4.70	4.50	0.08
		IV	5.65	5.70	0.15
Formed wt.	kg	I	1/	1/	1/
		II	4.69	4.45	0.09
		III	4.42**	4.13	0.07
		IV	5.23	5.26	0.16

* $P < .05$.
** $P < .01$.
1/ Not available, because of method of processing.

finished belly. A significantly ($P < .01$) larger pre-chill belly was found in Expt. III with respect to formed weight.

With regard to yield, no significant differences were found in the weight of the full slice, trim, or number of slices between the two processing treatments. No significant differences were found between the length and width measurements of the sides from the two chilling temperatures employed after smoking. Pooling of the -62° and 1.7°C data permitted comparison of the four experiments.

It was observed from the data presented in Table IV that highly significant ($P < .01$) differences existed with respect to measurements of

TABLE IV. THE EFFECT OF PROCESSING METHOD ON LENGTH AND WIDTH OF BACON SLABS.

Item		Expt.	Mean		Std. error of mean
			Pre-	Post-	
Unprocessed length	cm	I	50.50**	56.95	0.90
		II	52.27**	61.16	0.53
		III	53.09**	62.23	0.57
		IV	1/	1/	1/
Unprocessed width	cm	I	31.17**	27.58	0.36
		II	34.06**	27.53	0.41
		III	34.19**	27.79	0.40
		IV	1/	1/	1/
Smoked length	cm	I	1/	1/	1/
		II	50.47*	54.69	0.15
		III	53.11	52.27	0.14
		IV	54.46*	58.01	0.20
Smoked width	cm	I	1/	1/	1/
		II	25.78**	24.03	0.06
		III	24.49	23.88	0.04
		IV	26.67**	25.30	0.05
Pressed length	cm	I	1/	1/	1/
		II	51.18*	53.39	0.70
		III	52.12	50.75	0.65
		IV	53.59	56.18	0.90
Pressed width	cm	I	1/	1/	1/
		II	23.97**	22.91	0.21
		III	22.91	22.86	0.18
		IV	25.50**	24.59	0.20

* $P < .05$.
** $P < .01$.
1/ Not available, because of method of processing.

the unprocessed belly. Pre-chill bellies measured prior to chilling were shorter and wider than the opposite sides which had been chilled. The wide variation observed in the unprocessed sides was reduced after pressing. The post-chill sides, when measured unprocessed, were influenced by the stretching as a result of the 24-hour chilling period while the carcass hung from the rail in the cooler. After smoking, the bellies had contracted. Variation in the mean difference between the pre- and

post-chill processed bacon in the smoked state was not as large as in the unprocessed state. Smoking and/or heating caused shortening of the linear shape of the bellies. This was observed in both length and width measurements for smoked bellies.

Since the ultimate measure of bacon yield depends upon the final pressed measurements, more knowledge can be obtained through a study of these data. No significant difference was found in the final pressed length of the bacon slab (Expt. I bellies not pressed). Pressing failed to completely compensate for the wider bellies in the pre-chill processing technique, as shown in Expts. II and IV.

Since the pressed slab length was found to be non-significant (Table IV), the number of slices obtained from the slab was accordingly non-significant (Table V). While the weight of the pre-chill, procesed slices was found to be heavier in all experiments, this difference was found to be non-significant. The weight of the bacon trim from the pre- and post-chill sides was essentially the same due to the commercial pressing method used prior to slicing.

A significant ($P < .05$) difference in percent shrink was found between the pre- and post-chill processed sides in Expt. IV. No reason was apparent for this effect, as the processing method and curing brine were the same for the bellies in Expts. III and IV. A slower rise in temperature during the early part of smoking, even though the final temperature and length of time in the smokehouse were the same, could explain some of the difference. The data obtained in Expt. IV more closely agreed with those reported by Carpenter et al. (1962).

Several methods of estimating the influence of pre- and post-chill processing method were evaluated to obtain knowledge concerning apparent

TABLE V. THE EFFECT OF PROCESSING METHOD ON THE YIELD, NUMBER OF SLICES WEIGHT OF SLICES, WEIGHT OF TRIM AND SHRINK.

Item		Expt.	Mean		Std. error
			Pre-	Post-	of mean
Slices	no	I	1/	1/	1/
		II	156.30	166.40	5.56
		III	181.80	177.45	3.52
		IV	183.80	188.50	3.03
Slice wt.	kg	I	1/	1/	1/
		II	4.30	4.18	0.08
		III	4.04	3.76	0.04
		IV	4.46	4.45	0.11
Trim wt.	kg	I	1/	1/	1/
		II	0.33	0.27	0.04
		III	0.36	0.36	0.03
		IV	0.76	0.82	0.07
Shrink	%	I	1/	1/	1/
		II	25.35	25.61	1.04
		III	27.93	25.86	1.41
		IV	17.84*	13.50	1.19

* $P < .05$.

1/ Not available, because of method of processing.

differences seen by the eye in the sliced bacon. The total slice weight and the total weight of six slices from each slab, indicated that the slices from the pre-chill processing method were heavier ($P < .05$). This was also reflected by the greater belly depth measurements. No significant difference was found in the quantity of lean that was physically separated from each slice (Table VI). Significantly greater ($P < .01$) fat weight was found in Expt. III pre-chill processed sides. When the separable lean and fat were expressed on a percent basis, no significant difference was found. The percent lean in the bacon slices agreed with the work reported by Carpenter et al. (1962).

Acetate tracings of six slices removed from each slab were used to determine the area of lean and fat. These data are presented in Table VII. The total slice area was significantly greater for the slices pro-

TABLE VI. THE EFFECT OF PROCESSING METHOD ON THE QUANTITY OF LEAN AND FAT IN THE BACON SLICE.

Item		Expt.	Mean		Std. error of mean
			Pre-	Post-	
Total slice wt.	gm	I	133.68*	124.82	2.48
		II	148.00	131.44	5.31
		III	124.73*	116.85	2.16
		IV	1/	1/	1/
Lean wt.	gm	I	51.01	46.11	1.31
		II	47.12	45.18	2.01
		III	37.38	38.56	1.22
		IV	1/	1/	1/
Fat wt.	gm	I	82.67	78.71	2.60
		II	100.88	85.26	5.56
		III	87.31**	78.29	2.21
		IV	1/	1/	1/
Lean	%	I	38.18	37.11	1.31
		II	31.89	34.00	0.71
		III	30.01	31.45	1.04
		IV	1/	1/	1/
Fat	%	I	61.82	62.88	1.31
		II	68.10	66.00	0.71
		III	69.99	68.95	1.04
		IV	1/	1/	1/

* $P < .05$.
** $P < .01$.
1/ Not available, because of method of processing.

cessed by the pre-chill method when compared to those processed by the post-chill method. The area difference was fat, which was significantly greater in all experiments for the pre-chill processed slices. In only Expt. I, was the difference in lean area significant ($P < .05$). When the data were calculated on a percentage basis, few differences were shown in the composition of the pre- and post-chill bacon slices.

Pre-chill slices from Expt. II showed a significantly ($P < .05$) greater amount of fat and conversely a lesser amount of lean. Data for two other measures of the bacon slice are shown in Table VII. Slices processed by the pre-chill method were significantly longer. In Expt.

TABLE VII. THE EFFECT OF PROCESSING METHOD ON BACON SLICE SIZE, FAT AND LEAN.

Item		Expt.	Mean		Std. error of mean
			Pre-	Post-	
Total area	sq.cm	I	88.85**	80.71	1.50
		II	94.34**	83.79	1.42
		III	90.65**	81.14	1.21
		IV	1/	1/	1/
Lean area	sq.cm	I	29.14*	26.38	0.89
		II	23.94	23.64	0.67
		III	23.84	23.39	0.92
		IV	1/	1/	1/
Fat area	sq.cm	I	59.70*	54.33	1.43
		II	70.40**	60.35	1.29
		III	66.81**	57.75	1.46
		IV	1/	1/	1/
Lean	%	I	32.88	32.73	0.99
		II	25.46*	28.11	0.69
		III	26.33	28.97	0.50
		IV	1/	1/	1/
Fat	%	I	67.12	67.27	0.99
		II	74.54*	71.88	0.69
		III	76.67	71.03	0.50
		IV	1/	1/	1/
Slice length	cm	I	23.26**	21.89	0.27
		II	24.98*	23.82	0.36
		III	25.85**	23.94	0.27
		IV	1/	1/	1/
Slice depth	cm	I	4.12	3.98	0.06
		II	4.12*	3.84	0.07
		III	3.77	3.67	0.05
		IV	1/	1/	1/

* $P \leq .05$.
** $P \leq .01$.
1/ Not available, because of method of processing.

II the bacon slices were significantly wider.

Essentially no difference was detected in the yield of bacon during the various steps of processing (green weight, smoked weight, formed weight, and sliced weight). Pre-chill processed bellies were shorter and wider than those processed post-chill. Commercial forming prior to

slicing aided in overcoming these variations. The percent lean in the slices from formed slabs was essentially the same for bacon processed by both methods. The use of pre-chill processing techniques indicated many feasible applications to bacon production.

Loin- The weight of the unprocessed loin, while non-significant, was found to be slightly less for the pre-chill method in all experiments. This same trend was reflected in the weight of the fat trimmed from the loins (Table VIII). A significantly ($P < .05$) smaller loin

TABLE VIII. THE EFFECT OF PROCESSING METHOD ON YIELD OF FRESH LOIN.

Item		Expt.	Mean		Std. error of mean
			Pre-	Post-	
Unprocessed loin	kg	I	7.62	8.04	0.15
		II	8.60	8.94	0.18
		III	8.43	8.77	0.21
		IV	8.54	8.60	0.14
Fat trim	kg	I	2.64	2.80	0.10
		II	2.95	3.14	0.12
		III	2.83	3.05	0.12
		IV	3.07	3.13	0.13
Finished wt.	kg	I	4.89*	5.20	0.10
		II	5.57	5.78	0.10
		III	5.52	5.68	0.12
		IV	5.41	5.46	0.11

* $P < .05$.

yield was found in the first experiment. Since no difference was obtained in the yield of finished loin in the last three experiments, greater experience in fat removal was indicated.

Detailed study of the loins in Expts. II and III included moisture content as determined by the A.O.A.C. (1950) method. Essentially no difference was seen between the pre- and post-chill processed loins in the amount of total moisture which remained after being cooked. The Warner-Bratzler shear value for oven roasted loins from the pre- and

TABLE IX. THE EFFECT OF PROCESSING METHOD ON LOIN MOISTURE CONTENT, SHEAR VALUE, THAWING LOSS, AND COOKING LOSS.

Item		Expt.	Mean		Std. error of mean
			Pre-	Post-	
Moisture (A.O.A.C.)	%	II	59.32	58.93	0.52
		III	61.23	61.20	0.62
Shear value	kg	II	10.00	9.60	0.34
		III	10.44	10.75	0.28
Thaw loss	%	II	3.53	3.26	0.45
		III	4.28	4.03	0.37
Cooking loss	%	II	25.40	26.71	0.59
		III	23.44	24.06	0.61

post-chill processed loins was non-significantly different. Thaw loss value was larger for the pre-chill processed loins, but non-significant. Cooking loss, about 25% in this study, was non-significant between the pre- and post-chill processed methods. In both experiments, the cooking loss was less for the pre-chill processed loin samples.

Color Stability- Average ppm of nitroso-pigments extracted in a given elapse of time was determined (Table X). Prior to any exposure to light (zero time), there was no significant difference between the pre- and post-chill cured ham nitroso-pigments. Significantly ($P < .05$) more nitroso-pigments remained after 30 minutes exposure to light in the case of the pre-chill processed ham. After exposure to 200 ft.-c. of light for one hour through 24 hours, the extractable pigments were found to be non-significantly different between the two treatments. In all cases, the pre-chill ham contained more nitroso-pigments, although non-significant in this study. The variation within treatment was greatest for the pre-chill treatment through the fourth hour of exposure. During the fifth and sixth hour the pre-chill processed ham had less variation than the post-chill ham. At 24 hours, the means were 5.64 and 4.89 ppm,

TABLE X. NITROSO-PIGMENTS (ppm) FOUND AFTER EXPOSURE TO 200 ft.-c. OF LIGHT FOR VARIOUS TIME INTERVALS. 1/

Time	Mean		Std. error of mean	
	Pre-	Post-	Pre-	Post-
0	53.74	54.12	2.24	2.08
1/2	43.29*	35.52	2.41	1.76
1	37.88	31.67	2.50	1.74
2	32.88	28.48	2.76	2.05
3	30.97	26.13	2.52	2.32
4	29.18	24.44	2.50	2.35
5	28.39	23.13	2.42	2.45
6	26.64	22.02	2.34	2.49
24	5.64	4.89	0.71	0.59

* $P \leqslant .05$.

1/ Within treatment variances thought to be different, resulting in means having different standard errors.

respectively for the pre- and post-chill processed ham. In all cases the variation seen in the ham samples was considered to be large, and the individual observations are included as Appendix Table XII, for the reader's further study.

When the zero time reading was assumed to be 100% of the nitroso-pigments that could be extracted with the acetone solvent, then the ppm of nitroso-pigments at any time could be converted to percent of zero time. Table XI reports the percent nitroso-pigments remaining in the sample after exposure to light. With respect to the amount of nitroso-pigments retained after 30 minutes exposure to light the pre-chill processed samples contained 80.49% of the zero time compared to 65.88% for the post-chill samples. The greatest reduction in cured meat color would be expected shortly after exposure to air and light (Ramsbottom

TABLE XI. COLOR STABILITY AS MEASURED BY NITROSO-PIGMENTS (PERCENT) REMAINING AFTER EXPOSURE TO 200 ft.-c. LIGHT.

Time (hr)	Mean		Std. error of mean	
	Pre-	Post-	Pre-	Post-
1/2	80.49***	65.88	2.98	2.24
1	70.35**	59.51	3.62	1.66
2	60.14*	52.08	4.07	2.27
3	56.83*	47.49	3.60	2.85
4	53.63*	44.23	3.60	3.02
5	53.17**	41.64	3.80	3.09
6	49.27*	39.46	3.43	3.29
24	10.98	9.00	1.51	0.97

* $P < .10$.
** $P < .05$.
*** $P < .01$.

et al., 1951; and Hornsey, 1964). The difference seen at one and five hours were found to be significant ($P < .05$).

Two, three, four, and six hour exposures were significantly ($P < .10$) greater in retention of nitroso-pigments for the pre-chill processed ham. At 24-hour, there was no significant difference ($P > .10$) between the pre- and post-chill processed methods. The pre-chill method retained slightly more nitroso-pigments than the post-chill processed ham. In all cases the variation was larger for the pre-chill method. Commercially processed meat would be expected to have wide variation due to animal variation, and would not necessarily reflect processing faults according to Hornsey (1964). The percent nitroso-pigments that remained after exposure to 200 ft.-c. of light for the respective time intervals are graphically shown in Figure 2.

A plot of the variance of the mean nitroso-pigments (ppm) can be

found in Figure 3. Evidence that the treatment variance was different can be seen from the graph of the variance at different exposure times. While the amount of pigments retained after exposure were greater for the pre-chill processed ham, greatly increased variation was also found.

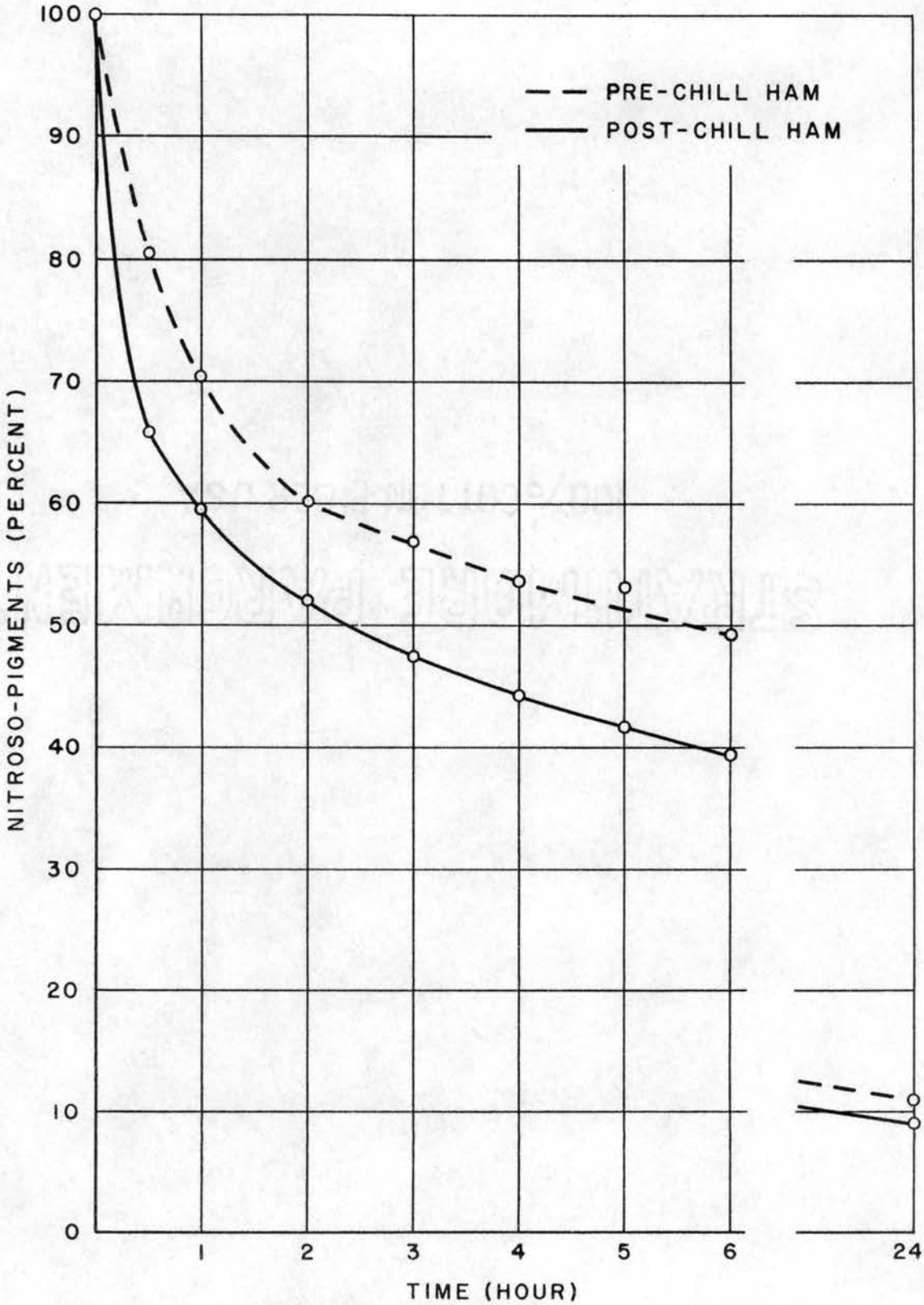


Figure 2. Nitroso-Pigments (Percent) Following Exposure to Light (200ft.-c.)

Figure 3. Variance of nitroso-pigments (ppm). Following exposure to light (200 ft.-c.).

SUMMARY AND CONCLUSIONS

Four groups of 20 barrows each were obtained from the Oklahoma Agricultural Experiment Station herd. The barrows in each experiment were of similar breeding, age, and weighed approximately 91 kg when slaughtered. Pre-chill processing was defined as completing some or all of the fabrication steps prior to the initial chilling of the cuts. The method involved removal of the wholesale cuts and processing within 30 minutes post-slaughter. Post-chill processing (the controls) involved a 24-hour chilling period at 1.7°C prior to cutting and processing.

In each of the four experiments, the fresh cuts were removed immediately post-slaughter. The loins were trimmed of fat and rapidly chilled. Chilling temperatures were -62°C until the center internal temperature reached 10°C at which time the loins were removed from the air-blast chamber and placed on shelves in a cooler at 1.7°C and allowed to temper. In the fourth experiment, the chilling temperature for the fresh cuts was -20°C. The post-chill processed loins were chilled on the carcass at 1.7°C.

Processing of the boneless, pressed hams was as follows: in the first experiment the hams were chilled immediately after slaughter at -62°C until the internal temperature reached 10°C followed by tempering, curing for three-days, and smoking. Experiment II hams were pumped immediately after slaughter and placed in a three-day cover cure, then smoked, and finally chilled. In the third and fourth experiments the

boneless, pressed hams were pumped immediately after slaughter and placed directly into the smokehouse, smoked, and fully cooked prior to chilling.

Bacon was processed similarily and in the last three experiments pressed prior to slicing. Yields, tenderness, moisture content, and various linear measurements were obtained. Color stability of ham was evaluated in the fourth experiment.

No significant difference was found in the yield of finished ham between the pre- and post-chill treatments. In Expt. I, pre-chill processed ham was found to be significantly ($P < .05$) more tender based on the shear value. There was no significant difference in shear value of ham between treatments in the last three experiments. Moisture content of ham was found to be non-significantly different in these experiments.

Weight of the unprocessed, pre-chill green belly was found to be greater in the first experiment. Greater care in cutting and removal of the belly reduced this effect in subsequent experiments. In Expts. I, III, and IV there was no significant difference in pumped weight or in the weight of the cold smoked bacon. A greater quantity of pre-chill processed bacon was found in Expt. II. Shorter but wider slabs were characteristic of bellies cut prior to chilling. Pressing the cured slabs partially reduced the length and width differences. There was no significant difference in the number of full slices, the weight of the sliced bacon, or the trim from the bellies. A significantly greater percent shrink was found for the pre-chill processed slices in Expt. IV.

Loin yield was found to be non-significantly different in the last three experiments. In the first experiment, cutting differences observed in the belly and ham weight were also found for the loin. Moisture

content of the loin was found to be essentially the same following cooking. Cooking loss from loin roasts was approximately 25% in both treatments.

Color stability expressed as the amount of nitroso-pigments remaining after exposure to light indicated that the greatest loss occurred in the first 30 minutes. Pre-chill processed ham retained significantly more color than the post-chill processed ham in all but the 24-hour sample. Wide variation in nitroso-pigments was found due in part to animal differences.

Results indicated that curing and smoking of ham and bacon could be satisfactorily processed immediately after slaughter and prior to initial chilling of the product. Fresh pork loin, which presented a need for greater attention to surface texture, could be processed with essentially the same yield, tenderness, and moisture content as the conventional loin. Processing of pork products in these experiments was accomplished in about 15 hours from the time of slaughter.

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A P P E N D I C E S

TABLE XII

NITROSO-PIGMENTS (PERCENT) REMAINING AFTER EXPOSURE TO LIGHT (200 ft.-c.),

Animal No.	Time (hour) 1/2 Pre-	1/2 Post-	1 Pre-	1 Post-	2 Pre-	2 Post-	3 Pre-	3 Post-	4 Pre-	4 Post-	5 Pre-	5 Post-	6 Pre-	6 Post-	24 Pre-	24 Post-
1	82.49	70.79	71.93	57.33	61.75	39.87	61.38	27.14	58.71	26.42	59.47	26.42	52.72	24.95	14.64	12.17
2	91.68	65.38	89.92	49.66	72.88	36.63	62.48	26.29	59.78	26.96	57.91	27.10	57.00	26.96	13.04	11.18
3	64.14	65.46	62.18	50.25	38.20	40.14	44.86	40.14	43.87	25.15	42.97	25.15	41.98	25.81	11.72	9.12
4	97.31	62.24	86.76	53.69	68.59	49.66	65.44	46.70	63.10	46.70	60.79	45.97	58.48	45.25	10.32	6.80
5	89.00	47.76	70.04	45.54	64.77	45.54	64.06	44.10	64.77	42.66	61.89	40.50	61.12	43.38	6.58	13.63
6	98.17	45.75	72.46	62.53	59.78	39.34	58.23	37.78	57.45	37.78	75.23	37.25	56.73	37.25	6.09	11.08
7	78.24	78.86	56.98	67.40	32.78	53.74	31.93	49.28	31.07	48.46	30.21	32.26	34.50	28.96	6.30	4.53
8	69.36	67.16	50.54	56.74	29.35	41.85	31.07	42.62	29.35	41.02	27.63	37.89	26.77	30.80	19.26	13.55
9	63.81	66.23	37.26	59.85	31.40	49.09	27.79	41.63	27.79	36.56	28.50	29.50	25.66	15.32	7.16	10.71
10	74.49	58.17	68.02	58.17	67.33	55.52	60.44	56.87	58.41	51.57	56.42	43.88	49.21	41.96	5.08	7.22
11	99.08	67.31	99.08	62.39	90.26	59.99	84.28	58.88	82.59	56.77	84.28	54.86	78.45	52.02	12.78	8.44
12	100.00	48.28	96.41	55.28	85.96	52.66	72.74	55.28	66.43	54.40	62.51	52.66	60.23	51.78	26.22	8.88
13	77.48	78.62	78.41	64.93	77.48	54.43	73.01	45.16	65.20	33.77	65.20	32.92	62.66	28.29	28.41	7.17
14	65.85	70.48	60.16	59.31	49.32	53.89	45.38	39.11	34.58	30.11	34.01	30.64	29.14	27.20	8.00	3.72
15	64.73	67.64	57.23	61.33	48.83	55.18	41.95	35.57	29.95	30.75	27.86	29.42	22.24	27.98	6.80	6.09
16	92.28	67.09	85.63	63.31	84.00	58.11	80.79	56.64	73.72	52.28	75.08	45.93	70.65	49.45	8.49	3.46
17	80.53	85.54	73.81	79.08	60.95	77.68	55.42	77.68	52.37	72.15	51.64	74.89	49.38	74.22	4.97	11.37
18	88.48	70.81	78.39	68.83	73.90	69.48	71.39	68.83	70.14	67.54	65.24	68.83	64.03	63.71	4.05	3.55
19	71.99	66.39	58.89	56.23	54.00	53.21	52.62	45.85	51.93	47.34	46.54	45.14	38.68	45.14	7.66	6.04
20	60.70	67.71	52.81	58.40	51.37	55.61	51.37	54.24	51.37	56.30	49.97	51.49	45.80	48.80	12.12	21.26
$\bar{x}$	80.49	65.88	70.35	59.51	60.14	52.08	56.83	47.49	53.63	44.23	53.17	41.64	49.27	39.46	10.98	9.00
$s_{\bar{x}}$	2.98	2.24	3.62	1.66	4.07	2.27	3.60	2.85	3.60	3.02	3.80	3.09	3.43	3.29	1.51	0.97
"t"	3.92***		2.72**		1.73*		2.04*		2.00*		2.36**		2.06*		1.10	

* $P < .10$.
** $P < .05$.
*** $P < .01$.

COLOR STABILITY STUDY FOR CURED HAM

PROCEDURE-

1. Remove and wrap twice in paper a two-inch cross-section of the pressed, boneless ham to be evaluated.
2. Exercise all possible care to avoid contact with light, and refrigerate immediately and prior to commencing the study.
3. Carry out all work in a dark cooler, red photography light for background illumination.
4. Unwrap ham sample, remove with a knife all outside edges containing smoked surfaces and excess fat.
5. Grind once through a refrigerated grinder, 1/8-inch plate and mix.
6. Weigh exactly 10.0 gm into 1/2 petri plate and spread uniformly over the entire surface.
7. Expose to light source for the prescribed time.
8. Remove from the light source to a dark room, and place meat into a 125 ml erlenmeyer flask.
9. Add 43 ml of solvent, shake for 10 minutes on a mechanical shaker.
10. Filter twice into a 50 ml erlenmeyer flask through qualitative filter paper.
11. Read nitroso-pigments at 540 mμ and total pigments at 512 and 640 mμ, using a spectrophotometer.

REAGENTS-

Solvent for nitroso-pigments extraction.

40 ml acetone
3 ml distilled water
7 ml water derived from meat to make to 4:1 ratio

Solvent for total pigment extraction.

40 ml acetone
3 ml concentrated hydrochloric acid
7 ml water derived from meat to make to 4:1 ratio

EXPERIMENTAL LAYOUT-

TIME (hr)	Nitroso-pigments		Blank	Total pigments		Blank
	Duplicates			Duplicates		
0	X	X	X	X	X	X
1/2	X	X	X	X	X	X
1	X	X	X	X	X	X
2	X	X	X	X	X	X
3	X	X	X	X	X	X
4	X	X	X	X	X	X
5	X	X	X	X	X	X
6	X	X	X	X	X	X
24	X	X	X	X	X	X

REFERENCES-

Hornsey (1956, 1957).

VITA

Roger Wellington Mandigo

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE INFLUENCE OF PRE-CHILL PROCESSING ON PORK PRODUCTS

Major Field: Food Science- (Meat Science)

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