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Factors influencing the sensory quality of boneless pork loin chops

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Factors influencing the sensory quality of boneless pork loin chops

by

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INTRODUCTION

Consumers are more concerned about fat in their diet than ever before. We are continually advised by health professionals to reduce fat intake. The food industry has responded with many lines of 'reduced calorie' and 'reduced fat' entrees introduced to the supermarket in the past decade. The fresh meat case, including pork loins, also has observed substantially lower fat contents (Buege, 1990).

With an increased emphasis on lean meat production, the pork industry faces many unanswered questions. These include: 1) Is today's pork too lean? 2) Will pork be too lean in the future? 3) Is there a minimum amount of intramuscular fat necessary for pork to be considered acceptable in terms of tenderness, juiciness and flavor? 4) What role does moisture have in the sensory quality of pork? With the potential of new production technologies to significantly decrease the intramuscular fat content of pork, the relationship between intramuscular fat and eating quality has been questioned. Historically, intramuscular fat was implicated as the major factor necessary to produce tender, juicy and flavorful pork. But numerous studies have reported a weak relationship between intramuscular fat and pork tenderness (Batcher et al., 1962; Kauffman et al., 1964; Murphy and Carlin, 1961; Rhodes, 1970; Saffle and Bratzler, 1959). Several researchers have also reported relatively low correlations between intramuscular fat content and juiciness and pork flavor (Davis et al., 1975; DeVol et al., 1988).

Any influence of intramuscular fat on pork quality may be overshadowed by the cooking method. In the past, consumers were advised to cook pork to the well-done stage. Now, the National Pork Producers Council recommends cooking pork to an internal temperature of 71°C for most cuts. Lowering the internal end-point temperature of pork chops from 77°C to 71°C significantly enhances the tenderness and juiciness (Boles, 1989). Intramuscular moisture content of the cooked product may contribute more to sensory quality than intramuscular fat content of the cooked product.

The objectives of this study were to examine the influence of genetic background and major raw and cooked meat compositional factors on the sensory quality of pork loin and, determine if a specific level of intramuscular fat and/or moisture is necessary for broiled pork loin to maintain satisfactory sensory quality, and predict juiciness, tenderness, and pork flavor using physical and chemical measurements.

REVIEW OF LITERATURE

Meat Consumption and Human Health

The topic of meat consumption and human health is an important issue that must be addressed. Consumers have the right to and should be concerned about their health. In order to effectively make decisions about food choices consumers must be educated about dietary facts. I will begin with some perceptions that consumers have about meat.

In a consumer panel about feelings on meat products served in the home, one consumer stated that meat is a 'no no' word and that she feels guilty when she serves meat to her family (Knutson, 1991). Not only do consumers feel negative about meat, but they feel more negative about pork. When asked to rate meats on various characteristics (health/nutrition, sensory appeal, preparation and price/value), pork items recieve poorer ratings than chicken, fish and beef items. While beef's greatest weakness is its perceived health hazards (salt, fat, calories, etc.), pork items share these same problems to an even greater extent (Courington, 1988). In terms of perceptions of specific meats, it is quite clear that pork suffers from an unhealthy image: all pork products receive low ratings in this area (Courington, 1988).

To many consumers the meat image is closely linked with fat and calories (Allen, 1987). High dietary consumption of food energy (calories), total fat, saturated fatty acids, and cholesterol are inter-related and are the food components that have the greatest effect on health (Swanson, 1991). With this information it is understandable that consumers perceive meat as a negative dietary component. It is possible, however, for consumers to choose very lean cuts of meat from grocery stores with proper information. A positive aspect that is not as widely appreciated by many consumers and health professionals as it should be, is that red meat contributes 13% to 52% of ten essential nutrients to the United States food supply (Allen, 1987). Educating consumers and health professionals about nutritional advantages of lean meats as well as which lean cuts to choose and how to prepare them is a continuing process that can benefit many healthy diets.

When asked what information consumers would like on the meat label, fat content was first on the list (Knutson, 1991). Of 300 consumers interviewed, over 75% of them preferred light marbling (2.1% fat) over medium marbling (4.6% fat) or heavy marbling (7.9% fat) when comparing raw pork chops for purchase from a meat case (Malphrus et al., 1975). Consumers know that lean meats are better for them, but many perceive leaner meats to be less juicy, less tender, and less flavorful than fatter cuts. Despite this perception, they may still choose the leaner cut because it is perceived to be more 'healthy' for them.

Sensory Quality of Pork

Breed and Carcass Quality Factors

The influence of breed on sensory quality is noteable. Breeds differ in carcass composition and therefore affect sensory quality of pork.

Eating quality traits are generally improved as the concentration of monounsaturated fatty acids increased and polyunsaturated fatty acids decreased (Cameron; Enser, 1991). Fatty acid composition of porcine adipose tissue differs between breeds (Kellogg et al., 1977 and Villegas et al., 1973). Levels of total unsaturated fatty acids for Yorkshire and crossbred pigs are intermediate between those of Hampshire and Duroc pigs (Villegas et al., 1973). Cholesterol and fatty acid composition of pork could be readily manipulated by selective breeding (Kellogg et al., 1977). Composition of the diet can alter fatty acid composition of both the adipose tissue and muscle tissue of the swine. The amount of oleic acid (monounsaturated fatty acid) deposited in swine adipose tissues was increased by the addition of sunflower and safflower oils to the diet without adversely affecting carcass quality (Miller et al., 1990). Wood et al. (1989) reported a higher ratio of polyunsaturated to saturated fatty acids (0.41) in the leanest pigs. Differences in fat characteristics between breeds are apparently largely attributable to differences in fatness rather than inherent breed factors (Warriss et al., 1990). Significant genetic variation exists between and within breeds for rate of lean tissue growth in swine (Cundiff, 1983).

Total carcass fat and backfat amount has been shown to influence sensory quality of loin chops. Five hundred consumers found chops of lean carcasses to be less juicy on average with a tendency toward toughness and less flavor (Kempster et al., 1986). Using a 9 point hedonic scale ranging from dislike extremely to like extremely, panel acceptability scores were significantly higher for pork loins with greater backfat (Saffle and Bratzler, 1959). Cameron and Enser (1991) suggest that the correlated responses in eating quality traits to selection for increased carcass leanness will primarily be a reduction in juiciness and, to a lesser extent, tenderness. Genetic correlations have suggested that selection for increased lean weight would result in increased muscle moisture content but decreased muscle pH, intramuscular fat content, pork flavor, and juiciness (Cameron, 1990). It is estimated that pork from carcasses with less than 1.25 cm backfat could have palatability and other quality problems (Dikeman, 1987).

Hiner et al. (1965) reported that the quantity of intramuscular fat deposited in the longissimus dorsi can be influenced by the genetic composition of the pig. It was found that Duroc pigs had significantly more intramuscular fat, smaller longissimus dorsi area, and more tender, juicier loins than Yorkshire pigs. Skelley et al. (1973) concluded that carcass quality scores, pH, percent moisture, and percent ether extract did not explain differences in palatability of pork chops broiled to 75°C. Wood et al. (1979) reported that the leanest group of pigs out of four different breed groups had the highest sensory panel score for tenderness, the lowest value for toughness, and similar scores for flavor and juiciness.

Animals become less efficient producers of lean as they increase in size, primarily due to slower relative rates of growth (Tess, 1983). Warriss et al. (1990) reported that the relationship between muscle fat and carcass fat is poor, suggesting that one may be changed without altering the other. Some researchers believe that it is desirable to select for increased intramuscular fat in the interests of meat palatability (Warriss et al., 1990).

Intramuscular Fat

Leanness may not be the cause of less tender, less juicy, and less flavorful pork. Many researchers have attempted to associate palatability of pork loin chops to lipid content. There has been much disagreement, however, on the role of intramuscular fat on palatability.

Seideman et al. (1989) reported that sensory properties of longissimus meat samples from lean and obese strains of pigs were not different. Average panel scores for texture, tenderness, and juiciness were not consistantly related to fatness in the carcass (Rhodes, 1970). Wood et al. (1981) concluded that the satisfactory eating quality of pork is maintained at very low values of carcass fatness. Instrumental toughness, sensory tenderness and flavor are similar while juiciness is lower in the 'very lean' group although the reaseachers considered the difference to be relatively unimportant.

Within a single pork chop there may be sensory variation. Batcher and Dawson (1960) found that the longissimus dorsi varies in tenderness within the muscle. Panel scores for juiciness and tenderness are not associated consistently with marbling index or with intramuscular fat content while there is more uniformity in flavor (Batcher et al., 1962). This may account for differences in panel ratings and results in each of these experiments.

Other researchers have found opposite results on the role of intramuscular fat on sensory quality. Acuff et al. (1988) reported that overall appearance scores for chops of high and intermediate marbling were generally higher than those of low marbling in almost all comparisons. Marbling of fat in the lean has a significant positive effect on both tenderness and juiciness of braised pork chops (Murphy et al., 1961). Greater quantities of intramuscular fat have been associated with higher flavor, tenderness, and especially higher juiciness ratings of cooked fresh loins (Kauffman et al., 1963). Davis et al. (1975) found that chops with lower percentages of moisture and/or higher percentages of fat were more juicy and tender than chops with higher percentages of moisture and/or lower percentages of fat when broiled to 75°C.

DeVol et al. (1988) reported substantial variation in carcass and palatability traits of pork entering the marketplace in a random sample of pork carcasses (n=20) at a commercial slaughter facility. Of the parameters evaluated, percentage of intramuscular fat was most highly related to tenderness and Warner Bratzler Shear force (r=0.32 and -0.29, respectively). It was suggested in this study that a threshold value of 2.5% to 3.0% fat is necessary for tender pork; below this threshold value chops are significantly tougher, but varying fat percentages above 2.5% to 3.0% has little effect on tenderness. Davis (1974) recommended between 3.5 and 4.5 percent intramuscular fat while Savell and Cross (1988) recommended a minimum level of 3 percent chemical fat for cuts from the pork loin based on palatability.

The differences in juiciness between lean and fatter samples observed in the literature may be due to the high endpoint cooking temperature (75 - 80°C). Fat may play a protective role against higher temperatures to make samples seem more juicy. When samples are cooked to lower temperatures (71°C) there is no difference in juiciness between lean and fat samples.

Cooking Method

Of all the factors influencing palatability cooking procedure, and more specifically, endpoint temperature seem to have the greatest influence on tenderness and juiciness. Increased endpoint temperatures of pork roasts are associated with increased cooking losses, graininess, brown color, and pork flavor , and decreased juiciness, pink color, and metallic flavor (Heymann et al., 1990). Consumers prefered pork roasts cooked to 71.1°C compared with roasts cooked to 76.7°C (Siemens et al., 1990). Renk et al. (1985) reported that neither degree of marbling (moderate or slight), internal temperature (68° or 79°C), nor method of cookery (broiled or roasted) significantly altered the quantity of intramuscular lipid retained after heating. Siemens et al. (1990) agreed that percent fat does not differ due to internal temperature and also determined that a higher internal endpoint temperature of broiled loin chops decreases percent moisture and increases percent protein. Heymann et al. (1990) recommends at least 71.1°C and no greater than 76.6°C as the endpoint temperature for fresh pork roasts to minimize pink color and maximize other sensory characteristics and yield of cooked meat.

Prior to cooking, handling procedures also may influence sensory quality. Freezing, frozen storage, and thawing improves textural properties but produces adverse affects on flavor (Jeremiah et al., 1990). Precooking does not increase cooking losses and the palatability attributes of the precooked roasts are as good or better than conventionally prepared roasts at storage periods up to eight weeks (Jones et al., 1987). While some researchers found that eliminating external fat prior to cooking reduces fat and caloric content of pork lean (Heymann et al., 1990 and Morgan et al., 1988), others have reported that it does not (Novakofski it al., 1989). The difference may be due to handling procedures after cooking (i.e., wiping chop with towel).

Sensory Measurements

Sensory analysis by human subjects can determine the characteristics of a sample that make it acceptable or unacceptable. Davis et al. (1978) grouped fresh loins into palatability groups (superior, acceptable, and inferior) by use of quality indicator scores. Sensory panel ratings for flavor of the broiled chop (endpoint temperature 75°C) were not significantly different between the three palatability groups while juiciness and tenderness received significantly higher scores in the superior group.

Results from sensory tests using human subjects are often very subjective and dependent on many different factors. Variations in individual responses from sensory panelists are difficult to control, and because of the destructive nature of sensory testing it is impossible to repeat analysis on the same sample. Sample to sample variation within the same cut of meat from the same animal also may play a role in individual differences in response.

Expert Panels

The use of highly trained panelists for evaluation of specific sensory characteristics is desirable for tests requiring knowledge of and familiarity with samples, evaluation procedures and scoring. If the panel hopes to attain the status of "expert panel" in a given field, it must demonstrate that it can use a concrete list of descriptors based on an understanding of the underlying technical differences among the attributes of a product (Meilgaard et al., 1991)

Score cards and Scales

Format and wording on score cards is a key factor in the results obtained. The number of points along an intensity scale is determined according to the degree of product differences. Many researchers have used a nine point scale (Heymann et al., 1990; Siemens et al., 1990; Dikeman, 1987; Murphy and Carlin, 1960, and others). The ends of the scale with this many points are rarely if ever used (as seen by ranges) unless many differences exist between samples. A set of well chosen reference points greatly reduces panel variability, allowing for comparison of data across time and products, and allows more precise correlation with stimulus changes and with instrumental data (Meilgaard et al., 1991).

Terminology

Juiciness. Juiciness of a sample in sensory terms is defined as the degree and amount to which moisture inside the sample is released upon chewing (Heymann et al., 1990). It is often measured as the initial impression of moistness or release of juice during the first bite of the sample.

Tenderness. Texture of meat is an important indicator of quality, and therefore important to the meat industry as well as consumers. Consumer preferences show a strong demand for tender meats (Finney, 1969). Tenderness is a measure of force required to compress a substance between molar teeth, or the force necessary to attain a given deformation (Heymann et al., 1990). Tenderness can be either initial or sustained. Initial tenderness is considered the 'first bite' impression and sustained tenderness includes the continued chewing of the sample. The procedure by which panelists evaluate hardness during the first downstroke of mastication appears to change from compression to biting as hardness increases (Boyd and Sherman, 1975). Cooked meat (ham in this study) was considered to rank midway between 'hard' and 'soft' foods.

Chewiness. Chewiness is defined as the energy required to masticate a solid food product to a state ready for swallowing. It is related to the primary parameters of hardness and cohesiveness (Szczesniak, 1962). Chewiness can be divided into first chew, chew down, and rate of melt (Meilgaard et al., 1991). The number of chews to disinegrate the sample is determined by counting the number of chews necessary before the sample is swallowed.

Pork Flavor. Flavor has been defined as the sum of perceptions resulting from stimulation of the sense ends that are grouped together at the entrance of the alimentary and respiratory tracts (Amerine et al., 1965). For practical sensory analysis the term is restricted to the impressions perceived via the chemical senses from a product in the mouth (Caul, 1957). According to Meilgaard et al. (1991), flavor includes the aromatics as determined by olfactory perceptions caused by volatile substances released from a product in the mouth, the tastes from gustatory perceptions caused by soluble substances in the mouth, and chemical feeling factors which stimulate nerve ends in the soft membranes of the buccal and nasal cavities. Pork flavor has been defined as a flavor commonly associated with cooked pork meat (Heymann et al., 1990).

Off Flavor. Numerous off flavors have been reported in pork sensory tests. Aromas and flavors such as metallic, sour, sweet, musky, and several others have been included in profiles of pork roasts (Gardze et al., 1979). None of the samples in this study, however, were scored "undesirable" overall by the rating panel. Jeremiah et al.(1990) reported a predominance of sour notes from pale, soft and exudative (PSE) condition pork loins that may be due to the increased accumulation of lactic acid during post mortem glycolysis. Off flavors were also detected in extreme dark, firm and dry (DFD) condition in pork loins in this study.

Physical Measurements

The physical characteristics of a sample as determined by instrumental analysis provide important useful information that can be correlated with sensory scores.

Cooking Loss

Cooking loss is the amount of substance in weight that is lost during cooking of the sample, and is generally reported as the percentage change in chop weight after cooking. Cooking losses of grilled and oven cooked pork loin chops increased ($P<0.05$) as temperature was increased from 70 to 80°C (Simmons et al., 1985). Renk et al. (1985) also reported increasing cooking losses with increased internal endpoint temperature, and reported increased cooking losses with increased degree of marbling. In this study, pork loin chops were divided into low and high degree of marbling groups and then broiled or roasted to either 68 or 79°C. Chops broiled to 68°C resulted in 19% cooking loss with low degree of marbling and 26.2% cooking loss with high degree of marbling. When broiled to 79°C, chops with low marbling had 40.7% cooking loss and chops with high marbling had 44.8% cooking loss. Batcher et al., (1962), however, found that the amount of marbling in the loin eye was not related to cooking loss. Differences in procedures, including leaving external fat on the chop when cooking and the high internal endpoint temperature of 85°C in the study by Batcher et al., may have influenced differences in results between studies.

Instrumental Tenderness

Meat tenderness is a very important factor to consumers. Instrumental analysis of tenderness includes compression or deformation tests, penetration tests, and shear tests. All of these are destructive to the sample, but provide important information about meat tenderness. Objective measurements of food texture may be influenced by a variety of test conditions, including rate of loading, the magnitude of deformations imposed upon the material, geometry of the loading surface, and localized yielding within the product tested (Finney, 1969). Bourne (1967) concluded that a small deforming force will usually give a better resolution between similar samples than does a large deforming force. Selecting the correct instrumental test and conditions are crucial to results (Boyd and Sherman, 1975).

Bourne (1967) divides deformation testing into two measurements: the distance that the food deforms when compressed and the force required to achieve a given deformation. The relationship between force and compression exhibited by the Instron Universal Testing Machine depends on the crosshead speed utilized: As Instron crosshead speed increases so does the force required to achieve a desired % compression. It is therefore necessary to closely simulate the mechanical conditions prevailing during the initial stage of mastication if instrumental data are to be utilized to predict the sensory evaluation of hardness (Boyd and Sherman, 1975).

Hinnergardt and Tuomy (1970) found high correlation between penetration force on raw pork loin chops and cooked meat tenderness. About 76% of the variation in this study was attributed to differences between loins, 9% to differences in chop location and 15% to the loin x chop position interaction. This indicates that differences in tenderness exist within each chop.

Skelley and Handlin (1973) reported that Warner-Bratzler shear values and sensory panel tenderness scores from broiled pork longisimus muscle were not related to any of the factors studied (breed, sex, backfat, length, loin eye area, and carcass traits). Shear force amount of the longissimus samples from the lean strain were slightly, but significantly ($P<.10$) higher than those from the obese strain (Seideman et al., 1989).

Oltrogge and Prusa (1987) reported a high correlation between sensory tenderness scores of baked hen breasts and Instron compression values using a five-point star-shaped puncture probe (-0.72, $P<0.01$).

Moisture and Lipid Analysis

Procedures for moisture and lipid analysis can vary between researchers and therefore lead to different results. Pork loin samples may differ in moisture and lipid contents depending on if they are tested in the raw or cooked state, fresh or frozen, and are also influenced by cooking temperature, internal endpoint temperature, and method of cooking. Sample to sample variation may also influence moisture and lipid content.

Moisture. Mean percentage of moisture for the raw loin muscle has been reported as high as 74.9% (DeVol et al., 1988). No explanation for this result was given. Batcher et al., (1962) reported mean intramuscular moisture to be 69.8% for raw center loin and 58.4% for cooked center loin cuts. Moisture content of cooked pork loin decreased from 66.0% to 61.9% as internal endpoint temperature increased from 65.6°C to 82.2°C (Heymann et al., 1990).

Lipid. USDA Handbook 8-10 (1983) reports intramuscular fat contents of raw boneless pork loin chops to be 7.5% and cooked boneless pork loin chops to be 14.9% (Anderson, 1983). These values were reduced to 5.3% and 7.8%, respectively, in a 1990 study of retail meat cases from 68 randomly selected supermarkets (Buege, 1990). This decrease in intramuscular fat may reflect changes in pork production practices in recent years.

MATERIALS AND METHODS

Fresh loin chops from 754 pigs entered in the National Pork Producers 1990 Genetic Evaluation Test (Phase 1), 629 pigs entered in the Fall, 1991 National Barrow Show (Phase 2), and 512 pigs entered in the Spring, 1992 National Barrow Show (Phase 3) were obtained for this study. Pigs from the Genetic Evaluation Test represented 13 breeds of sire and originated from 13 different states. Pigs from the National Barrow Show represented 8 breeds of sire.

Sample Preparation

Fresh loin chops from the tenth, eleventh and twelfth ribs (longissimus muscle) were removed from the bone and trimmed of external fat and epimysial connective tissue. The tenth rib chop was immediately ground, packed in Whirl-Pak plastic bags (Sargent-Welch Scientific Co., Skokie, Il.) and frozen until dry matter, total lipid, and cholesterol analysis on the raw tissue was performed. Chops from the eleventh and twelfth ribs were cut approximately 2.5 cm thick, vacuum packaged, and stored in a 4°C refrigerator less than 96 hours before broiling and sensory analysis.

Sensory Analysis

Sensory Panel Training

A total of seven panelists consisting of Iowa State University faculty and students was trained for this study. After panelists completed the training period, they were considered to be experts, and therefore only a small number of panelists was necessary in each study. Three of the panelists evaluated samples from the Genetic Evaluation Test and the other four panelists evaluated samples from the National Barrow Show. Approximately three months prior to each test, panelists were trained two or three times each week for one hour. Panelists were given a variety of samples (from different cuts of meat, different preparation methods and different endpoint temperatures) and discussed scoring among themselves after each sample in order to standardize scoring as much as possible.

Sensory Sample Preparation. Loin chops were removed from vacuum bags, weighed, and placed on broiler pans. Chops were broiled to 71°C in an electric oven broiler (215°C),using copper thermocouple wires with a digital temperature recorder. After broiling, chops were weighed again to determine cooking loss. Samples from the eleventh rib chop of each pig were cut lengthwise into a 1 cm center strip and then further cut into 1 cm cubes after trimming off edges.

Sensory Panel Evaluation. Each panelist was served a 1 cm cube labeled with a three digit number code on a paper plate. The trained panelists were instructed to evaluate the sample for tenderness and juiciness on the first bite impression, and chewiness, pork flavor and off-flavor after chewing completely and swallowing the sample. Panelists were provided with unsalted crackers and deionized water for rinsing between samples.

Score Cards. A five point category scale was used for each term, with 1 being the least intense and 5 the most intense. An additional space was provided for additional comments and descriptive terms for any off flavors that may have been present.

Cooking Loss

Both the eleventh and twelfth rib chops were weighed before and after cooking. The difference in weight was calculated as a percent cooking loss.

Instron Puncture

The cooked twelfth rib chop was measured in thickness at three central locations and punctured to 80% of the original sample height using a five-point star-shaped puncture probe mounted on an Instron Universal Testing Machine,Model 1122, (Instron Corp., Canton, MA). The probe was 9 mm in diameter with 6 mm between each point. The angle from the end of each point up into the center was 48°. A crosshead speed of 200 mm per minute was used. Results from the force deformation curves were measured in mm and converted to kilograms of force. All calculations were based on the mean value of the three recordings. Remaining samples were ground through a Kitchen-Aid mixer with meat grinder attachment, divided into Whirl-Pak plastic bags, and frozen until further analysis of the cooked sample.

Moisture

Broiled, ground samples were allowed to thaw for 24 hours in a refrigerator (4^{O}C). Duplicate 5 gm samples were each placed in aluminum moisture pans and allowed to dry for four hours in a 125^{O}C oven according to AOAC procedures. Covered moisture pans were allowed to cool in an airtight dessicator, and then weighed for moisture loss determination. Results were calculated as percent moisture loss.

Total Lipid, Dry Matter, and Cholesterol

Both raw and cooked ground samples were analyzed for total lipid, dry matter, and cholesterol content.

Total Lipid

Total lipid was measured by a modified procedure of Floch et al.(1957). Five hundred milligrams tissue were measured into extraction tubes. Twenty five milliliters of $CHCl_3$:MEOH:H_2O (1:2:0.8) were added to the tissue, mixed thouroughly, and put on a Burrell Wrist-Action shaker (Model 75, Pittsburg, PA) for 8 hours. Seven and five tenths ml $CHCl_3$ and 7.5 ml 0.37%KCl were added to the mixture, mixed and centrifuged 20 minutes at 1500 rpm. The top layer was aspirated off and discarded. Ten ml 0.37% KCl was added again, mixed, and centrifuged at 1500 rpm for 15 minutes. This step was repeated once more. The remaining sample was then filtered through glass wool into a pre-weighed scintillation vial. The sample was dried in a sample concentrator without boiling, and dried total lipid was calculated as a percent of the total sample.

Dry Matter

Dry matter was analyzed by freeze drying. Thirty grams raw or cooked tissue was weighed and pressed against the sides of an empty jar. The sample was then freeze dried for 48 hours, and the dry tissue weighed and calculated as a percent of the total sample.

Cholesterol

Total cholesterol was analyzed by the procedure of Allign (1974) using Sigma Diagnostic Kit 352.

Statistical Analysis

Percent cooking loss, cooked moisture, raw and cooked lipid, dry matter and cholesterol, and Instron puncture force were analyzed using a random design. Analysis of variance, least significant differences, correlation coefficients, and regression analysis were completed using SAS (1988) procedures. When a significant F-value (P<.05) was found, a least significant difference (LSD) was calculated. Variation in traits is reported using means, ranges, and correlation coefficients. For analysis of sensory differences, broiled chops were separated into four groups by percent fat (Group 1=0.00-1.99%, Group 2=2.00-2.99%, Group 3=3.00-3.99 and Group 4=4.00% and above) and three groups by percent moisture (Group 1= 53.12-64.99%, Group 2=65.00-67.99%, and Group 3=68.00% and above). Sensory means were analyzed using one-way analysis of variance with percent fat or percent moisture group as classification variable. For stepwise regression procedures, all independant variables were made available for use in determining the best model. Significant contribution to the model was accepted at the 0.05 probability level.

RESULTS AND DISCUSSION

Means and ranges for sensory scores of broiled pork loin chops for phases 1, 2 and 3 are summarized in Table 1. As observed in the ranges, panelists used the full scale for scoring samples, except in the case of off flavor where only mild off flavors were detected, if at all. Differences in scores between the three phases are most likely due to differences in crossbred animals used in phase 1 compared to purebred animals used in phases 2 and 3, and also due to different panelists used in each of the three phases. It is difficult to compare this sensory data with studies that use different scales, although correlation analysis may provide information by which to compare. Many differences in procedures, especially cooking method, cooking temperature, and internal endpoint temperature also make it difficult to compare results.

Table 2 summarizes total lipid content of raw pork loin samples for phases 1, 2 and 3, and dry matter and total cholesterol contents for phases 2 and 3. The mean intramuscular fat percentage ranged from 1.03 to 10.26 for crossbred pigs (Phase 1) and from 0.37 to 11.22 (Phases 2 and 3) for purebreds. The mean percentage intramuscular fat of 2.97 for the three phases combined is slightly lower than that of 5.3 reported by Buege (1990), 3.9 by Novakofski et al. (1989), 3.2 by Batcher et al. (1962), and 3.18 by DeVol

Table 1. Sensory scores for the broiled, eleventh rib broiled pork loin chop

	Mean	Minimum	Maximum
Phase 1[a]			
Juiciness	2.55	1.00	5.00
Tenderness	3.39	1.00	5.00
Chewiness	2.56	1.00	5.00
Pork Flavor	3.05	1.70	4.70
Phase 2[b]			
Juiciness	3.21	1.00	5.00
Tenderness	3.27	1.00	5.00
Chewiness	2.74	1.00	4.75
Pork Flavor	2.09	1.00	3.25
Off Flavor	1.04	1.00	2.00
Phase 3[c]			
Juiciness	2.93	1.00	5.00
Tenderness	3.07	1.00	4.75
Chewiness	2.76	1.50	4.75
Pork Flavor	2.01	1.75	2.50
Off Flavor	1.03	1.00	2.00
Phases 1, 2, and 3[d]			
Juiciness	2.87	1.00	5.00
Tenderness	3.27	1.00	5.00
Chewiness	2.67	1.00	5.00
Pork Flavor	2.45	1.00	4.70
Off Flavor	1.04	1.00	2.00

[a]Means of 752 samples.
[b]Means of 629 samples.
[c]Means of 512 samples
[d]Means of 1893 samples

Table 2. Chemical measurements of raw pork loin chops

	Mean	Std Dev	Minimum	Maximum
Phase 1[a]				
Lipid (%)	3.06	1.22	1.03	10.26
Dry Matter (%)	27.08	1.50	24.86	32.13
Cholesterol (mg/g)	57.77	14.83	33.81	158.64
Phase 2[b]				
Lipid (%)	2.80	1.15	0.37	7.63
Dry Matter (%)	26.89	1.29	24.12	37.48
Cholesterol (mg/g)	58.82	10.27	16.00	112.00
Phase 3[c]				
Lipid (%)	3.03	1.26	0.84	11.22
Dry Matter (%)	27.33	2.15	13.75	55.79
Cholesterol (mg/g)	65.42	13.33	26.00	118.00
Phases 1, 2, and 3[d]				
Lipid (%)	2.97	1.21	0.37	11.22
Dry Matter (%)	27.09	1.66	13.75	55.79
Cholesterol (mg/g)	60.63	13.15	16.00	158.64

[a]Mean of 744 samples.
[b]Means of 621 samples.
[c]Means of 512 samples.
[d]Means of 1877 samples

et al. (1988), while Rhodes (1970) reported slightly lower percentages. Renk et al. (1985) reported a lower mean value of 2.5% for pork longissimus muscle with a "slight degree" of marbling and Seideman et al. (1989) reported 1.91% intramuscular fat for selected lean strains of Duroc and Yorkshire pigs.

Cooked total lipid content increased slightly to 3.27% over raw measurements probably due to the concentration of sample in the cooking process (Table 3). This mean is also slightly lower than most reports (Buege, 1990; Novakofski et al., 1989) for cooked pork loin intramuscular fat content. The number of samples measured for cook loss was doubled in Table 3 due to anaysis on two chops (eleventh and twelfth rib chops). The mean percentage cook loss of 22.66 of the three phases combined is similar to the mean of 21.6 reported by Novakofski et al. (1989), and 22.3 by Wood et al. (1981).

Instron puncture measurements, dry matter (%), moisture content (%), and cholesterol (mg/g) means of broiled pork loin chops are also included in Table 3. Although dry matter is rarely reported in the literature, it provides another measure to check the accuracy of moisture analysis and therefore was included here. The mean percentage of intramuscular moisture of 65.71 for the three phases combined is similar the the value of 66.9% reported by Novakofski et al. (1989). Batcher et al. (1962) reported a lower moisture

Table 3. Physical and chemical measurements of broiled pork loin chops

	n	Mean	Std Dev	Minimum	Maximum
Phase 1					
Instron (kg)	752	5.48	0.89	3.29	8.80
Cook Loss (%)	1496	22.04	5.74	7.55	44.05
Lipid (%)	742	3.23	1.21	0.96	9.39
Moisture (%)	752	65.80	2.51	56.20	81.80
Phase 2					
Instron (kg)	629	6.53	1.17	2.00	10.51
Cook Loss (%)	1258	23.77	6.48	2.72	48.41
Lipid (%)	620	3.24	1.30	1.03	8.88
Dry Matter (%)	620	35.38	2.54	23.62	48.79
Cholesterol (mg/g)	618	96.70	22.99	49.00	203.00
Moisture (%)	612	65.66	2.47	53.12	77.35
Phase 3					
Instron (kg)	510	6.19	1.02	3.28	9.12
Cook Loss (%)	1019	22.22	5.90	4.88	45.31
Lipid (%)	503	3.41	1.73	1.09	13.43
Dry Matter (%)	503	35.37	3.13	20.01	43.09
Cholesterol (mg/g)	503	89.46	16.60	43.00	149.00
Moisture (%)	508	65.52	2.39	57.70	83.26
Phases 1, 2, and 3					
Instron (kg)	1891	6.01	1.12	2.00	10.51
Cook Loss (%)	3773	22.66	5.80	2.72	48.41
Lipid (%)	1862	3.27	1.33	0.96	13.43
Moisture (%)	1871	65.71	2.47	53.12	83.26

n=number of samples in mean Std Dev=standard deviation percentage of 58.4, although this may be attributed to the higher internal endpoint temperature of 85°C. Mean cholesterol contents of Phase 2 and Phase 3 differ by over 6 mg/g. The wide ranges of cholesterol content (43 to 203 mg/g) between pork loin samples and high standard deviations may account for this difference.

Very high correlations ($P<0.01$) are observed between moisture and all sensory parameters (juiciness, tenderness, chewiness, and pork flavor) for phases 1, 2, and 3 (Table 4). Juiciness was significantly negatively correlated with cooked lipid in Phase 1 and in the combined analysis of all three phases, although correlations were low (-0.08 and -0.05, respectively). Pork flavor was not correlated with raw lipid in any of the phases, but it was correlated with cooked lipid in phases 1 and 2. Tenderness was correlated with raw lipid content in all phases, and with cooked lipid in Phases 2, 3 and the three phases combined.

Instron puncture, measured in kilograms force to compress the sample 80% of original height using a five star puncture probe, was significantly highly correlated ($P<0.001$) with juiciness, tenderness, and chewiness in all three phases (Table 5). Instron puncture was only significantly correlated with pork flavor in Phase 2 and not significantly correlated with off flavor in any phase. Table 6 shows

Table 4. Simple correlation coefficients between sensory parameters and chemical measurements

	Cooked Moisture	Cooked Lipid	Raw Lipid
Phase 1			
Juiciness	0.47***	-0.07	0.06
Tenderness	0.23***	0.11**	0.10**
Chewiness	-0.14**	-0.09*	-0.07*
Pork Flavor	-0.18***	0.21***	0.19
Phase 2			
Juiciness	0.60***	-0.10	-0.02
Tenderness	0.26***	0.11**	-0.10**
Chewiness	-0.11**	-0.16***	-0.17***
Pork Flavor	-0.22***	0.18***	0.07
Off Flavor	0.10**	0.01	0.03
P2hase 3			
Juiciness	0.48***	0.04	0.04
Tenderness	0.33***	0.11*	0.10*
Chewiness	-0.21***	-0.08	-0.08
Pork Flavor	-0.12**	0.02	-0.01
Off Flavor	0.06	-0.11**	-0.13**
Phases 1, 2, and 3			
Juiciness	0.46***	-0.05*	0.00
Tenderness	0.27***	0.10***	0.10***
Chewiness	-0.15***	-0.11***	-0.11***
Pork Flavor	-0.06**	0.07*	0.13***
Off Flavor	0.08**	-0.05	-0.04

***=P<.001 **=P<.01 *=P<.05

Table 5. Simple correlation coefficients between sensory parameters and Instron puncture (kg)

	Phase 1 Instron (kg)	Phase 2 Instron (kg)	Phase 3 Instron (kg)
Juiciness	-0.25***	-0.27***	-0.33***
Tenderness	-0.50***	-0.52***	-0.56***
Chewiness	0.47***	0.46***	0.52***
Pork Flavor	-0.02	-0.09*	0.04
Off Flavor	nm	-0.01	0.03

***=P<.001 **=P<.01 *=P<.05 nm=not measured significant correlations between moisture and juiciness for all breeds in Phase 2, except for the Chester White.

Lack of correlation in this breed is probably due to the low number (only 7) of animals tested of this breed. Yorkshire, Duroc, Spotted and Poland breeds produced significant correlations between moisture and tenderness. Moisture and pork flavor are significantly correlated in Yorkshire, Duroc, and Berkshire breeds (Table 6). The Spotted is the only breed with significant correlations between cooked lipid content and juiciness (Table 7). Hampshire and Spotted produced significant correlations between cooked lipid and tenderness, and Yorkshire and Spotted breeds have significant correlations between cooked lipid content and pork flavor (Table 7).

Yorkshire, Spotted, and Landrace are significantly higher in both raw and cooked lipid contents than other breeds (Table 8). Breed effects have likewise been reported for intramuscular fat content of the longissimus muscle (Hiner and Alsmeyer, 1964). Moisture contents are not significantly different between breeds which may account for high correlations between moisture and juiciness for all breeds. Juiciness has been reported (Hiner and Alsmeyer, 1964) to have a breed effect, although no differences in juiciness were found in this study. This may be the result of different internal endpoint cooking temperatures (85^{o}C

Table 6. Simple correlation coefficients between moisture contents of eight different breeds (Phase 2) and sensory and Instron parameters

Breed	Juiciness	Tenderness	Chewiness	Pork Flavor	Off Flavor	Instron
1	0.58***	0.23*	-0.07	-0.25**	0.01	-0.18*
2	0.66***	0.36**	-0.07	-0.24*	0.16	-0.37**
3	0.70***	0.14	-0.06	0.02	0.05	-0.07
4	0.42**	0.32*	-0.24	-0.29	0.17	-0.29
5	0.32	0.53	-0.55	NA	NA	-0.62
6	0.69***	0.36*	-0.03	-0.31	0.31	-0.23
7	0.76***	0.28	-0.27	-0.35*	0.24	-0.40*
8	0.51***	0.01	0.23	-0.37	0.17	0.06

***=P<.001 **=P<.01 *=P<.05

Table 7. Simple correlation coefficients between cooked lipid contents of eight different breeds (Phase 2) and sensory and Instron parameters

Breed	Juiciness	Tenderness	Chewiness	Pork Flavor	Off Flavor	Instron
1	-0.07	0.16	-0.21*	0.19*	0.03	-0.20*
2	-0.20	-0.07	-0.16	0.19	0.13	0.09
3	-0.01	0.29*	-0.32**	0.12	0.18	-0.14
4	0.31*	0.31*	-0.13	0.66**	0.26	-0.41**
5	0.25	0.52	-0.21	NA	NA	-0.15
6	-0.31	-0.06	-0.14	0.18	-0.22	-0.15
7	-0.32	-0.04	-0.01	-0.07	-0.18	0.01
8	-0.11	0.24	-0.33	0.17	-0.18	-0.41**

***=P<.001 **=P<.01 *=P<.05

Table 8. Means of sensory, Instron, and chemical measurements for eight different breeds (Phase 2)

B	n	J	T	C	PF	OF	INST	MOIS	RLIP	CLIP
1	129	3.25	3.33	2.67	2.09	1.04	6.43	65.59	2.96	3.54
2	95	3.17	3.23	2.70	2.07	1.03	6.65	65.47	2.73	3.18
3	80	3.22	3.18	2.80	2.11	1.04	6.64	65.46	2.69	3.25
4	45	3.29	3.45	2.69	2.10	1.07	6.31	65.99	2.85	3.33
5	7	3.57	3.21	2.64	2.04	1.00	6.80	67.26	2.05	2.02
6	33	3.22	3.34	2.78	2.09	1.05	6.81	65.65	2.48	2.75
7	37	3.26	3.19	2.91	2.07	1.05	6.38	66.32	2.49	2.82
8	63	3.06	3.14	2.90	2.13	1.02	6.81	65.08	3.36	3.85

B=breed n=number in mean J=juiciness T=tenderness C=chewiness PF=pork flavor OF=off flavor INST=instron puncture (kg) MOIS=moisture content (%) RLIP= raw lipid content (%) CLIP=cooked lipid content (%)

compared to 71°C) and/or any number of different handling procedures.

When divided into four cooked lipid groups ranging from a mean lipid content of 1.73 percent to 6.28 percent, there was no difference between fat groups for any of the sensory parameters measured (Table 9). This indicates that loin chops with lipid contents at very low levels are not different in juiciness, tenderness, chewiness, pork flavor or off flavor than loin chops with high livels fo fat content. Although analysis of groups has been established for backfat levels (Wood et al., 1989; Hiner et al., 1965; Dikeman, 1987; and Murphy and Carlin, 1960), marbling level, color and muscle structure (Davis et al., 1975), shear force (Hodgson et al., 1991 and DeVol et al., 1988), and overall palatibility and juiciness (Hodgson et al., 1991), analysis for fat and moisture grouping could not be found in the literature.

As mean moisture content increased in three moisture groups (Table 10), both juiciness and tenderness significantly increased. This indicates an important relationship between moisture and sensory parameters of juiciness and tenderness.

Very few significant correlations are observed between cooked lipid and sensory parameters or Instron puncture (Table 11) while strong correlations were observed between

Table 9. Sensory score means from broiled pork loins for four cooked lipid groups

Group	Ave % Lipid	n	J	T	C	PF	OF
Phase 1							
1	1.69	70	2.71	3.24	2.63	2.90	
2	2.52	303	2.59	3.33	2.63	2.98	
3	3.43	219	2.50	3.45	2.52	3.05	
4	5.11	150	2.47	3.50	2.45	3.25	
Phase 2							
1	1.73	91	3.37	3.16	2.89	2.03	1.04
2	2.47	213	3.30	3.28	2.75	2.07	1.04
3	3.73	251	3.10	3.28	2.73	2.10	1.05
4	5.99	65	3.19	3.46	2.47	2.17	1.04
Phase 3							
1	1.73	65	2.86	2.96	2.86	2.01	1.07
2	2.51	183	2.96	3.06	2.78	2.00	1.04
3	3.81	193	2.89	3.07	2.74	2.01	1.02
4	6.31	61	3.01	3.25	2.70	2.01	1.02

n=number in mean J=juiciness T=tenderness C=chewiness
PF=pork flavor OF=off flavor

Table 10. Sensory scores from broiled pork loin chops for three moisture groups

Group	Ave % Moisture	n	J	T	C	PF	OF
Phase 1							
1	63.37	261	1.99	3.24	2.60	3.16	
2	66.37	371	2.72	3.36	2.62	3.03	
3	69.62	120	3.22	3.83	2.30	2.88	
Phase 2							
1	63.20	232	2.71	3.11	2.80	2.14	1.03
2	66.51	281	3.43	3.34	2.70	2.07	1.05
3	69.13	99	3.86	3.54	2.64	2.04	1.06
Phase 3							
1	63.18	193	2.52	2.84	2.90	2.02	1.02
2	66.38	246	3.10	3.13	2.72	2.00	1.05
3	69.02	69	3.47	3.51	2.52	2.01	1.03

n=number in mean J=juiciness T=tenderness C=chewiness
PF=pork flavor OF=off flavor

Table 11. Simple correlation coefficients between sensory parameters or Instron puncture and four cooked lipid(%) groups

	J	T	C	PF	OF	INST
Phase 1						
1	-0.14	-0.17	0.05	-0.18		0.22
2	-0.08	0.05	-0.06	0.11*		-0.10
3	-0.03	-0.03	0.03	0.09		-0.06
4	-0.05	0.17*	-0.12	0.10		-0.11
Phase 2						
1	-0.14	-0.02	-0.02	-0.15	0.02	0.06
2	-0.00	-0.02	0.06	0.05	-0.04	-0.01
3	-0.10	0.02	-0.09	0.15**	-0.02	-0.01
4	0.08	0.17	-0.13	-0.16	0.04	-0.03
Phase 3						
1	0.10	0.08	-0.18	0.04	0.16	0.02
2	-0.05	-0.03	0.00	0.09	-0.01	0.07
3	-0.01	-0.02	0.00	0.07	-0.13	-0.03
4	0.11	0.06	-0.13	-0.11	-0.05	-0.03

J=juiciness T=tenderness C=chewiness PF=pork flavor
OF=off flavor INST=instron puncture (kg)
**=P<.01 *=P<.05

moisture and sensory parameters of juiciness and tenderness (Table 12). Again, this emphasizes the importance of moisture in sensory quality.

Results of stepwise regression analysis conducted to determine the contribution of independent variables to juiciness, tenderness, and pork flavor for Phases 2 and 3 are presented in Table 13. Percent cook loss and percent raw dry matter were significant contributors to all three sensory parameters. This shows the importance of cooking methods and temperatures to minimize cooking losses and obtain juicy, tender, and flavorful pork loin chops, and also the importance of moisture within the raw sample. Instron puncture was the most important factor in tenderness, as expected because of the high correlation between these parameters, but it was also the most important contributor to juiciness. Cooked lipid (%) is the least important factor in juiciness, tenderness, and pork flavor in all three prediction equations. DeVol et al. (1988) reported that percentage fat was the most important contributor to tenderness and pork flavor and the second contributor behind final pH to juiciness. This difference may be due to a number of or combination of variations between the studies, including endpoint temperature, freezing of samples, number of samples, and breeds used.

Table 12. Simple correlation coefficients between sensory parameters or Instron puncture and three cooked moisture (%) groups

	J	T	C	PF	OF	INST
Phase 1						
1	0.19***	0.32***	-0.25***	0.22***		-0.32***
2	0.21***	0.19***	-0.11*	0.10*		-0.21***
3	0.08	0.23**	-0.23**	0.08		-0.11
Phase 2						
1	0.28***	0.33***	-0.39***	-0.01	-0.07	-0.32***
2	0.13*	0.20**	-0.14*	-0.12*	0.14*	-0.30***
3	0.03	0.11	-0.02	0.06	0.19*	-0.05
Phase 3						
1	0.31***	0.28***	-0.16*	-0.03	-0.07	-0.34***
2	0.24**	0.27***	-0.16**	0.10	-0.16*	-0.24**
3	0.39**	0.38**	-0.32**	-0.23	0.19	-0.29**

J=juiciness T=tenderness C=chewiness PF=pork flavor
OF=off flavor INST=instron puncture (kg)
***=P<.001 **=P<.01 *=P<.05

Table 13. Stepwise regression to predict sensory parameters (Phases 2 and 3)

	Juiciness	Tenderness	Pork Flavor
Intercept	0.2646	3.3760	2.1704
Instron (kg)	-0.0435	-0.2211	
Cook Loss (%)	-0.0551	-0.0105	0.0042
Dry Matter (%) (raw tissue)	-0.0394	-0.0378	-0.0096
Moisture (%) (cooked tissue)	0.0795	0.0419	
Lipid (%) (cooked tissue)	0.0822	0.0794	0.0132
R-Square	0.4597	0.3187	0.0483

CONCLUSIONS

Fat content of boneless pork loin chops may have less of an influence on sensory attributes of juiciness and tenderness than once thought. Segmentation of data into groups based on moisture and fat contents demonstrated that juiciness and tenderness are not as affected by fat levels as they are by moisture levels. Moisture may play a much more important role in sensory palatability than which it has been given credit. It is necessary, therefore, to practice handling and cooking procedures that ensure maximum moisture retention in cooked pork loin chops.

Breed may also influence the sensory quality of cooked pork loin chops. Moisture and lipid contents of loins from pigs with different genetic backgrounds vary, and therefore it is reasonable that sensory factors will vary. This effect appears small, but it does contribute to the overall sensory quality.

Juiciness and tenderness can be predicted by Instron puncture, percent cook loss, percent raw dry matter, percent cooked moisture content, and percent cooked lipid content. Flavor can be predicted by percent cook loss, percent raw dry matter, and percent cooked lipid content.

REFERENCES

Acuff, G. R., Savell, J. W., Cross, H. R., Boxer, M. K., and Vanderzant, C. 1988. Microbiological and sensory characteristics of pork loin chops: role of intramuscular fat. Meat Sci. 23:139.

Allain, C. C., Poon, L. S., Chan, C. S. G., and Fu, P. C. 1974. Enzymatic determination of total serum cholesterol. Clinical Chemistry 20:470.

Allen, C. E. 1987. A perspective on the implications of animal fat on human health. Reciprocal Meat Conference Proceedings 40:115.

Amerine, M. A., Pangborn, R. M., and Roessler, E. B. 1965. Principles of sensory evaluation of food. Academic Press, New York.

Anderson, B. A. 1983. Composition of foods: pork products: raw, processed, prepared. Agric. Handbook No. 8-10. Human Nutr. Info. Serv., U.S. Dept. Agric. Washington D. C. U.S. Govt. Print. Off.

Batcher, O. M., Dawson, E. H., Gilpin, G. L., and Eisen, J. N. 1962. Quality and physical composition of various cuts of raw and cooked pork. Food Tech. 16:104.

Batcher, O. M., and Dawson, E. H. 1960. Consumer quality of selected muscles of raw and cooked pork. Food Tech. 14:69.

Berndtson, W. E. 1991. A simple, rapid, and reliable method for selecting or assessing the number of replicates for animal experiments. J. Anim. Sci. 69:67.

Bourne, M. C. 1967. Deformation testing of foods. 1. A precise technique for performing the deformation test. J. Food Sci. 32:601.

Boyd, J. V. and Sherman, P. 1975. A study of force-compression conditions associated with hardness evaluation in several foods. J. Texture Studies 6:507.

Buege, D. R. 1990. Nutrient composition of pork. Pages 32-33 in E. M. Urenos, ed. Food and Nutrition News. Vol. 62 No. 5. National Live Stock and Meat Board, Chicago, Il.

Calkins, C. R., and Hellerich, T. L. 1990. Factors influencing fat content of cooked pork lean. J. Anim. Sci. 68 (Suppl. 1):325.

Cameron, N. D., and Enser, M. B. 1991. Fatty acid composition of lipid in longissimus dorsi muscle of Duroc and British Landrace pigs and its relationship with eating quality. Meat Sci. 29:295.

Cameron, N. D. 1990. Genetic and phenotypic parameters for carcass traits, meat and eating quality traits in pigs. Livestock Prod. Sci. 26:119.

Cameron, N. D., Warriss, P. D., Porter, S. J., and Enser, M. B. 1990. Comparison of Duroc and British Landrace pigs for meat and eating quality. Meat Sci. 27:227.

Caul, J. F. 1957. The profile method of flavor analysis. Adv. Food Res. 7:1.

Courington, S. M. 1988. Pork and the consumer market. National Live Stock and Meat Board Publ., Chicago, Il.

Cundiff, L. V. 1983. The application of genetic principles and genetic engineering to improve efficiency of lean meat production. Reciprocal Meat Conference Proceedings 36:11.

Davis, G. W., Smith, G. C., Carpenter, Z. L., and Freund, R. J. 1978. Segmentation of fresh pork loins into quality groups. J. Anim. Sci. 46:1618.

Davis, G. W., Smith, G. C., Carpenter, Z. L., and Cross, H. R. 1975. Relationships of quality indicators to palatability attributes of pork loins. J. Anim. Sci. 41:1305.

DeVol, D. L., McKeith, F. K., Bechtel, P. J., Novakofski, J., Shanks, R. D., and Carr, T. R. 1988. Variation in composition and palatability traits and relationships between muscle characteristics and palatability in a random sample of pork carcasses. J. Anim. Sci. 66:385.

Dikeman, M. E. 1987. Fat reduction in animals and the effects on palatability and consumer acceptance of meat products. Reciprocal Meat Conference Proceedings 40:93.

Finney, E. E., Jr. 1969. Objective measurements for texture in foods. J. Texture Studies 1:18.

Folch, J., Lees, M., and Stanley, G. H. S. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497.

Forrest, J. C., Kuei, C. H., Oreutt, M. W., Schinckel, A. P., Stouffer, J. R., and Judge, M. D. 1989. A review of potential new methods of on-line pork carcass evaluation. J. Anim. Sci. 67:2164.

Gardze, C., Bowers, J. A., Craig, J., and Allee, G. 1979. Sensory evaluations of roasts from boars, barrows, gilts and ovariectomized gilts. J. Food Sci. 44:617.

Harmon, C. J., Ramsey, C. B., and Davis, G. W. 1990. Effect of cooking method on consumer acceptance and composition of hot-processed pork loins. J. Anim. Sci. 68:143.

Heymann, H., Hedrick, H. B., Karrasch, M. A., Eggeman, M. K., and Ellersieck, M. R. 1990. Sensory and chemical characteristics of fresh pork roasts cooked to different endpoint temperatures. J. Food Sci. 55:613.

Hiner, R. L., Thornton, J. W., and Alsmeyer, R. H. 1965. Palatability and quantity of pork as influenced by breed and fatness. J. Food Sci. 30:550.

Hinnergardt, L. C. and Tuomy, J. M. 1970. A penetrometer test to measure meat tenderness. J. Food Sci. 35:312.

Hodgson, R. R., Davis, G. W., Smith, G. C., Savell, J. W., and Cross, H. R. 1991. Relationships between pork loin palatability traits and physical characteristics of cooked chops. J. Anim. Sci. 69:4858.

Johnson, L. P., Miller, M. F., Haydon, K. D., and Reagan, J. O. 1990. The prediction of percentage fat in pork carcasses. J. Anim. Sci. 68:4185.

Jones, S. L., Carr, T. R., and McKeith, F. K. 1987. Palatability and storage characteristics of precooked pork roasts. J. Food Sci. 52:279.

Jeremiah, L. E., Murray, A. C., and Gibson, L. L. 1990. The effects of differences in ingerent muscle quality and frozen storage on the flavor and texture profiles of pork loin roasts. Meat Sci. 27:305.

Kauffman, R. G., Carpenter, Z. L., Bray, R. W., and Hoekstra, W. G. 1964. Biochemical properties of pork and their relationship to quality II. Intramuscular fat. J. Food Sci. 29:70.

Kellogg, T. F., Rogers, R. W., and Miller, H. W. 1977. Differences in tissue fatty acids and cholesterol of swine from different genetic backgrounds. J. Anim. Sci. 44:47.

Kempster, A. J., Dilworth, A. W., Evans, D. G., and Fisher, K. D. 1986. The effects of fat thickness and sex on pig meat quality with special reference to the problems associated with overleanness. Anim. Prod. 43:517.

Knutson, B. 1991. Panel discussion: what consumers think about meat. Pages 3-13 in W. C. Haines and M. Ratliff, eds. Michigan State University Food Industry Topics. Food Industry Institute, East Lansing, Mi.

Malphrus, L. D., Skelly, G. C., and Johnston, W. E. 1975. Consumer preference for pork cuts with varying degrees of marbling. S. Carolina Agr. Exp. Sta. Bull. 583.

McKay, R. M., and Garnett, I. 1988. Growth and fat deposition curves in swine. Can. J. Anim. Sci. 68:57.

Meilgaard, M., Civille, G. V., and Carr, T. T. 1991. Sensory evaluation techniques. CRC Press, Boca Raton, Florida.

Miller, M. F., Shackelford, S. D., Hayden, K. D., and Reagan, J. O. 1990. Determination of the alteration in fatty acid profiles, sensory characteristics and carcass traits of swine fed elevated levels of monounsaturated fats in the diet. J. Anim. Sci. 68:1624.

Morgan, J. B. , Calkins, C. R., and Mandigo, R. W. 1988. Effect of trim level, cooking method, and chop type on lipid retention, caloric content, and cholesterol level in cooked pork. J. Food Sci. 53:1602.

Moskowitz, H. R. 1981. Relating subjective and instrumental measures. A psychophysical overview. J. Food Qual. 4:15.

Moss, M., Holden, J. M., Ono, K., Cross, R., Slover, H., Berry, B., Lanza, E., Thompson, R., Wolf, W., Vanderslice, J., Johnson, H., and Stewart, K. 1983. Nutrient composition of fresh retail pork. J. Food Sci. 48:1767.

Murphy, M. O., and Carlin, A. F. 1961. Relation of marbling, cooking yield, and eating quality of pork chops to backfat thickness on hog carcasses. Food Tech. 15:57.

Novakofski, J., Park, S., Bechtel, P. J., and McKeith, F. K. 1989. Composition of cooked pork chops: effect of removing subcutaneous fat before cooking. J. Food Sci. 54:15.

Oltrogge, M. H. and Prusa, K. J. 1987. Sensory analysis and Instron measurements of variable-power microwave-heated baking hen breasts. Poul. Sci. 66:1548.

Renk, B. Z., Kauffmann, R. G., and Schaefer, D. M. 1985. Effect of temperature and method of cookery on the retention of intramuscular lipid in beef and pork. J. Anim. Sci. 61:876.

Rhodes, D. N. 1970. Meat quality: influence of fatness of pigs on the eating quality of pork. 21:572.

Saffle, R. L., and Bratzler, L. J. 1959. The effect of fatness on some processing and palatability characteristics of pork carcasses. Food Tech. 13:236.

Savell, J. W., and Cross, H. R. 1988. The role of fat in the palatability of beef, pork, and lamb. Page 346 in Designing Foods. National Academy Press, Washington D. C.

Seideman, S. C., Crouse, J. D., and Mersmann, H. J. 1989. Carcass, muscle and meat characteristics of lean and obese pigs. J. Anim. Sci. 67:2950.

Siemens, A. L., Heymann, H., Hedrick, H. B., Karrasch, M. A., Ellersieck, M., and Eggeman, M. K. 1990. Effects of external fat cover, bone removal and endpoint cooking temperature on sensory attributes and composition of pork center loin chops and roasts. J. Sen. Stud. 4:179.

Siemens, A. L., Erickson, T. B., Lipsey, R. J., Hedrick, H. B., Seever, D. L., Bates, R. O., Williams, F. L.,Jr., and Yokley, S. W. 1989. Predictive equations for estimating lean cuts, fat standardized lean, chemical composition, bone and value of pork carcasses. J. Anim. Sci. 67:2033.

Simmons, S. L., Carr, T. R., and McKeith, F. K. 1985. Effects of internal temperature and thickness on palatability of pork loin chops. J. Food Sci. 50:313.

Skelley, G. C., Borgman, R. F., Handlin, D. L., Acton, J. C., McConnell, J. C., Wardlaw, F. B., and Evans, E. J. 1975. Influence of diet on quality, fatty acids and acceptability of pork. J. Anim. Sci. 41:1298.

Skelley, G. C., and Handlin, D. L. 1973. Pork acceptability as influenced by breed, sex, carcass measurements and cutability. J. Anim. Sci. 32:239.

Skelley, G. C., Handlin, D. L., and Bonnette, T. E. 1973. Pork acceptability and its relationship to carcass quality. J. Anim. Sci. 36:488.

Swanson, G. M. 1991. Diet and chronic disease prevention. Pages 14-21 in W. C. Haines, and M. Ratliff, eds. Michigan State University Food Industry Topics. Food Industry Institute, East Lansing, Mi.

Swatland, H. J. 1982. The challenges of improving meat quality. Can. J. Anim. Sci. 62:15.

Szczesniak, A. S. 1968. Correlations between objective and sensory texture measurements. Food Tech. 22:49.

Szczesniak, A. S. 1963. Classification of textural characteristics. J. Food Sci. 28:385.

Szczesniak, A. S., Brandt, M. A., and Friedman, H. H. 1963. Development of standard rating scales for mechanical parameters of texture and correlation between the objective and the sensory methods of texture evaluation. J. Food Sci. 28:397.

Tess, M. W. 1983. The application of modeling research to increase lean meat products. Reciprocal Meat Conference Proceedings 36:5.

Villegas, F. J., Hedrick, H. B., Veum, T. L., McFate, K. L., and Bailey, M. E. 1973. Effect of diet and breed on fatty acid composition of porcine adipose tissue. J. Anim. Sci. 36:663.

Warriss, P. D., Brown, S. N., Franklin, J. G., and Kestin, S. C. 1990. The thickness and quality of backfat in various pig breeds and their relationship to intramuscular fat and the stting of joints from the carcasses. Meat Sci. 28:21.

Warriss, P. D., Brown, S. N., Lopez-Bote, C., Bevis, E. A., and Adams, S. J. M. 1989. Evaluation of lean meat quality in pigs using two electronic probes. Meat Sci. 25:281.

Watts, D. R., and Cliplef, R. L. 1976. Consumer criteria for pork related to sensory, physical, and descriptive attributes. J. Inst. Can. Sci. Tech. Aliment. 9:151.

Wood, J. D., Enser, M., Whittington, F. M., Moncrieff, C. B., and Kempster, A. J. 1989. Backfat composition in pigs: differences between fat thickness groups and sexes. Livestock Prod. Sci. 22:351.

Wood, J. D., Mottram, D. S., and Brown, A. J. 1981. A note on the eating quality of pork form lean pigs. Anim. Prod. 32:117.

Wood, J. D., Dransfield, E., and Rhodes, D. N. 1979. The influence of breed on the carcass and eating quality of pork. J. Sci. Food Agric. 30:493.

Zondagh, I. B., Holmes, Z. A., Rowe, K., and Schrumpf, D. E. 1986. Prediction of pork and lamb meat quality characteristics. J. Food Sci. 51:40.

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