QUALITY, THICKNESS AND END POINT EFFECTS ON CHARCOAL-BROILED PORK RIB CHOP ACCEPTABILITY

by

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INTRODUCTION

Charcoal-broiling meat has become a favorite cooking method for restaurants and families, but little research has been completed using charcoal as a heat source. Pork was chosen for the study because of the lack of information on charcoal-broiling this meat and the recent realization that pork need not be cooked to the well-done stage. Since 10 billion lb of pork are processed each year in the United States and per capita consumption is 68 lb (Am. Meat Inst. Foundation, 1960), new methods of cooking should be shared with the public. Effect of thickness and types of chops and roasts, end point temperature and cooking-method upon palatability should be investigated.

An increased prevalence of pale, soft, watery porcine muscle has been noted by the packing industry and by researchers since the introduction of the lean, meat-type hog. The effect of quality, as judged by color, marbling and firmness, upon palatability of cooked pork has not been investigated fully.

Two objectives were considered in this study. The first was to determine the effect of varying end point temperature and thickness on palatability of charcoal-broiled pork rib chops. The second was to determine the effect of color, marbling and firmness characteristics of uncooked pork on acceptability of charcoal-broiled rib chops.

REVIEW OF LITERATURE

Quality of Uncooked Pork

Preference for lean pork cuts by consumers in all income brackets and a deteriorating market for lard in the last 25 years have decreased production of the standard fat hog and led to the development of a lean meaty animal (Vrooman, 1952; Birmingham _et al._, 1954). Desire to produce meat-type hogs with optimum palatability characteristics has stimulated research in many areas.

Methods of evaluation. Marbling scores for the gluteus medius at the posterior end of the loin and of the longissimus dorsi at the anterior end were used by Whitehair _et al._ (1964a) to develop a classification for degree of marbling. The longissimus dorsi, biceps femoris, semimembranosus, semitendinosus, rectus femoris and adductor muscles were studied by Batcher and Dawson (1960). Since differences were great among muscles, Batcher and Dawson advised that more than one muscle be used to evaluate carcass quality. However, they indicated that degree of marbling in raw longissimus dorsi between 10th and 11th ribs showed promise as a means of predicting tenderness and juiciness of cooked pork loin cuts.

Color and finish of wholesale or retail pork pieces may be judged by comparison with photographic standards. Examples are the University of Wisconsin 5-point scale (University of Wisconsin, 1963) and various U.S.D.A. charts. Specific gravity was used to indicate fatness or leanness of carcasses (Brown _et al._, 1951). Specific gravity of pork cuts investigated was closely related to that of the entire carcass (Pearson _et al._, 1956).

Variation within the loin. Pork longissimus dorsi area measured by Kropf (1962) was least at the 3rd thoracic and became significantly larger at the 5th, 7th and 10th thoracic vertebrae. The area at the 1st lumbar was larger than all others except at the 13th thoracic vertebrae. Kline and Goll (1964) also reported pork loin eye area increased posteriorly from the 5th thoracic to the 1st lumbar but found area constant at the 1st and 6th lumbar vertebrae. Longissimus dorsi area in each of 8 positions reported by Kline and Goll (5th, 6th, 7th, 8th, 9th, and 10th thoracic and 1st and 6th lumbar vertebrae) was related to average back-fat and % loin. The loin area at the last rib of 23 carcasses was noted by Kline and Hazel (1955) to average 0.43 sq in. greater than at the 10th rib.

Marbling of the longissimus dorsi in 95 pork carcasses (Kropf, 1962) showed that marbling was most abundant at the 5th lumbar and least abundant at the 3rd thoracic vertebrae. Marbling was similar in different sections of the longissimus dorsi of 48 carcasses by Murphy and Carlin (1961). Marbling, however, was studied only at the 10th thoracic and 4th lumbar vertebrae.

Post-mortem treatment. Muscles of living porcine animals are moderately dark in color, firm in texture and dry in appearance (Briskey et al., 1959). These conditions should be maintained post-mortem for optimum quality meat. Meyer et al. (1963) postulated that post-mortem change included metabolism of glycogen to lactic acid and resynthesis of adenosine triphosphate until creatine phosphate stores were exhausted. Muscle fibers then lost extensibility and elasticity and rigor mortis occurred. Temperature change affected the rate of these reactions.

The drop in pH following death is associated with the amount of lactic acid produced. The physical state of the muscle is not only related to pH but is associated with time involved in reaching the ultimate pH.
pH patterns and associated musculature were reported by Briskey (1963) as follows: A slow, gradual decrease to an ultimate pH (after cessation of post-mortem glycolysis) of 6.0-6.5 or above yielded dark musculature, but at 5.7-6.0 gave slightly dark muscles. Gradual decrease to approximately

5.7 at 8 hr with ultimate pH of 5.3-5.7 yielded normal tissue. Relatively rapid decrease to 5.5 at 3 hr with ultimate pH of 5.3-5.5 caused slightly pale, soft, exudative pork. Rapid to slightly gradual, but extensive, decrease to ultimate pH of 5.0 resulted in slightly dark to extremely pale, but exudative, musculature. A rapid decrease to pH 5.1-5.4 at 1/2-1 1/2 hr and retention of low pH or subsequent elevation to 5.3-5.6 yielded extremely soft, pale, exudative muscle.

Kauffman et al. (1964a) in a study of 439 carcasses and Judge et al. (1960) agreed with Briskey that increased muscle acidity was associated with pale, soft tissue and higher expressible moisture. Chilled muscles were normal, noted Sayre and Briskey (1963), when pH was above 6.0 at 2 hr post-mortem or at onset of rigor, regardless of the ultimate pH.

The influence of post-mortem temperature on porcine quality was studied by Bodwell et al. (1964). One side of each of 15 carcasses was chilled immediately after slaughter to 50°F in the longissimus dorsi muscle and the second side was retained at 99°F or higher for 4-5 hr. Soft, watery pork could not be induced consistently by high holding temperature. Conversely, holding carcasses at 99°F for 1 hr produced pale, soft exudative muscle (Wismer-Pedersen and Briskey, 1961); this phenomenon was confirmed by Sayre et al. (1964). Holding small sections of pork muscle in cold brine (28°F) accelerated chilling rate and retarded glycolysis thereby maintaining color and firm structure (Wismer-Pedersen and Briskey, 1961). Partial freezing of pork with liquid nitrogen immediately after dressing was noted by Borchert and Briskey (1964) to be extremely effective in preventing development of pale, soft, exudative tissue regardless of temperature of subsequent equilibration (0 or 39°F).

Wismer-Pedersen (1962) found no appreciable denaturation of fibrillar protein in watery fibrils and postulated that the higher protein content of watery fibrils was due to condensation of sarcoplasmic to fibrillar protein. Electron microscopy revealed some denaturation in fibrils of low quality meat (Cassens et al., 1963). Normal muscle exhibited a gradual disruption of sarcoplasmic components, but little or no change in myofibrils. Muscles that went into rigor rapidly at low pH and high temperature appeared soft, pale and watery and photomicrographs showed a rapid disruption of sarcoplasmic components and some disruption of myofilaments. Muscles that went into rigor mortis rapidly at high pH and reduced temperature ultimately appeared dark, dry and firm and myofibrillar structure possessed a high degree of organization and preservation.

Ante-mortem treatment. In a study of 123 fresh pork loins, Judge et al. (1959) found carcasses from hogs raised and slaughtered during cool weather had darker, more highly marbled loins than those from hogs raised in warmer weather.

High temperatures immediately before death also affected carcass characteristics. Warm ante-mortem treatment (108-113°F) of 37 Poland China pigs for 30-60 min was tested by Kastenschmidt et al. (1964). Rapid post-mortem glycolysis resulted with consequent rapid onset of rigor mortis and the development of extremely pale, soft exudative muscle at low pH. Cold ante-mortem treatment (34-37°F) for 30 min markedly improved muscle characteristics. Warm and then cold treatment produced most desirable muscles by reducing muscle temperature and glycogen at time of death. This limited glycolysis and resulted in rapid onset of rigor at high pH. Cold followed by warm treatment gave variable results.

Several studies have tested the effect of stress upon porcine muscle quality. Stress (electric shock every 10 min for 5 hr before slaughter) significantly increased yield and pH of longissimus dorsi of 40 No. 1 crossbred hogs studied by Lewis et al. (1961). Hedrick et al. (1964) also reported pH (30 min and 24 hr post-mortem) from stressed hogs (adrenalin-treated) higher than from untreated animals. Color of uncooked pork chops from stressed animals was more stable. Severe exercise and excitement before slaughter are also considered stress situations and affect carcass quality similarly.

Pigs fed 50% sucrose for 2 weeks and not fasted prior to slaughter and those fasted 56 hr, then fed 50% sucrose for 12 hr before slaughter had higher glycogen levels than fasted pigs and had slightly soft, pale muscle (Sayre et al., 1963). Those fasted 56 hr, fed 50% sucrose for 12 hr and given 15 min exercise before slaughter had lower glycogen content at slaughter than unstressed animals. Faster and more extensive glycolysis, rapid pH decline and pale, soft, watery pork were observed. A final lot fasted 70 hr prior to slaughter retained highest pH after 24 hr and maintained desirable texture and color. Lewis et al. (1961) found 10% brown sugar added to drinking water for 48 hr prior to slaughter significantly increased yield, moisture and ash of loin.

Although only temperature, stress and sugar have been discussed here in their relation to pale, soft, watery pork, other factors such as breed, feed, and stunning procedure, have been shown to affect the condition (Briskey, 1964).

Trichinosis Infection from Pork

Infestation with nematode <u>Trichinella spiralis</u> causes trichinosis in man and usually results from consumption of raw or incompletely cooked pork containing larvae (Frazier, 1958). In 1954, 16% of the pork-eating population of the United States was estimated by Bundesen to have some trichinae infection. More recent surveys reported by Bradley (1964) showed less than 4% of human muscle samples contained trichinae. Incidence of trichinosis in man had been reduced by 80% and in farm-raised swine, by more than 95% since 1906.

Prevalence of <u>Trichinosis spiralis</u> in approximately 10,000 samples of sausage available in Iowa decreased from 12.4 to 1.2% in bulk sausage and from 11.7 to 3.4% in link sausage during the period from 1944-46 to 1953-55 (Zimmerman <u>et al</u>., 1961). Schwartz (1952) indicated that processing swine feed was important in decreasing infected pork. He found the incidence of trichinae in hogs fed raw or uncooked garbage was more than 11% whereas only 0.6% of Midwestern swine with occasional access to garbage were infected. Garbage feeding regulations have now been passed in 47 states. Better swine management methods, widespread freezing of meat and less home butchering of pork have also contributed to a decrease in trichinosis (Zimmerman <u>et al</u>., 1961).

After infected pork is consumed, the larvae are released in the intestinal tract during digestion and invade mucous membranes of the small intestine where they develop into adult worms (Frazier, 1958). Each fertilized female produces 1000-1500 larvae which travel through the blood and lymphatic systems to skeletal muscle where they are encysted. Helvig and Weaver (1954) stated that the encapsulated larvae embedded in muscle fibers are present in the slaughtered carcass and may remain viable in fresh pork under normal storage conditions. There are no grossly visible indications of manifestation nor any practical method of determining their presence, thus home economists have recommended that pork be cooked to the well-done (185°F) stage to insure safety from trichinosis.

The Meat Inspection Division (U. S. Dept. Agr., 1960) reported that a temperature of 137°F was sufficient to destroy the organism. The report emphasized that innermost portions of the meat must reach this temperature to assure destruction. Meat frozen and stored for 20, 10 and 6 days at 5, -10 and -20°F, respectively, in packages less than 6 in. in depth or for 30, 20 and 12 days at 5, -10 and -20°F, respectively, for products in layers or containers of 6-27 in. thickness was determined free of viable trichinae by the U.S.D.A. Other approved methods of destruction include processing by recommended schedules of irradiation, salting, drying and smoking.

Quality of Cooked Pork

Backfat thickness. Cooking and defrosting drip losses and flavor of pork loin chops from 75 carcasses (Saffle and Bratzler, 1959) increased significantly with increase in backfat thickness (1-1.3 in., 1.3-1.6 in., 1.6-1.9 in.). Total cooking losses were unrelated to backfat thickness. Murphy and Carlin (1961) also reported that drip losses and separable fat (48 carcasses) of raw and cooked rib or loin chops increased with increasing backfat thickness from 1.0-2.3 in. Tenderness, juiciness, flavor and total cooking losses of braised chops were not affected by amount of backfat. However, shear force values on raw longissimus dorsi muscle showed slight increase in tenderness as backfat increased.

With pork loin roasts, drip losses and separable fat increased, but flavor, tenderness and juiciness were not affected by increase in backfat thickness (Onate and Carlin, 1961). Total cooking losses of loin roasts also increased with increased fat cover noted Weir (1960). Rate of heat penetration was found by Batcher et al. (1962) to be slower for roasts with more fat cover, whereas Weir (1960) reported that temperature increased independently of fat thickness except for roasts with very little fat; these cooked faster than those with more fat cover.

Backfat thickness and degree of marbling do not appear related. Murphy and Carlin (1961) reported a tendency for higher marbling scores in loins with more backfat but high scores were not limited to those loins. Backfat thickness had little influence on marbling or quality of fresh loin cuts (Batcher et al., 1962; Onate and Carlin, 1961).

Marbling. Results do not agree on relationships of marbling and palatability characteristics of pork. Pork loin chops (1/2 in.) with high marbling scores had higher tenderness and juiciness scores when braised by Murphy and Carlin (1961) than did those with smaller amounts of marbling. Kauffman et al. (1964b) also found intramuscular fat of 439 pork loins positively related to flavor, tenderness and juiciness and inversely related to cooking losses. Loin chops were baked to 165°F in a 325°F oven. However, palatability scores for broiled 3/4-in. rib chops showed no significant relationships for juiciness or flavor and marbling (Judge et al., 1960). Marbled loins were higher in ether extract and lower in moisture than were longissimus dorsi lacking marbling.

The following studies have been reported on palatability and marbling in pork loin roasts. Juiciness increased with marbling (Onate and Carlin, 1961; Hiner et al., 1964) as did tenderness (Batcher and Dawson, 1960). However, Weir (1960) and Batcher et al. (1962) found tenderness and juiciness unrelated to marbling, although Batcher et al. (1962) found more intramuscular fat and less moisture in uncooked cuts with high rather than less marbling. Moisture also was found to be inversely related to marbling (Whitehair et al., 1964a).

Variation within the loin. Anterior and posterior parts of the loin were noted by Weir (1953) to be more tender than center sections. Variation between animals and with position in the loin was reported by Mackey and Oliver (1954) in a study on 1-in. pork chops from 3 pairs of loins cooked in covered pans at approximately 250°F to 185°F. Drip and total cooking losses increased from rib through loin in 2 of the 3 carcasses; press fluid decreased in 1 carcass. Weight losses during storage, cooking time, evaporative cooking losses and shear values varied randomly with position. Working on pork loin roasts, Pengilly (1965) indicated that juiciness and total moisture of the cooked center loin section were significantly higher than those of anterior or posterior sections. Volume of exuded fluid was significantly greater and overall palatability acceptance significantly less for the posterior than for anterior sections.

Cross-sectional variation in tenderness of pork longissimus dorsi was studied by Alsmeyer et al. (1965) who noted lateral locations were most tender and medial, least tender. Panel scores, Warner-Bratzler shear and slice-tenderness evaluator values were determined. Conversely, Onate and Carlin (1961) found medial sections more tender than lateral or dorsal when studying roasts and Murphy and Carlin (1961) reported similar results on pork chops. No difference in tenderness values for dorsal, lateral or medial positions was noted by Pengilly (1965) when working with roasts.

Cooking method. Broiled pork chops (3/4 in. to 185°F) were more tender and juicy than braised chops (Pohl, 1959). Opposite results were obtained by Cline and McLachlan (1940). They cooked 1-in. chops to internal temperatures of 183°F by braising with and without water and by broiling at constant temperatures of 300 and 350°F. Broiled chops at either temperature showed greater cooking losses, required longer time to cook and scored lower in palatability than either type of braised chops. Braising chops without water proved the best cooking method in that study. Broiling pork chops (3/4, 1, 1 1/2 in.) to internal temperatures of 185°F required less time than braising but caused greater cooking losses (Weir et al., 1962). However, broiled 3/4-in. chops were juicier and tenderer but less flavorful than when braised. Roasted pork was preferred (flavor, tenderness, juiciness) to either broiled or braised chops (Pohl, 1959).

Chop thickness. One and 1 1/2-in. chops were less juicy than 3/4-in. chops when broiled to 185°F (Weir et al., 1962). The flavor of thicker cuts was more fully developed, however. Cooking losses increased and yield decreased with increased thickness. These chops were broiled 4 in. from heat source at air temperatures of 275, 350 and 425°F and were not turned during cooking. For baked chops, Goertz (1964) indicated that cooking time and cooking losses usually were less for thinner (1/2, 3/4 in.) than for thicker chops (1, 1 1/2 in.). These were prepared by browning 1 min per side at 420°F, baking at 350°F and turning at 140°F internal temperature. Desirability of flavor, doneness, tenderness and appearance of chops was not greatly affected by thickness.

End point and oven temperature. The initial effect of heat on pork as reported by Tuomy and Lechnir (1964) was a toughening that increased as temperature was increased. Little change in tenderness with time was noted at 140°F, but at 150°F and above there was appreciable tenderizing with time. Pork never became as tough as beef and the total range of tenderness was less for pork. After 4 hr at 210°F or 5 hr at 200°F, the pork muscle fell apart due to disintegration of connective tissue and could not be tested.

End point temperature. As end point temperature of broiled rib chops increased (Goertz, 1964), juiciness decreased and cooking time increased. For 1/2 and 1-in. chops, cooking losses were higher as end point increased. Flavor for 1/2-in. chops broiled to 185°F was higher than for those broiled to 170°F. In 1-in. chops, flavor was similar for 170 and 185°F and higher than for 155°F. When baking, palatability characteristics were not greatly affected by end point temperatures but, generally, chops were darker brown and less juicy when baked to 185°F than to 170°F. Cooking time and cooking losses were less for chops baked or braised to 155 than to 170°F or cooked to 170 than to 185°F. Braised chop juiciness decreased with increasing end point temperature. Tenderness scores of 3/4 in. chops were lower when braised to 185°F plus 15 min than to 170°F and lower for 1 1/2-in. chops braised to 170°F or 185°F plus 15 min than to 155°F.

The tenderness of pork loin roasts from 14 carcasses studied by Webb et al. (1961) decreased as internal temperature was increased from 150 to 167 to 185°F and slightly increased as time was prolonged (maintained at 150°F for 1 hr). Flavor scores increased as internal temperature increased.

Cooking time and drip, evaporation and total losses during cooking increased as internal temperatures and cooking time were increased. Juiciness scores were significantly higher for roasts cooked to 150°F than for those cooked to 185°F. Weir et al. (1963) reported roasting to 170°F gave greater cooked meat yields and higher juiciness scores but lower odor scores when compared to pork roasted to 185°F. Pengilly (1965) found no marked organoleptic preference for any one end point temperature (149, 167, 185°F) but 149 or 167°F resulted in significantly less cooking losses and cooking times than roasting to 185°F. Juiciness, total moisture and water holding capacity decreased significantly with each 18°F rise in end point temperature. Exuded fluid was significantly less at 185°F whereas pH and press fluid were not affected significantly by temperature. End points of 167 and 185°F produced better flavor than 149°F but the difference was not significant. Overall acceptability decreased slightly as end point increased.

Oven temperature. Broiling temperatures (275, 350 and 425°F) did not greatly affect palatability of pork loin chops (Weir et al., 1962), but higher broiling temperatures increased evaporation losses and reduced yield of cooked meat. Child (1938) reported 350°F preferable for broiling pork as did the National Livestock and Meat Board in 1942.

Pork roasted at 350°F was more tender than at 300, 325 or 400°F (Weir et al., 1963). Juiciness was unaffected by variation in oven temperature. Previous work by Weir (1960) showed roasting at 350°F gave more tender pork than at 300°F and slightly more tender than at 400°F. Pork loin roasts under 3 lb in weight were more flavorful when cooked at 350°F than at other temperatures but tenderness and juiciness were similar at 300 and 350°F.

Smoking of Meat

Smoked food has a long history. The first meat cooked was probably broiled over an open fire. Centuries later, peasants in the Middle Ages prepared pork for Easter feasts by burying fresh pork legs along the seashore in fall and winter. After the meat was cured by action of salt water, it was dug up and smoked over wood fires (Am. Meat Inst. Foundation, 1960). In the United States, a small percentage of meat is smoked commercially; these are usually hams, bacon and other pork and fish products. Charcoal broiling with its characteristic smokiness currently is gaining popularity with the American family. In some countries of the world, such as those of middle and northern Europe, 40% of the meat and 15% of the fish is smoked (Tilgner, 1959). Much work has been done in Scandinavia, Russia, Poland and Czechoslavakia on burning and smoking reactions.

Smoking and burning reactions. The generation of wood smoke entails an extremely complex series of chemical reactions. Wood is of heterogeneous and partially unknown composition. Hardwood is 40-60% cellulose, 20-30% hemicellulose and 20-30% lignin (Feit and Hoff, 1963). The reactions of decomposition in the presence of heat are many. According to Wilson (1961), at temperatures of 302 to 482^{o}F, gas and volatile acids are released. Above 500^{o}F the cellulose and hemicellulose decompose rapidly to form acids and pyroligneous liquors. Above 500^{o}F the lignin yields phenolic compounds and tars. About 220 compounds have been found in the liquid products from the destructive distillation of woods. Relatively few have been identified.

Carcinogenic substances in smoke. Benzpyrene, a carcinogenic substance, is present in smoke of wood fires just as it is in cigarette smoke.

In commercial processing, Muller (1959) indicated that 3,4-benzpyrene and other carcinogenic substances were produced only at high temperatures (above 522°F). He found that neither oxidation of smoke components nor use of high frequency electric fields lowered the amount of carcinogenic substances. Electric filters placed directly in the smoke generator were of some help.

Lapshin (1959) reported during an international conference on the technology of smoked food in Gdanst, Poland, that the concentration of 3,4-benzpyrene in smoked fish varied according to the process used but was between 7 and 50 µg per kg of fish. Concentration on the surface was about 10 times that of the interior. He found use of a smoke dip instead of conventional smoking reduced 3,4-benzpyrene to 1% of above indicated amounts. Hollenbeck and Marinelli (1963) stressed that benzpyrene could be removed from liquid smoke solutions by absorption-filtration procedures but carcinogenic substances were found in some smoke solutions in concentrations up to 3 ppm. Genest (1964) found no smoked food examined contained as much as 0.05 ppm 3,4-benzpyrene.

A greater concentration of carcinogenic compounds was found by Lijinsky and Shubik (1964) than by some other workers. They charcoal-broiled 15 beef steaks, removed the outer surfaces, extracted the polynuclear material and separated the fractions by column and paper chromotography. The amount of benzo (a) pyrene was 9 µg per steak, the same amount present in 600 cigarettes. The compound was formed from melted fat dripping on the coals in amounts averaging 8 µg per kg.

A study of the smoked meat and fish in Iceland was conducted by Dungal (1959) who noted that smoked meat and fish are an important part of the native diets. Lamb, mutton and fish are smoked many months. Cancer of the stomach is common in Iceland, amounting to half of all cancers in the male population. Dungal fed rats a diet consisting exclusively of this smoked meat and all rats died within a short time. Later 20 g smoked meat mixed with standard diet was fed to 4 rats. Two of the 4 died after 18 months. One had cancer of the liver with peritoneal metastases; the other, a malignant tumor of the lung. Thus excessively smoked meat of Icelanders' diets could be a contributing factor to stomach cancer, but Dungal noted that the small amounts in American food probably caused no danger.

Flavor and aroma constituents of smoke. The 4 fractions of smoke are non-condensable gases, condensable vapors, dispersed bases and tars (Feit and Hoff, 1963). Wilson (1961) found 95% of the smoke deposit on meat to be from the vapor phase. The acids, phenols and carbonyls of this phase contributed to smoke odor and flavor, whereas other vaporous components caused smoked color and surface denaturation. The principal reaction during smoking (Foster and Simpson, 1961) involves vaporous components dissolving in the surface and interstitial moisture of the food. Smoke deposit on wet surfaces is about 10-20 times as great as on dry surfaces (Wilson, 1961).

The following substances were observed in the vaporous phase of hardwood smoke by Hollenbeck and Marinelli (1963): formic, acetic, propionic, vanillic and syringic acids, dimethoxyphenol, methyl glyoxal, furfural, acetaldehyde, acetone, ethanol and 3,4-benzpyrene. Hoff and Feit (1963) recognized acetaldehyde, propionaldehyde, methacrolein, n-butyraldehyde, crotonaldehyde, acetone, ethyl methyl ketone, diacetyl, methanol, ethanol, methyl formate, methyl acetate, benzene, t-butyl methyl ether and 12 other hydrocarbons and ethers in trace amounts. The relative proportions were greatly affected by conditions in the smoke generator. Substances produced in smoke (Hollenbeck and Marinelli, 1963) varied with type of wood, amount of air, temperature of pyrolysis, condensation and polymerization effects and additional reactions of esterification, condensation, oxidation and polymerization in the solutions tested.

Charcoal. There are presently about 50 charcoal briquet manufacturers in the United States, producing 300,000 tons of briquets annually (Kansas State University Extension Service, 1964). To make a good wood charcoal, dried hardwoods are cut into chunks, preheated to drive off sulfur, then processed in an air-tight retort at 900°F to accomplish carbonization. This lump charcoal is then pulverized, cornstarch added as adhesive and the mixture compressed. Dean and Rust (1961) reported 1 lb charcoal can be made from 6 lb hardwood. Kansas State University Extension specialists (1964) explained that 100% hardwood charcoal should be used for charcoal broiling. It is reactive, easy to light and comes to temperature quickly. It is lighter in weight for given volume than other charcoals and has an ash content of 4-4.5%. Softwood charcoal and carbonization-complete-kiln charcoal are acceptable. Charcoal made with lignite, West Virginia coal or coal mixed with wood flour or sawdust should not be used. Coal has 10-12% ash and lignite, 16-18%. Some briquets have been salted with ground limestone to give the product more weight and should not be used.

EXPERIMENTAL PROCEDURE

The effects of quality, thickness and end point temperature on charcoal-broiled pork rib chop acceptability were studied.

Selection of Samples

Ten paired pork loin sections were purchased from Maurer-Neuer, Inc., of Arkansas City, Kansas, on October 30, 1964. No attempt was made to choose carcasses of known breed, sex, nutritional record or environmental background. Animals had been slaughtered October 29 and carcasses hung in a chilling room at 35°F. After preliminary selection for uniformity, trimmed loins were grouped into 2 quality lots, low (1) and average (3) by Dr. D. H. Kropf, Department of Animal Husbandry, Kansas State University. The criterion was visible marbling of the longissimus dorsi at the anterior end and of the gluteus medius at the posterior end (Whitehair _et_ _al_., 1964a). Loins were refrigerated and shipped to Manhattan, Kansas, November 4. Final selection of five pairs of each quality was made before loins were broken into sections.

Loins were broken into shoulder, rib and center loin sections November 6, sharp frozen and stored at 0°F in a walk-in circulating-air freezer. Rib sections included the entire loin between the 8th and 14th ribs. Frozen rib sections were cut November 9, according to a previously randomized statistical schedule into chops 3/4 and 1 1/4-in. thick. Four chops were packaged single layer in heavy duty aluminum foil (No. .0015) and stored at 0°F.

Statistical Design and Analyses

A split-plot design was used for cutting, cooking and evaluating pork rib chops. A half rib was a "main plot" in the design and the split was on the 4 temperature-thickness treatments (Table 1). Chops were cut from

Table 1. Split-plot design for cutting, cooking and evaluating pork rib chops.[1]

Animal number	Animal quality	Anterior portion	Posterior portion
1	Low	d c a b	b d c a
2	Average	d b a c	b d c a
3	Low	c d b a	c d b a
4	Average	c b a d	b c d a
5	Low	d c b a	c a d b
6	Average	a c d b	a b c d
7	Low	a c b d	d c a b
8	Average	a c d b	b c a d
9	Low	c d b a	d c b a
10	Average	d a b c	c b a d

[1]a 3/4-in. chop, 160°F

b 1 1/4-in. chop, 160°F

c 3/4-in. chop, 175°F

d 1 1/4-in. chop, 175°F

the rib section in order indicated by the schedule. There were 4 treatments resulting from a combination of 2 temperatures with 2 thicknesses of chop. Two qualities of carcass were used. Each rib section furnished chops for a complete block of 4 treatments in the anterior half (both right and left sides) and a complete block in the posterior half. Twenty cooking periods were used. Loins of different qualities were cooked during alternating periods.

Analyses of variance were determined for subjective and objective evaluations and least significant differences run when F values were significant. For quality and animal analyses, halves within animal error (10 D.F.) was used for calculation of F values. For all other sources of variance and their interactions, a 30 D.F. error was used. Correlation coefficients were determined with thickness and temperature grouped within a quality for selected factors.

Cooking Method

Two chops were cooked per variable per period. Prior to broiling, foil-wrapped chops were defrosted in a refrigerator (39°F) for 36 hr. After approximately 15 hr defrosting, backfat of chops was trimmed to an even thickness (1/4 in.) to standardize procedure and to cut fat drip on the fire; 1 1/4-in. thick chops were maintained at room temperature for 1 hr at this time and then replaced in the refrigerator. Internal temperature of chops at the time of cooking was 41°F ± 3°.

KamKap's Trig-a-Matic folding brazier (Model 6310) with 24 in. firebowl and adjustable grill was used. The firebowl was lined with aluminum foil, 2-3 in. of Kingsford fire base and a single layer of Kingsford hardwood charcoal (about 4 lb or 75 briquets). The charcoal was started in pyramid formation with a Heatflo electric fire starter (No. HL-5, Underwriter's Laboratory approved, 500 watts, 120 volts). The starter was kept in the charcoal mound 10 min and then removed. The briquets were left in pyramid form 10 additional min to assure uniform burning and then spread into a single layer around the firebowl.

The temperature at the surface of the grill was maintained at $350^{\circ}F \pm 5.5^{\circ}$ for low and $\pm 4.5^{\circ}$ for average quality chops during broiling. This temperature could be maintained about 90 min after the fire was started by varying height of the grill from charcoal and removing ash coating from briquets.

For chops broiled to an internal temperature of $160^{\circ}F$, those 3/4-in. thick were turned after 6.5 min and the 1 1/4 in., after 11.5 min; for $175^{\circ}F$ chops, those 3/4-in. thick, after 8.5 min and the 1 1/4 in., after 13 min. Average temperatures at turning were 102.0, 100.2, 126,6, $113.0^{\circ}F$, respectively. Total cooking times and total cooking losses were determined.

Subjective Evaluations

Uncooked loins and cooked chops were evaluated for acceptability. Quality of uncooked loins as measured by color, firmness and marbling of uncooked loins was scored on a 5-point scale (University of Wisconsin, 1963) by a 6-member panel (Table 2). The loins were not frozen and were evaluated on freshly cut surfaces behind the last rib. Pictures of typical rib chops of low and average quality are shown in Plate I.

Palatability and appearance of cooked rib chops were evaluated by 5 experienced judges. Flavor, juiciness, tenderness and doneness were scored with 1/2-in. cores from the longissimus dorsi muscle of left loin chops (Plate II). Samples were served in coded warmed casseroles.

Table 2. Evaluation of quality in uncooked loins.[1]

Factors	Low quality	Average quality
Color scores	2.98 ± .61	3.28 ± .39
Firmness scores	1.96 ± .33	3.38 ± .30
Marbling scores	1.76 ± .32	3.08 ± .51
Longissimus dorsi area, sq cm	31.90 ± 1.90	29.20 ± 2.10
Loin weight, lb	12.92 ± 1.39	13.42 ± 1.26

[1]Scoring range, 5-1.

Degree and uniformity of brownness on both sides and amount of coagulum on side 2 of whole cooked right rib chops were scored under a Macbeth Super Skylight (daylight). Typical chops are shown in Plates III and IV. The panel evaluated palatability (Form 1, Appendix) and then appearance (Form 2, Appendix) using 7-point scales.

Objective Evaluations

Total moisture, expressible moisture, pH, color and shear values were determined on the longissimus dorsi of cooked rib chops. The right chops were used for color; left chops, for shear cores and expressible moisture (Plate II). The remaining meat of both right and left chops (surfaces removed) was ground directly into glass jars with a Kenmore electric food grinder (model 400, 82000) equipped with a fine blade.

The total moisture (%) of 5 g samples of ground cooked meat was determined with a C. W. Brabender rapid moisture tester. Duplicate samples were spread evenly into calibrated aluminum pans and dried 70 min at 250°F.

EXPLANATION OF PLATE I

a Low quality chop as evaluated by color, firmness and marbling.

b Average quality chop as evaluated by color, firmness and marbling.

PLATE I

a b

EXPLANATION OF PLATE II

Sampling of left chop for evaluations

a Palatability samples

b Shear value sample

c Expressible moisture sample

The remaining meat was ground for total moisture and pH evaluations.

PLATE II

EXPLANATION OF PLATE III

a Side 1 of 3/4-in. pork rib chop charcoal-broiled to 160°F

b Side 1 of 1 1/4-in. pork rib chop charcoal-broiled to 160°F

c Side 1 of 3/4-in. pork rib chop charcoal-broiled to 175°F

d Side 1 of 1 1/4-in. pork rib chop charcoal-broiled to 175°F

PLATE III

a b c d

EXPLANATION OF PLATE IV

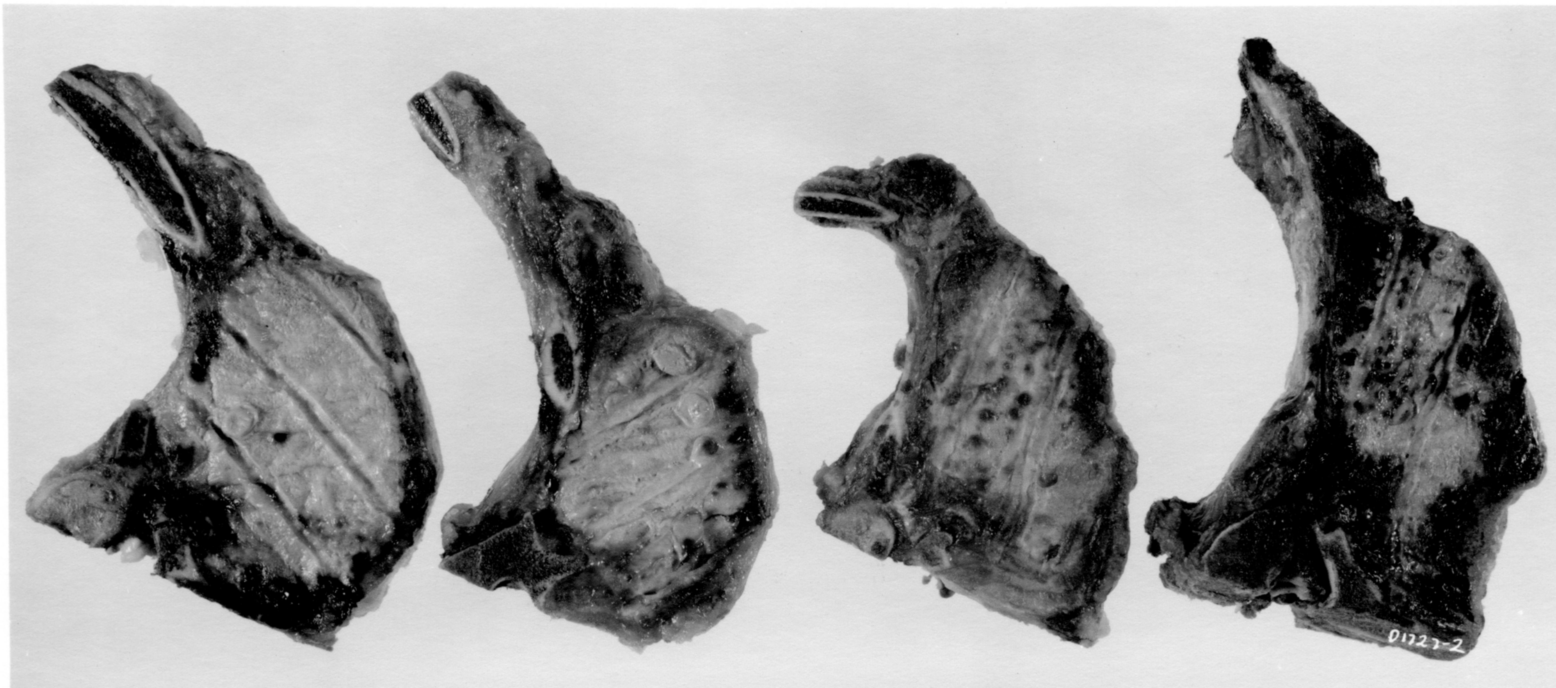
a Side 2 of 3/4-in. pork rib chop charcoal-broiled to 160°F

b Side 2 of 1 1/4-in. pork rib chop charcoal-broiled to 160°F

c Side 2 of 3/4-in. pork rib chop charcoal-broiled to 175°F

d Side 2 of 1 1/4-in. pork rib chop charcoal-broiled to 175°F

PLATE IV



a b c d

Expressible moisture (%) was determined on triplicate weighed samples (0.2-0.4 g) of cooked meat. They were placed on 3 pieces of aluminum foil (2 in. diameter) on Whatman No. 1 filter paper (6 in. × 6 in.). These were stacked alternately among 4 Plexiglas plates (6 in. × 6 in.) and the unit was placed on a Carver laboratory press and held for 3 min at 10,000 lb pressure. The meat was removed from the foil, reweighed and weight loss divided by original sample weight to determine expressible moisture (%).

The pH of ground cooked samples was determined with a Beckman expanded scale pH meter (model 76) on a slurry of 7.5 g meat and 75 ml distilled water blended in a Waring Blendor (model PB-5) at high speed for 2 min. A buffer of pH 6.86 was used to standardize the instrument. The expanded scale was used for pH readings taken at room temperature.

The color of both cooked surfaces was determined with a Gardner color difference meter. The instrument was standardized with light brown ceramic tile with an Rd (reflectance) of 37.64, +a (redness) of +6.21 and +b (yellowness) of +14.98. Thin slices (1/4 in.) of meat were placed between Plexiglas plates, pressed on a Carver laboratory press for 30 sec at no recordable pressure and color readings determined. Readings were made 30-45 min after chops were broiled.

Shear values of 1/2-in. cores of cooked meat, taken from near the center of the longissimus dorsi muscle (Plate II), were determined with a Warner-Bratzler shearing apparatus.

RESULTS AND DISCUSSION

Factors Related to Juiciness

Juiciness scores for 3/4 and 1 1/4-in. charcoal-broiled pork rib chops decreased as end point temperature increased from 160 to 175°F ($P < .001$) (Table 3). Total and expressible moisture also decreased with rise in end point ($P < .001$) indicating a less juicy product. Cooking losses and cooking time increased ($P < .001$) with rise in temperature, thus partially explaining the decrease in moisture and juiciness scores. These results agree with work previously reported on broiled chops and roasts. Goertz (1964) found juiciness decreased and cooking time increased as end point of broiled rib chops increased. Similar results were obtained on roasts studied by Weir _et al_. (1963), Webb _et al_. (1961) and Pengilly (1965).

Some factors were related to thickness of chop. Cooking time increased ($P < .001$) with increasing thickness (Table 3) as did total and expressible moisture ($P < .05$) of chops broiled to 175°F (Table 8, Appendix). A similar but nonsignificant trend was noted for moisture values of 160°F chops. At 160°F cooking losses increased and at 175°F losses decreased with thickness ($P < .05$). Juiciness scores and thickness were not related in this study. One and 1 1/2-in. chops studied by Weir _et al_. (1962) were less juicy than 3/4-in. chops; these were broiled to 185°F without turning. With baked chops, Goertz (1964) indicated that cooking time and cooking losses increased with thickness.

Pork muscle is extremely variable in its ability to retain natural juices. The variability results from both inherent and environmental

Table 3. Factors related to juiciness of charcoal-broiled pork rib chops.

Source of variation		Juiciness scores (7-1)	Total moisture, %	Expressible moisture, %	Cooking losses, %	Cooking time, min
Low quality						
160°F, 3/4 in.		5.6	64.8	44.9	21.5	18.9
1 1/4 in.		5.3	65.8	46.8	23.2	32.6
175°F, 3/4 in.		4.4	59.8	36.6	31.6	27.0
1 1/4 in.		4.5	62.7	40.7	29.5	40.4
Average quality						
160°F, 3/4 in.		5.8	63.5	48.5	18.4	17.8
1 1/4 in.		5.5	63.8	48.4	19.4	28.8
175°F, 3/4 in.		4.4	58.6	37.8	30.0	26.0
1 1/4 in.		4.8	61.4	42.8	27.7	37.8
	D.F.			F Values		
Qualities	1	1.34	8.20 *	2.68	6.64 *	1.53
Animals: Q	8	4.59 *	3.56 *	2.08	2.55	1.82
Halves: A	10					
Temperature	1	91.80 ***	194.45 ***	73.78 ***	166.70 ***	164.33 ***
Thickness	1	0.01	39.61 ***	7.30 *	0.01	373.27 ***
T × Q	1	0.01	0.37	0.01	4.43 *	0.12
Th × Q	1	0.79	0.69	0.00(1)	1.43	3.61
T × Th × Q	1	0.42	0.33	0.03	1.03	0.36
Trt × A: Q	24	0.83	1.30	1.25	1.05	1.19
Error	30					
Total	79					

* Significant at 5% level.
** Significant at 1% level.
*** Significant at .01% level.

factors. Often a rapid decrease to pH 5.1-5.4 within 1 1/2 hr post-mortem yields pale, soft, exudative pork (Briskey, 1963). Low quality chops (as judged by color, marbling and firmness) were significantly higher ($P < .05$) in cooking losses of 160°F chops (Table 9, Appendix) and in total moisture (Table 3) than were average quality chops. A similar but nonsignificant trend was noted for cooking losses of 175°F chops. Higher fat content of average quality meat could account for lower moisture (Batcher and Dawson, 1960). Similar results were reported by Judge et al. (1960) for broiled 3/4-in. rib chops, marbled chops were lower in moisture than unmarbled chops. Batcher et al. (1962) found less total moisture and Whitehair et al. (1964b) found less expressible moisture in highly marbled than in unmarbled pork. Weir (1960) noted little difference attributable to marbling.

Juiciness scores, expressible moisture and cooking time were not significantly related to quality. However, there was a trend for greater expressible moisture and less cooking time in average than low quality chops. The trend helps explain lower cooking losses in average quality meat. Even though juiciness was not related to quality in this study, higher juiciness scores were reported for well-marbled loin chops braised by Murphy and Carlin (1961) and baked by Kauffman et al. (1964b) than for unmarbled cuts. Juiciness was not related to marbling in roasts (Batcher et al., 1962). Difference in cooking method may help explain this variation.

Correlation coefficients run on selected factors (Table 4) showed juiciness was directly related to total and expressible moisture ($P < .001$) and inversely related to cooking losses ($P < .001$). Cooking losses were

Table 4. Correlation coefficients for selected factors related to juiciness of charcoal-broiled pork rib chops.[1]

Factors			Low quality	Average quality
Juiciness scores	with	Doneness scores	.7402 ***	.5388 ***
" "	"	Cooking losses, %	-.5130 ***	-.7049 ***
" "		Expressible moisture, %	.6687 ***	.6984 ***
" "	"	Total moisture, %	.5917 ***	.6596 ***
" "	"	Flavor scores	.2878	.0197
" "	"	pH	-.1602	.2592
Cooking time, min	"	Cooking losses, %	.4302 **	.5404 ***
" "	"	Cooking time, min/lb	.4506 **	.4978 ***
" "	"	Initial weight, g	.7086 ***	.6904 ***
Cooking losses, %	"	Expressible moisture, %	-.3896 *	-.7414 ***
" "	"	Total moisture, %	-.6239 ***	-.8587 ***
" "	"	Cooking time, min/lb	.5575 ***	.6598 ***
" "	"	pH	-.2059	-.4052 *
" "	"	Initial weight, g	.0731	.0631
Expressible moisture, %	"	pH	-.2254	.3408 *
Total moisture, %	"	pH	.2718	.4664 **

[1] = 38 D.F.

* Significant at 5% level. (r = .312)
** Significant at 1% level. (r = .408)
*** Significant at 0.1% level. (r = .496)

inversely related to total and expressible moisture. Longer cooking times caused significantly greater cooking losses, and cooking time was dependent on initial weight of chops.

In general, juiciness scores, total moisture and expressible moisture decreased and total cooking losses and cooking time increased as end point temperature increased from 160 to 175°F. Total and expressible moisture and cooking time increased with thickness from 3/4 to 1 1/4 in. but the trend was not significant for moisture values of 160°F chops. Low quality chops were higher in total moisture and cooking losses (160°F) than were average quality charcoal-broiled pork rib chops. Several objective measurements of moisture were correlated significantly with each other and with subjective juiciness scores.

Factors Related to Tenderness

Tenderness scores decreased ($P < .01$) with increase in end point temperature from 160 to 175°F for both 3/4 and 1 1/4-in. chops (Table 5). Shear values tended to increase with higher end point, but the values were not significant. The initial effect of heat on pork as reported by Tuomy and Lechnir (1964) was a toughening that increased with temperature. Work by Goertz (1964) on 3/4-in. pork chops also substantiated this idea since tenderness scores were less for chops braised to 185°F plus an additional 15 min than for those cooked to 170°F. Tenderness of pork loin roasts decreased as internal temperature was increased from 150 to 167 to 185°F (Webb _et_ _al_., 1961).

Tenderness scores also were related to thickness of chop; 1 1/4-in. were more tender than 3/4-in. rib chops ($P < .001$) for both end points.

Table 5. Factors related to tenderness and flavor of charcoal-broiled pork rib chops.[1]

Source of variation		Tenderness scores	Shear values	pH	Flavor scores	Doneness scores
Low quality						
160°F, 3/4 in.		6.0	5.9	5.75	5.7	5.9
1 1/4 in.		6.3	6.0	5.72	6.0	5.8
175°F, 3/4 in.		5.9	7.0	5.75	5.7	5.4
1 1/4 in.		6.0	6.4	5.76	5.9	5.6
Average quality						
160°F, 3/4 in.		6.2	5.0	5.84	5.6	5.9
1 1/4 in.		6.5	4.6	5.78	6.1	6.0
175°F, 3/4 in.		5.9	5.1	5.84	5.7	5.6
1 1/4 in.		6.3	4.8	5.82	6.1	5.7
	D.F.	F Values				
Qualities	1	11.32 **	30.35 **	13.30 **	2.77	2.63
Animals: Q	8	7.29 **	9.05 **	37.16 ***	3.39 *	0.87
Halves: A	10					
Temperature	1	12.42 **	1.50	5.60 *	0.12	20.95 ***
Thickness	1	16.59 ***	0.64	6.73 *	35.27 ***	0.68
T × Th	1	0.61	0.28	3.40	0.03	0.68
T × Q	1	0.39	0.34	0.00	0.74	0.03
Th × Q	1	2.71	0.23	3.87	4.63 *	0.31
T × Th × Q	1	1.77	0.45	0.20	0.03	0.57
Trt × A: Q	24	1.24	0.63	1.07	1.47	0.88
Error	30					
Total	79					

[1]Scoring range, 7-1.

* Significant at 5% level.
** Significant at 1% level.
*** Significant at 0.1% level.

Shear values were negatively related to tenderness; greater degree of significance was noted for low ($r = .4682^{**}$) than for average quality chops ($r = -.3627^{*}$). Broiled 3/4-in. chops were more tender than braised chops (Weir et al., 1962), whereas no apparent relationship was noted for thicker (1 and 1 1/2 in.) chops.

Quality influenced tenderness in that tenderness values were higher ($P < .01$) and shear values lower ($P < .001$) in average than in low quality chops. Additional marbling in the longissimus dorsi has been associated with tenderness (Weir, 1960; Whitehair et al., 1964b). Intramuscular fat was positively related to tenderness of pork chops braised by Murphy and Carlin (1961) and baked by Kauffman et al. (1964b).

Dark, dry firm muscles of high pH were more tender than those of pale, soft watery nature (Whitehair et al., 1964a). The study reported here had similar results. pH of average quality cooked pork chops was significantly higher than for low quality chops, as reported previously by Judge et al. (1960) and Sayre and Kiernat (1963) for uncooked meat. pH was higher ($P < .05$) for 3/4-in. than for 1 1/4-in. chops and for end points of 175 than for 160°F in 1 1/4-in. chops. Variation among animals within a quality affected both tenderness scores and shear values ($P < .01$).

Factors Related to Flavor

Flavor scores were higher ($P < .001$) for 1 1/4 than for 3/4-in. chops regardless of end point temperature or quality (Table 5). The flavor of thicker chops also was reported by Weir et al. (1962) to be more fully developed than that of 3/4-in. chops.

There were few significant differences in flavor between qualities or temperatures, although flavor of average quality meat was preferred ($P < .05$) to that of low quality in 1 1/2-in. chops (Table 9, Appendix). Better flavor was noted in well-marbled than unmarbled chops by Weir (1960) and Kauffman et al. (1964b). There was a significant difference in flavor scores among animals within a quality in this study.

Doneness was not highly related to flavor; a low level of significance (r = .4310 **) was noted for low quality chops and none (r = .1484) for average chops. Many studies have associated highly developed flavor scores with well-done meat; however, desirability of doneness scores were higher for meat cooked to 160 than to 175°F in the study reported here. Goertz (1964) found desirability of flavor and doneness not greatly affected by thickness, but flavor scores were higher for 1/2-in. chops broiled to 185 than to 170°F. Flavor scores also increased with internal temperature in roasts studied by Webb et al. (1961).

Doneness was not significantly related to quality or thickness of chop, although there was a trend for higher doneness scores in average than low quality meat (Table 5). Doneness scores were positively related to juiciness scores (r = .7402 *** for low; r = .5388 *** for average quality), but were not related to tenderness (r = .1920 for low; r = .2477 for average quality).

Generally, flavor scores were higher for 1 1/4-in. than for 3/4-in. chops and higher in 1 1/4-in. chops for average than low quality meat. Flavor was unrelated to temperature. Also flavor was not generally correlated with doneness. Doneness scores based on desirability were higher for meat cooked to 160 than to 175°F and were significantly related to juiciness scores.

Factors Related to Appearance

Degree of brownness scores as well as redness and yellowness values of chops generally ($P < .001$) increased with increasing end point temperature and thickness (Table 6). However, for yellowness values, those for 3/4-in. 160°F chops were lower than for 1 1/4-in. 160°F or 175°F chops (Table 8, Appendix). Uniformity of brownness and reflectance decreased ($P < .001$) with higher end point and thickness of charcoal-broiled pork rib chops (Table 6). Amount of coagulum (scoring range 1-7) of cooked chops increased with increased end point temperature and thickness. Coagulum was negatively correlated with cooking time, cooking losses and degree of brownness (Table 7). Reflectance values increased with increase in coagulum indicating coagulum reflected light and decreased color intensity of chops.

Quality, in general, did not significantly affect color or appearance scores, although variation was noted among animals of a similar quality (Table 6). Color was unaffected by marbling (Whitehair _et_ _al_., 1964b); however a relationship between color development and level of reducing sugar in pork was noted by Pearson _et_ _al_. (1962). pH was inversely related to degree of brownness and directly related to reflectance values, indicating chops of low pH (low quality) browned more than those of high pH (average quality). This could be explained by Pearson's relationship between color and reducing sugar.

Degree of brownness evaluated subjectively was highly related ($P < .001$) to 2 objective color determinations with the Gardner color difference meter (Table 7). Degree of brownness was positively related to redness and negatively related to reflectance. No relationship was noted between degree

Table 6. Factors related to appearance of charcoal-broiled pork rib chops.[1]

Source of variation	D.F.	Appearance: Brownness, Degree	Appearance: Brownness, Uniformity	Appearance: Coagulum	Color: Reflectance	Color: Redness	Color: Yellowness
Low quality							
160°F, 3/4 in.		3.4	5.2	4.7	29.5	+0.7	+11.1
1 1/4 in.		4.8	4.0	3.3	25.2	+2.8	+12.7
175°F, 3/4 in.		4.7	4.3	3.6	23.3	+3.4	+13.2
1 1/4 in.		5.7	3.7	2.7	17.7	+4.6	+13.2
Average quality							
160°F, 3/4 in.		3.2	4.8	4.5	30.9	-0.6	+11.7
1 1/4 in.		4.8	3.9	3.5	24.3	+3.5	+14.0
175°F, 3/4 in.		4.5	4.2	3.7	26.6	+1.5	+12.7
1 1/4 in.		5.7	3.9	2.9	18.4	+5.0	+13.7
	D.F.	F Values					
Qualities	1	0.85	0.27	0.12	1.43	1.02	1.91
Animals: Q	8	20.33 ***	5.09 **	4.03 *	7.11 **	2.05	2.56
Halves: A	10						
Temperature	1	143.08 ***	18.28 ***	17.22 ***	92.00 ***	58.66 ***	8.98 **
Thickness	1	203.99 ***	42.61 ***	31.06 ***	116.92 ***	107.26 ***	19.80 ***
T × Th	1	4.07	6.63 *	0.72	0.60	2.45	7.49 *
T × Q	1	0.28	1.66	0.33	1.11	0.57	3.00
Th × Q	1	1.04	1.32	0.37	2.74	17.07 ***	2.27
T × Th × Q	1	0.01	0.00(2)	0.15	0.38	0.16	0.08
Trt × A: Q	24	1.74	1.34	0.94	3.10 **	2.04 *	1.56
Error	30						
Total	79						

[1]Average scores for sides 1 and 2.

* Significant at 5% level.
** Significant at 1% level.
*** Significant at 0.1% level.

Table 7. Correlation coefficients for selected factors related to appearance of charcoal-broiled pork rib chops.[1]

Factors			Low quality	Average quality
Appearance scores[2]				
Degree of brownness	with	Redness	.7339 ***	.8117 ***
" "	"	Reflectance	-.8529 ***	-.8936 ***
" "	"	Yellowness	.1939	.0793
" "	"	pH	-.4709 **	-.6933 ***
Coagulum,[3]	"	Brownness, degree,[3]	-.6365 ***	-.5784 ***
"	"	Brownness, uniformity,[3]	.1880	.5388 ***
"	"	Redness,[3]	-.5966 ***	-.4577 **
"	"	Reflectance,[3]	.6202 ***	.5681 ***
"	"	Yellowness,[3]	-.1542	-.0731
"	"	Cooking time, min	-.6651 ***	-.6278 ***
"	"	Cooking losses, %	-.5786 ***	-.5093 ***
"	"	Total moisture, %	.2610	.3594 *
"	"	Expressible moisture, %	.0341	.2694
"	"	Juiciness scores	.2240	.2108
Color				
Reflectance[2]	"	pH	.3704 *	.6009 ***
Reflectance[3]	"	Initial weight	-.2801	-.4514 **

1 D.F. = 38
2 Average scores for sides 1 and 2.
3 Scores for side 2.

* Significant at the 5% level (r = .312)
** Significant at the 1% level (r = .408)
*** Significant at the 0.1% level (r = .496)

of brownness and yellowness.

Thus, as temperature increased from 160 to 175°F and thickness from 3/4 to 1 1/4 in., amount of coagulum, degree of brownness, redness and yellowness usually increased. Uniformity of brownness and reflectance of cooked chops decreased as temperature and thickness increased. Quality did not affect color significantly. Chops of low pH browned more readily than those of high pH. Degree of brownness evaluated subjectively was positively related to redness and negatively related to reflectance measured objectively.

SUMMARY

The effects of quality, end point temperature and thickness on palatability and appearance of charcoal-broiled pork rib chops were studied. Average and low quality chops as measured by color, firmness and marbling of the anterior end of the loin were evaluated. Two end point temperatures (160 and 175°F) and two thicknesses of chop (3/4 and 1 1/2 in.) were used. A split-plot design for cutting, cooking and evaluating chops involved 10 replications (2 chops each) for each of 4 treatments within a quality. Meat was cooked over charcoal and temperature at the surface of the meat was maintained at 350°F.

Low quality chops were higher in cooking losses (160°F), total moisture and shear values than average quality meat. Average quality chops were more tender and had higher pH than those of low quality. Juiciness scores, expressible moisture and cooking time were not significantly related to quality. A trend was noted for greater expressible moisture and less cooking time in average than low quality meat. Flavor

scores were higher in 1 1/4-in. chops for average than low quality meat in this study, and there were significant flavor differences among animals within a quality. In general, doneness scores were higher for average than low quality chops. Quality generally was not significantly related to color or appearance scores, although variation was observed among animals of a similar quality.

As end point temperature increased from 160 to 175°F, juiciness, total and expressible moisture decreased and cooking losses and cooking time increased. These factors indicated a less juicy product with well-done meat. Tenderness decreased and shear values increased with increased end point temperature. Flavor was not significantly affected by end point temperature although desirability of doneness scores were higher for meat cooked to 160 than to 175°F. Chops gained color intensity with the higher end point as noted by increased degree of brownness scores, redness and yellowness values and decreased reflectance. However, color of chops was less uniform and amount of coagulum increased at higher rather than at lower end points.

Total and expressible moisture of 175°F chops and cooking time increased significantly with increased thickness of chop from 3/4 to 1 1/4 in. At 160°F, cooking losses increased and at 175°F losses decreased with thickness. Juiciness scores and thickness were not related. Tenderness scores were higher and shear values, lower, for 1 1/4-in. than 3/4-in. chops. Flavor scores were higher for 1 1/4-in. chops; however, doneness was unrelated to thickness. Chop color became more intense as thickness increased; evidence included higher degree of brownness scores, redness and yellowness but lower reflectance values. Less coagulum was noted in 3/4 in. than 1 1/4-in. chops.

A number of objective and subjective evaluations were highly correlated. Juiciness was directly related to total and expressible moisture and inversely related to cooking losses. Tenderness and Warner-Bratzler shear values were negatively related. As degree of brownness measured subjectively increased, redness increased and reflectance decreased as measured objectively with the Gardner color difference meter.

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APPENDIX

Explanation of Terms and Abbreviations for Appendix Tables

Treatments

a   3/4-in. chop broiled to 160°F

b   1 1/4-in. chop broiled to 160°F

c   3/4-in. chop broiled to 175°F

d   1 1/4-in. chop broiled to 175°F

A   low quality chop

B   average quality chop

Significance of F values for treatment and quality

ns	non significant		
*	significant at 5% level	r = .312	for correlation coefficients
**	significant at 1% level	r = .408	for correlation coefficients
***	significant at 0.1% level	r = .496	for correlation coefficients

LSD*   least significant difference at 5% level

SCORE CARD FOR PORK CHOPS

Form 1

Judge ______________________________ Date ____________________________

Sample Number	Tenderness		Juiciness	Flavor	Doneness
	No. chews	Score			
1					
2					
3					
4					
5					
6					

Juiciness

7. Very juicy
6. Juicy
5. Moderately juicy
4. Slightly juicy
3. Moderately dry
2. Very dry
1. Extremely dry

Flavor and Doneness

7. Very desirable
6. Desirable
5. Moderately desirable
4. Slightly desirable
3. Slightly undesirable
2. Moderately undesirable
1. Undesirable

SCORE CARD FOR WHOLE PORK CHOPS

Form 2

Judge ____________ Code ____________ Date ____________

Sample Number	Brownness: Degree 1	Brownness: Degree 2	Brownness: Uniformity 1	Brownness: Uniformity 2	Coagulum 2	Comments
1						
2						
3						
4						
5						
6						

<u>Degree of Brownness</u>

7. Dark
6. Moderately dark
5. Slightly dark
4. Neutral
3. Slightly light
2. Moderately light
1. Light

<u>Uniformity of Brownness</u>

7. Uniform
6. Moderately uniform
5. Slightly uniform
4. Neutral
3. Slightly uneven
2. Moderately uneven
1. Uneven

<u>Coagulum</u>

7. None
6. ____
5. ____
4. Moderate amount
3. ____
2. ____
1. Large amount

Table 8. Temperature and thickness interactions for factors contributing to acceptability of charcoal-broiled pork rib chops.[1]

Factors	LSD*	160°F		175°F	
		3/4 in.	1 1/4 in.	3/4 in.	1 1/4 in.
Juiciness	.30	5.68	5.42	4.41	4.69
Total moisture, %	.79	64.16	64.76	59.20	62.06
Expressible moisture, %	2.72	47.30	47.42	36.80	41.76
Total cooking losses, %	1.89	20.02	22.42	30.80	28.56
Cooking time, min/lb	5.68	65.46	65.88	95.70	83.81
Degree brownness, side 2	.39	3.62	4.97	5.46	6.09
Uniformity brownness, av. sides 1 and 2	.31	4.98	3.99	4.24	3.80
Uniformity brownness, side 2	.45	4.53	3.90	3.41	3.70
Yellowness, av. sides 1 and 2	.78	11.42	13.36	12.96	13.42
Yellowness, side 2	1.16	11.50	13.32	13.40	12.90

[1]See page 54 for explanation of terms.

Table 9. Various interactions for factors contributing to acceptability of charcoal-broiled pork rib chops.[1]

Factors	LSD*	3/4 in. A	3/4 in. B	1 1/4 in. A	1 1/4 in. B
Thickness × quality interactions:					
Flavor	.17	5.70	5.66	5.92	6.14
Initial weight, g	3.34	126.98	128.82	215.38	210.90
Uniformity, brownness side 1	.28	5.52	4.97	3.96	4.02
Reflectance, side 1	2.15	27.74	28.93	22.12	19.76
Redness, av. 1 and 2	.76	2.06	0.43	3.70	4.27
Redness, side 1	1.22	1.47	0.80	3.50	5.30
		160°F A	160°F B	175°F A	175°F B
Temperature × quality interactions:					
Total cooking losses, %	1.89	23.44	19.00	30.52	28.85

[1]See page 54 for explanation of terms.

Table 10. Factors related to initial weight (g) and cooking time (min/lb) for charcoal-broiled pork rib chops.[1]

Source of variation		Initial weight, g	Cooking time, min/lb
Low quality			
160°F, 3/4 in.		128	68.2
1 1/4 in.		215	69.1
175°F, 3/4 in.		126	97.8
1 1/4 in.		215	86.0
Average quality			
160°F, 3/4 in.		130	62.2
1 1/4 in.		211	62.0
175°F, 3/4 in.		128	93.4
1 1/4 in.		210	81.8
	D.F.	F Values	
Qualities	1	0.35	1.26
Animals:Q	8	25.37 ***	1.68
Halves:A	10		
Temperature	1	0.85	150.02 ***
Thickness	1	5438.20 ***	8.50 **
T × Th	1	0.14	9.79 **
T × Q	1	0.16	0.19
Th × Q	1	7.49 *	0.02
T × Th × Q	1	0.03	0.01
Trt × A:Q	24	3.91 ***	0.86
Error	30		
Total	79		

[1]See page 54 for explanation of terms.

Table 11. Factors related to appearance of side 1 of charcoal-broiled pork rib chops.[1]

Source of variation	D.F.	Appearance: Brownness Degree	Appearance: Brownness Uniformity	Color: Reflectance	Color: Redness	Color: Yellowness
Low quality						
160°F, 3/4 in.		2.9	5.7	28.1	+1.2	+11.1
1 1/4 in.		4.3	4.2	24.8	+2.4	+12.4
175°F, 3/4 in.		3.5	5.4	27.4	+1.6	+12.6
1 1/4 in.		5.1	3.8	19.4	+4.6	+13.5
Average quality						
160°F, 3/4 in.		3.2	5.3	30.3	0.0	+11.7
1 1/4 in.		5.0	4.0	21.3	+4.8	+14.5
175°F, 3/4 in.		4.0	4.6	27.6	+1.6	+12.4
1 1/4 in.		5.5	4.0	18.2	+5.8	+14.3
	D.F.	**F Values**				
Qualities	1	6.69 *	1.04	0.29	1.24	3.19
Animals:Q	8	10.50 ***	2.54	6.01 **	2.49	2.99
Halves:A	10					
Temperature	1	45.94 ***	12.64 **	15.97 ***	8.28 **	6.78 *
Thickness	1	239.49 ***	164.27 ***	98.79 ***	59.27 ***	28.48 ***

Table 11. (concl.)

Source of variation		Appearance		Color		
		Brownness				
		Degree	Uniformity	Relectance	Redness	Yellowness
T × Th	1	0.01	2.60	2.82	0.62	1.11
T × Q	1	0.00(1)	0.00(1)	0.02	0.00	2.63
Th × Q	1	0.26	9.90 **	5.68 *	8.48 **	3.77
T × Th × Q	1	1.79	4.08	2.05	2.31	0.18
Trt × A:Q	24	1.79	2.51 **	2.16 *	0.98	2.05 *
Error	30					
Total	79					

[1]See page 54 for explanation of terms.

Table 12. Factors related to appearance of side 2 of charcoal-broiled pork rib chops.[1]

Source of variation		Appearance: Brownness		Color		
		Degree	Uniformity	Reflectance	Redness	Yellowness
Low quality						
160°F, 3/4 in.		3.9	4.6	30.9	-0.5	+11.2
1 1/4 in.		5.3	3.9	23.4	+3.2	+13.2
175°F, 3/4 in.		6.0	3.2	19.2	+5.1	+13.8
1 1/4 in.		6.3	3.7	15.8	+4.3	+12.8
Average quality						
160°F, 3/4 in.		3.3	4.4	31.5	-1.3	+11.8
1 1/4 in.		4.7	3.9	27.3	+1.4	+13.5
175°F, 3/4 in.		4.9	3.6	25.6	+1.4	+13.0
1 1/4 in.		5.8	3.7	18.5	+4.1	+13.0
	D.F.	F Values				
Qualities	1	9.18 *	0.17	4.67	5.43 *	0.05
Animals:Q	8	7.11 **	9.22 ***	6.12 **	2.48	0.79
Halves:A	10					
Temperature	1	116.97 ***	18.07 ***	94.52 ***	45.64 ***	3.44
Thickness	1	52.69 ***	1.24	40.35 ***	21.62 ***	2.70

Table 12. (concl.)

Source of variation		Appearance: Brownness		Color		
		Degree	Uniformity	Reflectance	Redness	Yellowness
T × Th	1	6.78 *	8.94 **	0.11	6.07 *	8.34 **
T × Q	1	0.49	1.80	1.87	0.78	0.83
Th × Q	1	0.91	0.14	0.02	1.67	0.16
T × Th × Q	1	1.29	0.73	3.95	7.62 **	0.72
Trt × A:Q	24	1.53	0.96	2.86 **	1.69	0.81
Error	30					
Total	79					

[1]See page 54 for explanation of terms.

Table 13. Correlation coefficients for selected factors related to tenderness and flavor of charcoal-broiled pork rib chops.[1]

Factors		Low quality	Average quality
Tenderness scores with	Shear values	-.4682 **	-.3627 *
" " "	pH	-.5177 ***	-.3222 *
" " "	Doneness scores	.1921	.2478
Flavor scores with	Doneness scores	.4310 **	.1484
" " "	pH	-.1371	-.0697

[1]See page 54 for explanation of terms.

Table 14. Initial weight (g) of uncooked pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	133	236	130	220	132	212	130	212
	122	219	122	222	120	220	127	212
	133	226	136	232	124	198	114	188
	128	220	140	216	108	190	106	193
	151	254	146	259	146	211	136	214
	142	232	138	231	134	206	126	223
	112	177	110	184	124	188	126	192
	114	186	114	188	120	190	116	190
	120	200	114	199	142	250	148	242
	120	204	114	202	149	249	149	238
Mean	128	215	126	215	130	211	128	210

[1]See page 54 for explanation of terms.

Table 15. Juiciness scores of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	5.8	6.0	4.2	5.0	5.0	4.5	4.2	4.5
	4.8	5.8	4.6	4.8	5.4	5.2	4.6	4.4
	5.8	5.2	3.2	3.6	6.6	5.6	4.8	5.4
	5.6	4.6	4.8	3.4	---	5.4	3.4	5.2
	6.4	6.2	5.0	5.2	6.8	6.2	4.8	6.0
	5.8	5.4	5.2	5.4	5.8	6.0	5.0	5.0
	5.6	5.0	4.6	4.6	6.4	5.8	4.0	5.0
	5.6	5.0	4.4	4.2	5.4	5.6	4.6	4.0
	5.5	5.2	3.8	4.8	5.0	5.0	5.0	4.5
	5.4	5.0	4.4	4.4	5.6	5.6	3.6	4.4
Mean	5.6	5.3	4.4	4.5	5.8	5.5	4.4	4.8

[1]See page 54 for explanation of terms.

Table 16. Total moisture (%) of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	64.4	67.5	61.0	62.3	62.1	60.5	58.7	58.7
	64.7	66.8	59.9	65.9	61.8	64.7	57.1	60.8
	63.8	64.2	58.5	58.9	64.6	66.6	60.0	63.6
	66.1	63.7	58.0	61.7	67.8	64.9	61.3	66.5
	65.6	64.4	59.9	62.7	62.7	66.1	58.3	62.6
	63.3	64.8	58.8	62.5	63.3	67.6	61.2	62.6
	64.6	65.1	59.4	64.0	64.9	62.4	56.6	60.0
	64.2	65.1	59.5	63.3	63.9	62.9	58.7	59.8
	64.9	67.4	59.8	62.5	59.4	58.1	56.5	57.7
	66.2	68.6	63.3	63.6	64.9	63.7	57.5	61.5
Mean	64.8	65.8	59.8	62.7	63.5	63.8	58.6	61.4

[1] See page 54 for explanation of terms.

Table 17. Expressible moisture index (%) of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	48.1	52.7	37.6	46.0	47.9	50.4	33.1	37.9
	41.3	53.0	36.0	51.4	46.6	48.2	41.7	45.3
	50.4	51.6	31.6	37.5	59.5	47.5	36.8	48.9
	38.0	50.7	45.2	37.1	51.4	51.8	39.0	44.3
	45.8	50.2	40.3	44.4	51.7	54.0	35.1	51.4
	45.2	43.9	37.4	45.8	44.7	51.6	39.5	48.0
	41.3	42.4	44.0	46.4	46.3	47.3	39.0	39.6
	48.0	41.1	30.8	31.5	50.1	43.8	42.2	37.4
	45.1	35.9	20.7	29.0	45.3	42.5	32.3	37.3
	46.2	47.0	42.0	37.6	41.4	47.2	39.0	38.4
Mean	44.9	46.8	36.6	40.7	48.5	48.4	37.8	42.8

Table 18. Cooking loss (%) of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	18.0	19.5	29.6	25.4	23.0	21.4	31.6	30.0
	24.6	21.2	35.2	28.0	20.8	20.6	35.1	29.0
	24.0	22.8	33.3	32.2	10.8	14.2	24.6	24.6
	18.8	26.3	31.6	32.4	10.8	17.2	26.6	16.6
	17.4	24.4	28.5	29.4	16.6	16.4	27.4	31.5
	24.0	28.7	35.8	30.9	19.9	14.7	26.1	27.4
	21.1	23.7	29.9	28.7	17.7	22.2	31.0	28.4
	28.0	27.4	35.4	31.6	18.0	19.2	29.7	29.0
	20.0	18.5	31.4	26.8	23.8	25.6	32.8	31.3
	19.2	19.8	25.1	29.2	23.1	22.4	35.4	28.9
Mean	21.5	23.2	31.6	29.5	18.4	19.4	30.0	27.7

[1]See page 54 for explanation of terms.

Table 19. Total cooking time (min) of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	15.75	26.00	22.00	33.25	16.75	26.00	19.50	34.25
	22.00	29.25	31.00	42.50	22.25	26.25	34.25	40.25
	14.00	22.75	21.75	31.75	13.00	25.00	20.00	30.25
	17.75	39.75	28.00	41.50	12.75	26.50	25.00	28.00
	18.50	39.75	26.00	48.00	18.50	27.75	26.00	35.00
	20.75	43.00	34.00	44.00	20.50	27.75	25.75	45.00
	19.00	32.50	28.00	41.50	17.50	32.00	29.75	38.25
	25.00	33.25	29.50	40.50	21.00	31.00	28.75	45.00
	17.75	30.00	23.50	43.00	18.75	34.00	27.25	42.50
	18.25	29.25	26.00	38.25	17.50	32.25	24.00	38.75
Mean	18.88	32.55	26.98	40.42	17.85	28.85	26.02	37.78

[1]See page 54 for explanation of terms.

Table 20. Cooking time (min/lb) of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	53.8	49.9	76.9	68.6	57.4	51.1	67.2	73.0
	82.5	60.8	115.4	87.2	84.4	54.0	122.9	86.2
	47.8	45.8	72.8	61.4	47.5	57.6	79.6	73.4
	63.0	81.7	90.6	88.0	53.9	63.9	107.5	65.9
	55.2	71.6	81.0	84.4	57.3	59.7	86.7	76.0
	66.4	83.8	111.6	86.4	69.6	61.1	92.5	91.6
	77.4	83.4	115.6	102.2	64.0	77.1	107.9	90.6
	99.7	81.1	117.0	98.0	79.4	74.8	112.7	107.8
	67.2	68.2	93.6	98.2	55.2	61.4	83.8	79.5
	69.4	65.1	104.0	86.0	53.1	59.0	73.7	73.9
Mean	68.2	69.1	97.8	86.0	62.2	62.0	93.4	81.8

[1]See page 54 for explanation of terms.

Table 21. Tenderness scores of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	6.2	6.6	6.0	5.6	6.5	7.0	6.2	6.0
	5.6	6.2	6.4	6.0	6.2	6.6	6.8	6.8
	6.6	6.2	5.8	6.0	6.4	6.0	6.2	6.6
	6.8	6.6	6.0	6.4	---	6.4	5.8	6.0
	6.2	6.6	6.0	6.2	6.0	6.6	5.8	5.8
	6.2	6.6	6.4	6.2	5.8	6.0	5.4	6.2
	5.4	6.0	5.2	6.0	6.2	7.0	5.2	6.4
	6.0	6.0	6.0	5.8	5.8	6.6	5.6	6.4
	5.5	6.0	5.8	5.8	6.5	6.5	6.2	6.2
	5.4	6.0	5.8	5.6	6.4	6.6	5.8	6.6
Mean	6.0	6.3	5.9	6.0	6.2	6.5	5.9	6.3

[1]See page 54 for explanation of terms.

Table 22. Shear force values (lb) for 1/2 in. cores of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	5.2	5.4	6.2	7.0	6.3	4.4	4.6	5.6
	7.3	4.4	9.8	3.8	4.8	4.0	4.3	4.0
	4.1	4.4	6.9	6.3	3.5	3.5	5.7	5.3
	4.5	5.1	4.8	5.0	4.9	4.2	5.7	3.9
	4.7	4.0	5.1	5.5	7.2	6.5	5.8	5.1
	5.6	5.8	4.7	5.0	5.5	7.7	6.0	6.8
	6.0	4.7	6.0	7.2	4.7	4.9	7.3	5.7
	5.5	8.0	7.0	7.2	5.0	3.7	3.6	4.3
	5.9	9.7	9.5	9.4	2.9	2.5	3.4	2.8
	10.6	8.2	10.1	7.2	4.7	4.1	4.5	4.2
Mean	5.9	6.0	7.0	6.4	5.0	4.6	5.1	4.8

[1]See page 54 for explanation of terms.

Table 23. pH values of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	5.87	5.81	5.88	5.86	5.76	5.77	5.77	5.78
	5.81	5.83	5.85	5.82	5.83	5.71	5.83	5.76
	5.60	5.55	5.54	5.60	5.99	5.92	5.98	5.98
	5.58	5.56	5.58	5.78	6.05	5.99	6.12	6.01
	5.55	5.55	5.60	5.58	6.06	5.95	6.06	5.98
	5.58	5.54	5.56	5.54	6.06	5.98	5.96	5.96
	5.78	5.72	5.73	5.67	5.76	5.73	5.78	5.76
	5.60	5.66	5.68	5.69	5.77	5.75	5.71	5.74
	6.06	5.99	6.02	6.02	5.46	5.42	5.56	5.52
	6.06	6.03	6.07	6.09	5.62	5.62	5.66	5.67
Mean	5.75	5.72	5.75	5.76	5.84	5.78	5.84	5.82

[1]See page 54 for explanation of terms.

Table 24. Flavor scores of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	5.4	6.0	5.2	5.8	6.0	6.2	5.5	6.2
	5.8	5.8	5.4	5.8	5.0	6.0	5.6	6.2
	6.0	5.6	6.0	5.8	5.8	6.2	5.8	6.0
	5.6	5.6	5.8	5.4	---	6.2	5.4	6.0
	5.6	6.4	6.2	6.2	6.0	6.0	6.0	6.0
	6.0	6.2	6.2	6.2	5.8	6.0	5.8	5.8
	5.4	5.8	5.2	5.8	5.2	6.2	5.6	6.6
	6.0	6.4	5.4	5.2	5.8	6.0	5.6	6.2
	6.0	6.0	5.5	6.5	5.2	6.5	5.8	6.0
	5.6	5.8	5.8	6.2	5.8	6.0	5.8	6.4
Mean	5.7	6.0	5.7	5.9	5.6	6.1	5.7	6.1

[1]See page 54 for explanation of terms.

Table 25. Doneness scores of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	5.6	5.8	5.0	5.6	6.0	5.8	6.0	6.0
	5.8	5.8	5.4	6.0	5.4	6.0	5.8	5.6
	6.0	5.6	5.0	5.2	5.6	6.0	6.0	6.0
	6.4	5.6	5.6	4.8	---	6.0	4.6	5.6
	5.8	6.4	5.6	5.8	5.8	5.8	5.4	6.0
	6.0	5.4	6.0	5.8	6.2	6.0	5.8	5.6
	6.0	6.0	5.4	5.8	6.2	6.4	5.6	5.8
	6.0	5.8	5.8	5.2	6.0	6.2	5.8	5.2
	5.8	5.8	4.8	5.8	5.8	6.0	5.8	5.5
	5.8	6.0	5.8	5.8	6.4	6.0	5.0	5.6
Mean	5.9	5.8	5.4	5.6	5.9	6.0	5.6	5.7

[1]See page 54 for explanation of terms.

Table 26. Degree of brownness scores for the average of sides 1 and 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	3.4	4.4	4.3	5.2	3.7	5.4	4.1	6.0
	3.3	4.2	4.6	4.9	3.6	4.9	5.1	6.1
	3.4	4.8	4.8	6.4	2.3	3.5	3.1	4.7
	3.0	6.2	5.1	6.6	1.6	4.0	2.9	3.6
	4.5	5.9	4.8	6.2	3.4	3.4	3.2	5.3
	4.0	5.3	5.1	5.8	2.4	4.0	3.5	5.4
	3.2	5.3	5.4	5.5	2.8	5.4	5.4	5.9
	4.4	5.5	5.5	6.2	4.0	5.0	5.6	5.9
	2.0	2.5	3.8	4.6	4.4	6.3	6.0	6.9
	2.8	3.8	3.8	5.9	4.3	6.2	5.7	6.9
Mean	3.4	4.8	4.7	5.7	3.2	4.8	4.5	5.7

[1]See page 54 for explanation of terms.

Table 27. Uniformity of brownness scores for the average of sides 1 and 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	4.7	4.1	3.4	2.3	5.1	4.5	4.9	3.8
	5.5	4.4	4.5	4.3	5.2	3.7	3.8	3.2
	5.5	4.0	4.6	3.5	5.5	5.2	5.6	4.4
	6.1	2.1	3.8	4.3	6.0	4.8	5.3	5.0
	5.0	4.6	4.6	3.5	4.4	4.8	4.7	4.7
	4.8	4.5	4.6	4.0	4.9	4.9	4.5	4.5
	5.0	3.8	3.9	4.2	5.3	3.8	3.6	3.4
	4.4	3.3	3.8	2.6	4.7	3.6	3.1	3.9
	5.4	5.4	4.8	4.2	3.5	2.3	2.4	2.3
	5.2	4.2	4.7	4.3	3.4	2.7	4.1	3.7
Mean	5.2	4.0	4.3	3.7	4.8	3.9	4.2	3.9

[1]See page 54 for explanation of terms.

Table 28. Coagulum scores for side 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	3.8	3.8	3.6	3.4	4.5	4.0	4.2	3.2
	5.0	2.5	2.8	3.0	6.4	5.8	3.0	2.0
	4.2	2.8	3.6	1.8	6.6	5.2	5.4	3.4
	5.4	3.8	4.2	3.0	6.2	3.0	3.4	4.6
	5.2	2.0	3.8	2.2	4.4	2.8	3.4	2.4
	3.8	2.0	2.4	1.8	3.6	5.2	5.2	2.8
	4.8	4.0	4.0	3.2	2.4	2.0	3.0	2.6
	4.4	3.4	3.6	2.4	3.2	2.2	3.2	2.8
	4.5	6.2	4.0	3.2	3.8	2.4	3.4	2.4
	5.8	2.6	3.8	2.6	3.6	2.0	3.0	2.6
Mean	4.7	3.3	3.6	2.7	4.5	3.5	3.7	2.9

[1]See page 54 for explanation of terms.

Table 29. Gardner color difference meter reflectance (Rd) values for the average of sides 1 and 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	33.2	29.8	31.3	29.6	25.7	21.2	30.2	22.4
	28.6	26.6	22.4	26.4	27.4	23.1	22.0	19.3
	29.8	22.9	28.2	13.3	36.0	35.4	39.2	28.9
	28.2	15.4	20.4	6.1	35.4	28.2	31.4	31.3
	29.4	20.5	27.7	18.4	35.0	31.9	30.2	20.2
	27.7	17.8	18.3	12.8	30.0	28.6	27.6	17.7
	29.6	22.2	17.2	17.5	31.5	20.0	20.0	12.6
	24.5	21.5	17.9	12.2	29.8	24.7	25.7	14.4
	31.9	33.0	24.6	25.6	29.7	13.0	23.0	10.4
	32.4	31.8	24.6	15.0	28.6	16.8	17.1	6.3
Mean	29.5	25.2	23.3	17.7	30.9	24.3	26.6	18.4

[1]See page 54 for explanation of terms.

Table 30. Gardner color difference meter redness (+a) and greenness (-a) values for the average of sides 1 and 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	-1.2	0.0	+0.4	+0.2	0.0	+3.8	0.0	+2.6
	+1.5	+3.3	+5.4	+3.8	+2.4	+4.4	+3.0	+6.2
	+1.0	+5.5	+2.6	+6.4	-3.0	-1.1	-2.4	+4.0
	+0.8	+4.7	+5.2	+5.9	-1.7	+2.2	+0.4	+1.7
	+0.1	+4.0	+1.5	+4.3	-1.4	+2.7	+0.4	+7.8
	+1.0	+3.6	+4.5	+2.4	-2.6	+2.4	+2.4	+6.8
	+0.4	+3.2	+3.4	+3.7	0.0	+5.3	+2.0	+5.8
	+1.8	+3.7	+4.5	+6.6	+0.2	+2.7	+1.4	+4.8
	+0.2	-0.9	+3.5	+4.1	-0.3	+7.6	+2.7	+5.8
	+1.2	+1.4	+3.3	+8.2	0.0	+5.1	+5.1	+4.8
Mean	+0.7	+2.8	+3.4	+4.6	-0.6	+3.5	+1.5	+5.0

[1]See page 54 for explanation of terms.

Table 31. Gardner color difference meter yellowness (+b) values for the average of sides 1 and 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	+10.7	+12.4	+12.9	+12.4	+10.5	+9.8	+11.4	+11.0
	+10.9	+13.0	+14.2	+14.6	+11.6	+15.0	+13.0	+14.4
	+10.3	+11.5	+12.4	+12.4	+12.4	+14.6	+11.1	+17.6
	+10.9	+12.0	+13.4	+8.6	+12.0	+15.5	+14.0	+15.6
	+9.7	+13.8	+12.0	+13.4	+12.4	+12.8	+13.0	+16.4
	+12.2	+10.5	+13.4	+10.8	+12.2	+14.5	+13.6	+14.8
	+10.9	+13.5	+12.4	+12.4	+11.0	+15.0	+11.6	+13.4
	+11.8	+14.0	+13.5	+15.3	+11.4	+13.5	+12.8	+12.1
	+11.8	+12.9	+14.2	+16.3	+11.8	+14.8	+13.0	+11.8
	+12.0	+13.6	+13.6	+15.6	+12.0	+14.4	+13.8	+9.6
Mean	+11.1	+12.7	+13.2	+13.2	+11.7	+14.0	+12.7	+13.7

[1]See page 54 for explanation of terms.

Table 32. Degree of brownness scores for side 1 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	2.4	4.0	2.8	4.8	3.2	6.5	4.2	6.2
	2.4	2.8	2.6	4.0	3.0	4.8	4.0	6.0
	4.0	6.4	4.2	6.6	2.2	3.4	2.4	4.2
	2.8	6.0	4.2	6.2	1.6	4.6	2.2	4.4
	3.5	5.0	4.2	5.5	3.8	3.8	3.2	5.0
	3.0	3.6	3.4	4.6	2.6	3.8	3.0	4.8
	2.8	4.2	4.0	4.2	3.2	5.2	5.0	5.6
	4.0	4.8	4.4	5.8	3.6	5.2	4.8	5.0
	2.0	2.2	2.8	4.2	4.6	6.0	5.8	6.8
	2.0	4.0	2.0	5.4	3.8	6.2	5.4	7.0
Mean	2.9	4.3	3.5	5.1	3.2	5.0	4.0	5.5

[1]See page 54 for explanation of terms.

Table 33. Uniformity of brownness scores for side 1 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	5.0	3.8	5.0	2.6	6.2	4.2	5.0	4.5
	6.4	5.2	6.2	4.8	5.6	3.8	4.8	3.6
	5.2	2.4	5.2	3.0	5.8	5.0	6.4	4.4
	6.4	2.2	5.0	3.6	6.0	4.8	6.0	5.2
	5.8	4.8	5.5	3.2	4.4	5.0	5.0	4.8
	5.6	5.0	5.2	3.6	5.2	4.2	4.6	4.4
	5.4	5.0	5.4	5.2	5.4	4.0	4.0	3.6
	5.2	3.6	4.6	3.0	5.4	4.0	3.8	4.0
	5.8	5.8	5.8	4.5	3.8	2.4	2.8	2.0
	6.0	3.8	5.8	4.2	5.4	2.8	3.8	3.8
Mean	5.7	4.2	5.4	3.8	5.3	4.0	4.6	4.0

[1]See page 54 for explanation of terms.

Table 34. Gardner color difference meter reflectance (Rd) values for side 1 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	32.2	30.4	31.2	28.8	29.2	13.7	31.9	17.0
	25.5	29.8	27.3	29.6	25.4	20.6	22.4	13.2
	29.3	19.4	29.5	9.8	34.0	32.9	39.8	27.2
	27.8	9.0	27.0	6.7	32.9	24.3	30.2	26.5
	26.0	25.8	32.0	21.1	32.9	26.8	30.7	19.0
	28.2	26.5	24.6	20.8	31.2	27.4	24.4	25.6
	28.0	25.9	24.6	26.0	30.6	17.5	28.0	13.9
	24.8	24.5	23.8	13.3	28.7	20.4	28.4	20.6
	30.5	30.4	27.6	21.5	29.2	14.9	24.9	14.9
	29.0	26.5	26.0	16.6	28.6	14.3	15.2	4.4
Mean	28.1	24.8	27.4	19.4	30.3	21.3	27.6	18.2

[1]See page 54 for explanation of terms.

Table 35. Gardner color difference meter redness (+a) and greenness (-a) values for side 1 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	-0.5	0.0	0.0	+0.3	0.0	+7.1	0.0	+5.1
	+3.3	+0.8	+1.6	+1.3	+2.8	+4.7	+3.1	+9.1
	+0.2	+4.8	+1.6	+6.4	-2.2	-0.2	-3.4	+5.5
	+1.6	+5.8	+2.0	+7.4	-0.8	+5.2	+1.2	+4.4
	+0.2	+2.2	-0.7	+4.9	-1.8	+4.7	+0.4	+9.0
	+0.5	+2.5	+2.2	-0.4	+0.6	+2.6	+4.8	+3.0
	0.0	+0.8	+2.6	+2.1	+1.0	+6.9	+0.4	+6.8
	+2.3	+2.2	+2.2	+7.6	+0.5	+4.5	+0.4	+4.7
	+1.1	+1.5	+1.4	+6.4	+0.8	+6.6	+1.8	+5.8
	+2.8	+3.4	+3.0	+10.0	-0.6	+6.3	+6.9	+4.1
Mean	+1.2	+2.4	+1.6	+4.6	0.0	+4.8	+1.6	+5.8

[1]See page 54 for explanation of terms.

Table 36. Gardner color difference meter yellowness (+b) values for side 1 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	+10.4	+12.2	+12.2	+12.6	+11.2	+9.2	+11.4	+11.8
	+11.5	+11.8	+13.1	+12.2	+11.6	+14.7	+12.2	+13.8
	+10.9	+11.4	+12.3	+10.5	+12.1	+16.7	+9.6	+18.9
	+11.1	+10.1	+13.4	+8.9	+11.8	+18.3	+14.5	+18.6
	+9.3	+12.9	+10.6	+13.8	+13.7	+14.9	+13.6	+16.7
	+10.9	+11.2	+12.8	+14.6	+11.5	+13.6	+12.2	+15.2
	+10.6	+12.4	+12.4	+11.6	+11.8	+15.0	+12.0	+14.8
	+11.5	+13.1	+13.0	+16.4	+10.8	+14.7	+12.9	+13.2
	+12.3	+12.5	+13.1	+17.6	+12.0	+14.5	+12.4	+14.4
	+12.1	+16.1	+13.5	+17.2	+10.9	+13.3	+13.6	+5.9
Mean	+11.1	+12.4	+12.6	+13.5	+11.7	+14.5	+12.4	+14.3

[1]See page 54 for explanation of terms.

Table 37. Degree of brownness scores for side 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	4.4	4.8	5.8	5.6	4.2	4.2	4.0	5.8
	4.2	5.6	6.6	5.8	4.2	5.0	6.2	6.2
	2.8	3.2	5.4	6.2	2.4	3.6	3.8	5.2
	3.2	6.4	6.0	7.0	1.6	3.4	3.6	2.8
	5.5	6.8	5.5	7.0	3.0	3.0	3.2	5.6
	5.0	7.0	6.8	7.0	2.2	4.2	4.0	6.0
	3.6	6.4	6.8	6.8	2.4	5.6	5.8	6.2
	4.8	6.2	6.6	6.6	4.4	4.8	6.4	6.8
	2.0	2.8	4.8	5.0	4.2	6.6	6.2	7.0
	3.6	3.6	5.6	6.4	4.8	6.2	6.0	6.8
Mean	3.9	5.3	6.0	6.3	3.3	4.7	4.9	5.8

[1]See page 54 for explanation of terms.

Table 38. Uniformity of brownness scores for side 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	4.4	4.4	1.8	2.0	4.0	4.8	4.8	3.0
	4.6	3.6	2.8	3.8	4.8	3.6	2.8	2.8
	5.8	5.6	4.0	4.0	5.2	5.4	4.8	4.4
	5.8	2.0	2.6	5.0	6.0	4.8	4.6	4.8
	4.2	4.5	3.8	3.8	4.4	4.6	4.4	4.6
	4.0	4.0	4.0	4.4	4.6	3.8	4.4	4.6
	4.6	2.6	2.4	3.2	5.2	3.6	3.2	3.2
	3.6	3.0	3.0	2.2	4.0	3.2	2.4	3.8
	5.0	5.0	3.8	3.8	3.2	2.2	2.0	2.6
	4.4	4.6	3.6	4.4	2.8	2.6	3.0	3.6
Mean	4.6	3.9	3.2	3.7	4.4	3.9	3.6	3.7

[1]See page 54 for explanation of terms.

Table 39. Gardner color difference meter reflectance (Rd) values for side 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	34.2	29.2	31.4	30.4	22.2	28.6	28.4	27.8
	31.8	23.4	17.6	23.1	29.4	25.6	21.7	25.4
	30.2	26.4	26.8	16.8	38.1	38.0	38.5	30.6
	28.7	21.8	13.9	5.5	37.8	32.1	32.6	36.1
	32.9	15.1	23.4	15.6	37.1	37.0	29.6	21.4
	27.2	9.1	12.0	4.9	28.7	29.7	30.7	9.8
	31.2	18.4	9.8	9.0	32.4	22.4	11.9	11.4
	24.2	18.5	12.0	11.0	30.8	29.0	23.0	8.2
	33.3	35.5	21.5	27.8	30.2	11.1	21.0	5.9
	35.7	37.1	23.2	13.4	28.6	19.2	19.0	8.2
Mean	30.9	23.4	19.2	15.8	31.5	27.3	25.6	18.5

[1]See page 54 for explanation of terms.

Table 40. Gardner color difference meter redness (+a) and greenness (-a) values for side 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	-1.9	-0.1	+0.7	0.0	0.0	+0.5	0.0	0.0
	-1.8	+5.8	+9.1	+6.4	+2.1	+4.2	+2.8	+3.3
	-1.2	+6.2	+3.6	+6.4	-3.9	-2.0	-1.4	+2.6
	+0.1	+3.6	+8.5	+4.4	-2.6	-3.0	-0.8	-2.7
	0.0	+5.7	+2.2	+3.7	-1.1	-2.0	+0.5	+6.5
	+1.6	+4.7	+6.8	+2.8	-3.2	+2.3	0.0	+10.6
	+0.8	+5.6	+4.2	+5.3	-1.0	+3.7	+3.5	+4.8
	-0.5	+5.2	+6.8	+5.7	-3.0	-1.8	+2.5	+4.8
	-0.9	-2.4	+5.6	+1.8	-1.1	+8.5	+3.6	+5.9
	-1.6	-2.0	+3.6	+6.4	+0.6	+3.9	+3.3	+5.6
Mean	-0.5	+3.2	+5.1	+4.3	-1.3	+1.4	+1.4	+4.1

[1]See page 54 for explanation of terms.

Table 41. Gardner color difference meter yellowness (+b) values for side 2 of charcoal-broiled pork rib chops.[1]

	Low quality				Average quality			
	a	b	c	d	a	b	c	d
	+11.0	+12.6	+13.6	+12.1	+10.8	+10.3	+11.5	+10.2
	+10.3	+15.3	+15.3	+17.1	+11.5	+15.2	+13.8	+14.9
	+9.7	+11.6	+12.5	+14.2	+12.6	+12.6	+12.6	+16.3
	+10.7	+14.0	+13.4	+8.2	+12.2	+12.7	+13.6	+12.7
	+10.1	+14.7	+13.5	+13.0	+11.2	+10.8	+12.4	+16.2
	+13.5	+9.8	+14.0	+6.9	+12.9	+15.4	+14.9	+14.4
	+11.2	+14.6	+12.3	+13.1	+10.2	+15.0	+11.3	+12.1
	+12.0	+14.8	+14.0	+14.2	+12.1	+12.3	+12.6	+11.0
	+11.3	+13.3	+15.4	+15.0	+11.6	+15.0	+13.7	+9.3
	+11.9	+11.0	+13.8	+14.0	+13.2	+15.4	+13.9	+13.2
Mean	+11.2	+13.2	+13.8	+12.8	+11.8	+13.5	+13.0	+13.0

[1]See page 54 for explanation of terms.

QUALITY, THICKNESS AND END POINT EFFECTS ON CHARCOAL-BROILED PORK RIB CHOP ACCEPTABILITY

by

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The effects of quality, end point temperature and thickness on palatability and appearance of charcoal-broiled pork rib chops were studied. Average and low quality chops as measured by color, firmness and marbling of the anterior end of the loin were evaluated. Two end point temperatures (160 and 175°F) and two thicknesses of chop (3/4 and 1 1/2 in.) were used. A split-plot design for cutting, cooking and evaluating chops involved 10 replications (2 chops each) for each of 4 treatments within a quality. Meat was cooked over charcoal and temperature at the surface of the meat was maintained at 350°F.

Low quality chops were higher in cooking losses (160°F), total moisture and shear values than average quality meat. Average quality chops were more tender and had higher pH than those of low quality. Juiciness scores, expressible moisture and cooking time were not significantly related to quality. A trend was noted for greater expressible moisture and less cooking time in average than low quality meat. Flavor scores were higher in 1 1/4-in. chops for average than low quality meat in this study, and there were significant flavor differences among animals within a quality. In general, doneness scores were higher for average than low quality chops. Quality generally was not significantly related to color or appearance scores, although variation was observed among animals of a similar quality.

As end point temperature increased from 160 to 175°F, juiciness, total and expressible moisture decreased and cooking losses and cooking time increased. These factors indicated a less juicy product with well-done meat. Tenderness decreased and shear values increased with increased end point temperature. Flavor was not significantly affected by end point temperature although desirability of doneness scores were higher for meat cooked to 160 than to 175°F. Chops gained color intensity with the higher end point as noted by increased degree of brownness scores, redness and yellowness values and decreased reflectance. However, color of chops was less uniform and amount of coagulum increased at higher rather than at lower end points.

Total and expressible moisture of 175°F chops and cooking time increased significantly with increased thickness of chop from 3/4 to 1 1/4 in. At 160°F, cooking losses increased and at 175°F losses decreased with thickness. Juiciness scores and thickness were not related. Tenderness scores were higher and shear values, lower, for 1 1/4-in. than 3/4-in. chops. Flavor scores were higher for 1 1/4-in. chops; however, doneness was unrelated to thickness. Chop color became more intense as thickness increased; evidence included higher degree of brownness scores, redness and yellowness but lower reflectance values. Less coagulum was noted in 3/4 in. than 1 1/4-in. chops.

A number of objective and subjective evaluations were highly correlated. Juiciness was directly related to total and expressible moisture and inversely related to cooking losses. Tenderness and Warner-Bratzler shear values were negatively related. As degree of brownness measured subjectively increased, redness increased and reflectance decreased as measured objectively with the Gardner color difference meter.