# HISTOLOGICAL CHARACTERISTICS OF PORK LOIN CHOPS COOKED BY DRY OR MOIST HEAT IN A CONVENTIONAL OR MICROWAVE OVEN

by

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B.S., Kansas State University, 1965

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A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

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# INTRODUCTION

Some research that compared microwave and conventionally-cooked pork has shown differences in sensory, physical, or chemical characteristics of muscles that were attributable to cooking method (Montgomery et al., 1977; Korschgen et al., 1976; Apgar et al., 1959). Decareau (1968, 1974) stated that past research comparing conventional and microwave cookery, for the most part, was done without consideration for the differences between the heating processes of conventional (conduction) and microwave (volume heating) cooking.

To date, microwave cookery has not been used widely to study effects of production and processing treatments on meat quality attributes. However, Baldwin et al. (1979) showed that the influence of a technique, such as cooking in a microwave oven, on differences among treatments can be assessed by appropriate statistical analyses. They compared the sensitivity of microwave and conventional cooking of meat by applying statistical analyses to data from two studies similar in experimental design. Their analyses indicated that microwave heating is as suitable as conventional heating for cooking tender cuts of meat. Differences among sensory scores and shear values were a function of treatment differences and not cooking method.

Joubert (1956) stated that knowledge regarding structural composition of muscle affords a ready means of comparing effects of given treatments on meat. Histological methods have been used widely to observe the changes occurring in cooked meat structure in relation to sensory, physical and chemical changes (Carpenter et al., 1963; Hiner et al., 1950;

Buck and Black, 1968; Herring et al., 1965). Chambers (1979) reported no significant differences in histological characteristics of samples from U.S. Choice top round steaks cooked by conventional or microwave methods. Bowers and Heier (1970) reported no differences in fragmentation of turkey muscle cooked conventionally or in a microwave oven.

No research was found where fat, connective tissue, muscle fiber width, or sarcomere length were studied histologically for pork cooked by dry or moist heat in the microwave or conventional oven. The objectives of this research were: 1) to compare the quantity and distribution of fat, quantity of connective tissue, muscle fiber width, and sarcomere length in the longissimus dorsi (LD) muscle of pork loin chops cooked by four oven-heat treatment combinations, including microwave heating, 2) to compare the histological characteristics of raw porcine LD muscle with those of porcine LD cooked by the four oven/heat treatment combinations, and 3) to study relationships of selected histological characteristics of cooked porcine muscle to sensory characteristics, ether extract, and Warner-Bratzler shear force of the cooked muscle.

# REVIEW OF LITERATURE

## Composition and structure of muscle tissue

Muscle fibers. Skeletal (voluntary) muscle is made up of muscle fibers, connective tissue, and adipose tissue (Paul, 1972). The muscle fibers are held together by a network of connective tissue, the endomysium. The fibers consist of fibrils or myofibrils with the basic unit (sarcomere) repeating itself every few microns (Szczesniak and Torgeson, 1965; Fukuzawa and Briskey, 1970). Each sarcomere is composed of alternating bands that have varying staining affinity for iron hematoxylin and give the appearance of cross-striations. The cross-striations are categorized as A bands, I bands and Z bands (Copenhaver, 1964). The space between two Z bands is called the sarcomere and is usually about 2.5 μ long when the muscle is at rest. The unit can shorten or elongate considerably during contraction or stretching of the fiber as the thin filaments move toward or away from the center of the sarcomere. Those changes produce the variations in I band width observed in muscle fixed at different stages of contraction (Paul, 1972; Hiner et al., 1953). The myofibrils are enclosed in a thin, colorless, elastic membrane called the sarcolemma. Within the muscle, the fibers are grouped into bundles or fasciculi. Size of the bundles varies in different muscles and helps determine the grain or texture of the raw meat (Szczesniak and Torgeson, 1965). The perimysium, which varies in thickness between and within muscles, is the connective tissue surrounding the fasciculi.

Connective tissue. Connective tissue consists of collagenous, elastic, and reticular protein fibers embedded in an amorphous ground

substance. The proportions and arrangement of these fibers and the composition of the ground substance differentiates the various types of connective tissue (Szczesniak and Torgeson, 1965). Collagenous connective tissue is composed of variable components and is relatively high (5 to 13%) in hydroxyproline (American Meat Institute, 1960; Meyer, 1968). Collagenous tissue is found between, around, and within the fasciculi, and fine strands are found in the endomysium of certain muscles. The fibers are colorless, longitudinally striated and consist of unbranched units with many parallel fibrils (0.3-0.5 μ in diameter), which appear to be composed of helically entwined filaments that are themselves bundles of large numbers of polypeptide chains (Paul, 1972). When arranged in wavy rows, the fibers can be stretched until the waves are straightened giving them flexibility, but not elasticity (Lowe, 1955). The amount of collagenous tissue may fluctuate from muscle to muscle, 0.5 to 30% or more (Hamm, 1960; Paul, 1965; Szczeniak and Torgeson, 1965).

Elastic fibers are less abundant than collagenous fibers and are found largely in tendons and ligaments (Meyer, 1968).

Reticulin occurs as highly branched fibers where connective tissue adjoins other tissues as between endomysial collagenous fibers and muscle fiber membranes or sarcolemma.

Fat. Fat occurs in meat as adipose tissue, marbling and separable fat. Adipose tissue is a specialized form of connective tissue serving both as a supporting substance and as a deposit of usable neutral fat (American Meat Institute, 1960; Szczesniak and Torgeson, 1965; Meyer, 1968). Blumer (1963) stated that marbling is a popular name used to indicate a more explicit term for intramuscular fat; in the strictest sense it refers only to fat on the meat surface visible to the unaided

eye. Intramuscular fat refers to visible fat and microscopic deposits between muscle fibers. Marbling is a representative of neutral fat deposits in the muscle. An undifferentiated cell stores droplets of fat, which eventually coalesce into one large globule (American Meat Institute, 1960). Large masses, regularly located, are grouped by connective tissue strands into primary, secondary and tertiary lobules. Most of the intramuscular fat is deposited between the fasciculi, but some is deposited between the muscle fibers; the total amount varies among muscles. The amount of fat in a particular muscle also may vary in different locations within the muscle. For example, the longissimus dorsi muscle of a 2-month old pig contained 8% fat at the anterior end and 2% fat at the posterior end (Lowe, 1955).

## Effects of structural components on sensory characteristics

Sensory characteristics of meat depend on many factors. Muscle fiber width and sarcomere length, quantity of fibrous and granular connective tissue, and quantity and distribution of fat have been associated with sensory properties.

Muscle fiber width and sarcomere length. Researchers consider fiber width (or diameter) and sarcomere length of the muscle fibers important when studying the muscle histologically. Generally, the narrower the muscle fiber, the more tender the meat. Montgomery et al. (1977) observed that muscle fiber diameter was positively related ($r = 0.55$) to Warner-Bratzler shear values, indicating that samples with large fiber diameters tended to be less tender than muscle with small fiber diameters. Carpenter et al. (1963) reported a decrease in taste-panel tenderness scores with an increase in muscle fiber diameter of porcine longissimus

dorsi muscle ($r = -0.48^{**}$). However, Hostetler and Landmann (1968) found more narrow fibers/unit area in tough than in tender meat. They postulated that when proteins of myofilaments denature, immobile water is freed and the diameter of the fiber is decreased in a manner parallel to the loss of water-holding capacity. Their work may indicate that smaller fibers are less hydrated than wider fibers, and that hydration is a factor involved in decreasing scores for tenderness.

Tuma et al. (1962) and Swanson et al. (1965) found a decrease ($P < 0.05$) in fiber diameter from dorsal to lateral position of longissimus dorsi muscle of beef. Their data indicated that studies pertaining to muscle fiber diameter or meat texture should have carefully-designed sampling plans.

Herring et al. (1965) reported a low simple correlation ($r = -0.28$) between sarcomere length and shear force values. Cross et al. (1972) reported that longer sarcomere lengths were associated slightly ($r = 0.10$) with less dense fibers and increased tenderness in ovine loin chops as scored by a sensory panel. Gillis and Henrickson (1967) and Howard and Judge (1968) found measurement of sarcomere length at one place in a fiber did not represent adequately the overall contraction state of the muscle.

Connective tissue. Greater amounts of connective tissue as determined histologically and chemically have been related to increased shear values and decreased tenderness by several workers (Hiner et al., 1950; Callow, 1957; and Parrish et al., 1961). Carpenter et al. (1963) found no significant relationships between tenderness measurements and total amount of connective tissue when working with porcine longissimus dorsi muscle. The coarseness of connective tissue strands was inversely related ($r = -0.38^{**}$) to tenderness, the coarser the connective tissue the less

tender the meat. Collagenous connective tissue is of great importance, because it composes the majority of the connective tissue in skeletal muscle (Forrest et al., 1975). Some of the collagen is solubilized when collagenous connective tissue is heated, which suggests that the amount of residual collagen rather than total connective tissue may be important (Morgan et al., 1933; Ritchey and Cover, 1962; Ritchey et al., 1963; Hill, 1966). Less dense or indistinct fasciculi appear to be the principal source of solubilized collagen (Lowe, 1955; Strandine et al., 1949). Cross et al. (1972) stated that percentage of soluble collagen had a low but significant correlation ($r = 0.17^{**}$) with tenderness of lamb muscle. Cross et al. (1973) reported low values for amount of connective tissue, but a high percentage of soluble collagen in bovine longissimus dorsi muscle that was rated low in tenderness by a sensory panel and by shear force values. It seemed obvious that panel tenderness ratings and resistance to shear depend more on muscle fiber properties than on connective tissue components of the LD muscle. Irvin and Cover (1959); Cross et al. (1973) and Szczesniak and Torgeson (1965) stated that because both muscle fibers and connective tissues contribute to toughness, data such as WB shear values or taste panel scores, which do not distinguish between muscle fibers and connective tissue, may not be closely related to histological or chemical tests for connective tissue. Szczesniak and Torgeson (1965) stated that although histological methods for estimation of connective tissue are generally only qualitative, the stained sections give valuable information on the type and distribution of patterns of connective tissue fibers, on fiber size, and on the amount of ground substance. That type of information is essential for fundamental studies on structure and role of connective tissue in meat tenderness.

Hamm (1960) observed that collagen in meat may contribute considerably to the water-holding capacity. Water-holding capacity of meat is increased with an increased amount of connective tissue. That property may contribute to the juiciness of cooked muscle.

Fat. The effect of fat content on the amount of connective tissue present in a muscle is of fundamental interest. Cover (1959) found that tenderness of connective tissue as demonstrated by chemical changes was not affected by an increase in the amount of chemical fat present. Therefore, she believed that any effect fat has on tenderness of connective tissue is by indirect means. Carpenter et al. (1963) and Hiner et al. (1955) found an increase in intramuscular fat was accompanied by a decrease in coarseness of connective tissue in pork and beef, respectively. That may be a result of separation and formation of a loose network of collagen fibers by formation of fat cells between the fibers. Ramsbottom et al. (1945) stated that the amount of connective tissue associated with intramuscular fat may explain why it is impossible to show a high relationship between high fat content of muscles and low shear values. Wang et al. (1954) presented the view that it is not total fat in a muscle but its distribution throughout the muscle that affects tenderness. A positive correlation was found between tenderness of cooked samples and quantity of linear fats as determined by measuring under the microscope the longest axis of fat droplets in a section of raw beef. Those considerations may explain, at least partially, conflicting results obtained in different laboratories on the correlation between tenderness and fat deposition.

Fat is found between the muscle bundles and within muscle bundles and may lubricate fibers and fibrils and enhance tenderness. Batcher et al. (1962) reported that tenderness and juiciness were related to marbling

score or to intramuscular fat content of pork muscle in only a few cases; correlation varied with the muscle in the carcass. Those results contradict earlier findings of Batcher and Dawson (1960) in which marbling was correlated with sensory tenderness of cooked pork. Naumann et al. (1960) found that heavily marbled pork chops had lower Warner-Bratzler shear values. Henry et al. (1963) indicated a low but significant correlation (0.37**) between ether extract and pork tenderness. Harrington (1962) reported that mean chew counts and shear values both showed moderate, but significant correlations with marbling scores and intramuscular fat contents on 36 pork loins. Zessin et al. (1961) found that a reduction in intramuscular fat in pigs fed a restricted diet before slaughter was accompanied by reduced tenderness and juiciness of cooked roasts and chops. Pearson (1961) suggested that marbling may influence tenderness more in pork than in beef.

Effects of heating methods on structural components of the muscle

Muscle fiber width and sarcomere length. Satorius and Child (1938) reported a 12 to 16% decrease in muscle fiber diameters during coagulation of three bovine muscles heated by roasting to 58°C and a continued decrease with increased heating up to 67°C. Two research groups found that as fiber diameter increased, shear force increased (Hiner et al., 1953, $P < 0.001$ and Herring et al., 1965, $P < 0.01$) in bovine muscles roasted to internal temperatures of 60 or 66°C. Paul (1965) reported that muscle fiber width and sarcomere length decreased with conventional roasting of the psoas major muscle of rabbit. Reid (1971) reported smaller ($P < 0.01$) fiber diameters for bovine longissimus dorsi muscles cooked by dry heat (37.69 μ) than for longissimus dorsi muscle cooked by moist

heat (38.57 μ) to an end point temperature of 75°C. Montgomery et al. (1977) observed decreased ($P < 0.05$) diameters and increased ($P < 0.05$) sarcomere lengths with increased tenderness of hot-processed pork roasts precooked by conventional roasting. Microwave precooking of the pork roasts produced less tender meat.

Connective tissue. Paul (1963) found staining properties of collagenous tissue changed as heating progressed, eventually resulting in a structural change from fibrous to granular tissue. Winegarden et al. (1952) heated connective tissue strips in a thermostat-controlled water-bath and studied collagenous fibers under those conditions. The fibers shortened, lost their waviness, and appeared as if fused together. They found that the extent of the softening varied with the temperature and time of heating. The temperature at which softening began appeared to be 65°C, with increased softening as temperature increased. Carpenter et al. (1963) stated that it seemed reasonable to assume that marbling, which had infiltrated connective tissue, might aid in the ultimate alteration of collagenous tissue during cooking.

Numerous researchers (Winegarden et al., 1952; Griswold, 1955; Irvin and Cover, 1959; Yang and Couvillia, 1964; Bayne et al., 1971; Paul et al., 1973; Penfield and Meyer, 1975; Williams and Harrison, 1978) reported that collagen is partially degraded by either moist or dry conventional heating. The belief that moisture is needed to help solubilize collagen brought about the tradition of cooking less tender cuts of meat (those with a relatively high proportion of connective tissue) in a moist atmosphere (Paul, 1972). Cover (1941) stated that meat is approximately 70% water and probably needs no added moisture to soften the collagenous tissue.

Fielder et al. (1962) and Yang (1964) found that two bovine muscles cooked in a microwave oven had decreased ($P < 0.01$) collagen content. McCrae and Paul (1974) found that greater change in the histological appearance of connective tissue occurred with dry heat, microwave cooking than with cooking in a conventional oven by either moist or dry heat.

Fat. Fatty tissue, irrespective of amount of connective tissue, improved in tenderness when cooked conventionally (Ramsbottom et al., 1945; Carpenter et al., 1963). Wang et al. (1954) studied changes in beef muscles caused by heating to 82°C and observed that a fair amount of fat was released by diffusion from the fat cells and dispersed along the degraded collagen in a manner similar to emulsification. They suggested that the longer the cooking time and the higher the internal temperature, the greater the dispersion of fat. Chambers (1979) reported that differences in the mobility of the fat in meat cooked by conventional methods or in a microwave oven may be observed because the microwave oven heats the meat faster than conventional heating.

Tenderness and juiciness. Marshall (1960) reported that beef top-round roasts received higher scores for juiciness, tenderness, and flavor when cooked in a conventional oven than when cooked in an electronic (microwave) oven. Headley and Jacobson (1960) found that roasted and electronically cooked lamb legs did not differ in tenderness, but the meat cooked in the electronic oven appeared to be more done and received lower scores for juiciness and flavor than that cooked by conventional method. Korschgen and Baldwin (1978) reported that beef round roasts cooked at "High" (550W) and "Simmer" (250W) power levels by moist heat in a microwave oven had mean scores for juiciness that differed little from those for roasts cooked by moist heat, conventional oven to an internal

temperature of 98°C. An end point temperature of 98°C would be expected to produce extremely dry beef regardless of cooking method. Mean scores for tenderness were higher and shear values were lower for the conventionally cooked meat than for that cooked by microwaves.

# MATERIALS AND METHODS

Samples for the histological study reported here were available from another phase of the Agricultural Experiment Station project of which this study is a part. In the first phase of the project, cooking and sensory data and data for selected chemical and physical measurements were collected. Eight fresh pork loins (6 to 7.5 kg) were purchased on the local retail market.

Each loin was divided into 14 chops (numbered 0-13, approximately 3.5 cm. thick) (Fig. 1). Individual chops were wrapped in aluminum foil (0.0015 gauge), frozen at -20°C, and stored at -20°C for 1 to 3 weeks. There were eight replications of each of the following treatment combinations: conventional oven, dry heat (CD); conventional oven, moist heat (CM); microwave oven, dry heat (MD), and microwave oven, moist heat (MM). Details of the experimental design for cooking and cooking methods are given in the Appendix, pp. 48 to 54; respectively.

Histological samples were removed from the longissimus dorsi (LD) muscle of four randomly selected cooked chops from each loin and were used to study the effects of cooking by dry or moist heat in a conventional or microwave oven on: 1) muscle fiber width and sarcomere length, 2) quantity and distribution of fat, and 3) quantity and type of collagenous connective tissue. Also, samples for histological examination were taken from raw chops 0, 6 and 13 (anterior end, center, and posterior end of the pork loin) (Fig. 1) after freezing and thawing.

One sample was removed for histological measurements from each raw and cooked chop according to the sampling plan (Fig. 2). Samples were

Figure 1 - Sampling plan for pork loin

0-13 Number of chops in loin

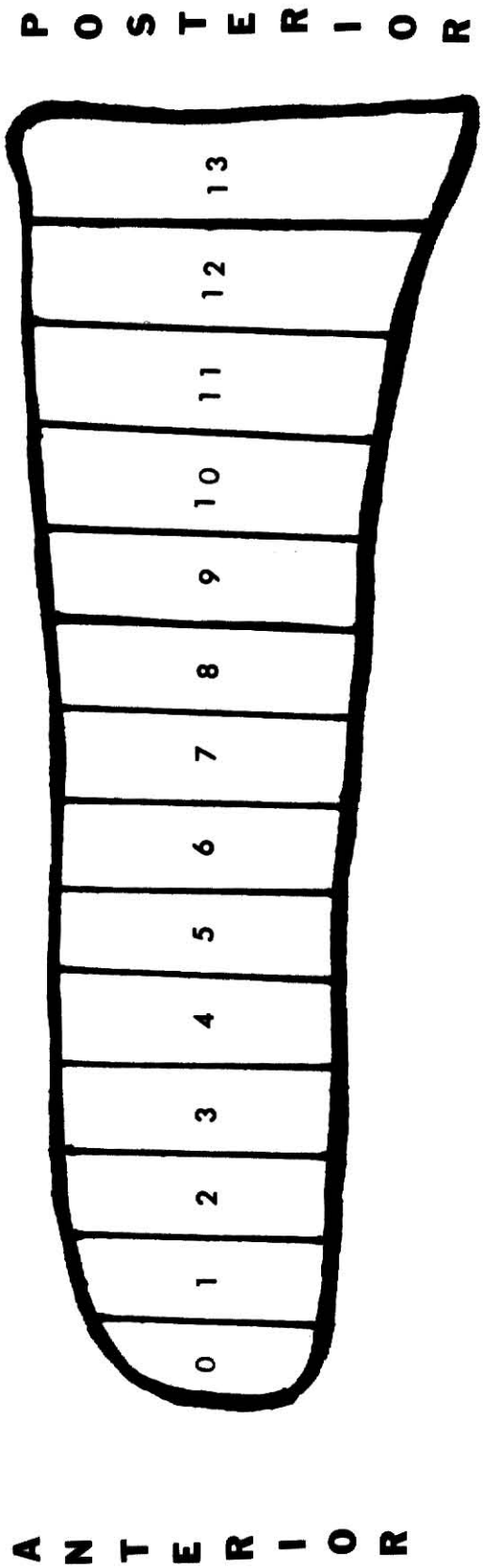

POSTERIOR
13
12
11
10
9
8
7
6
5
4
3
2
1
0
ANTERIOR

Fig. 2 - Sampling plan for cooked pork loin chops.

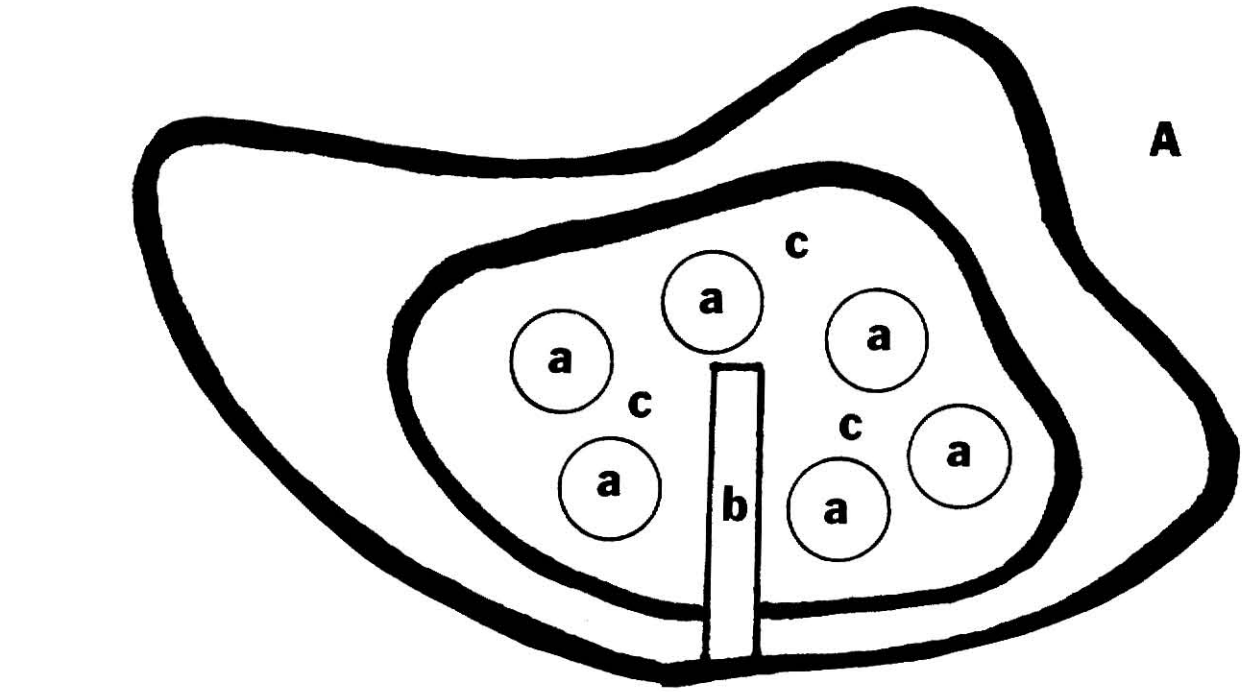
a. Cores for sensory evaluation.

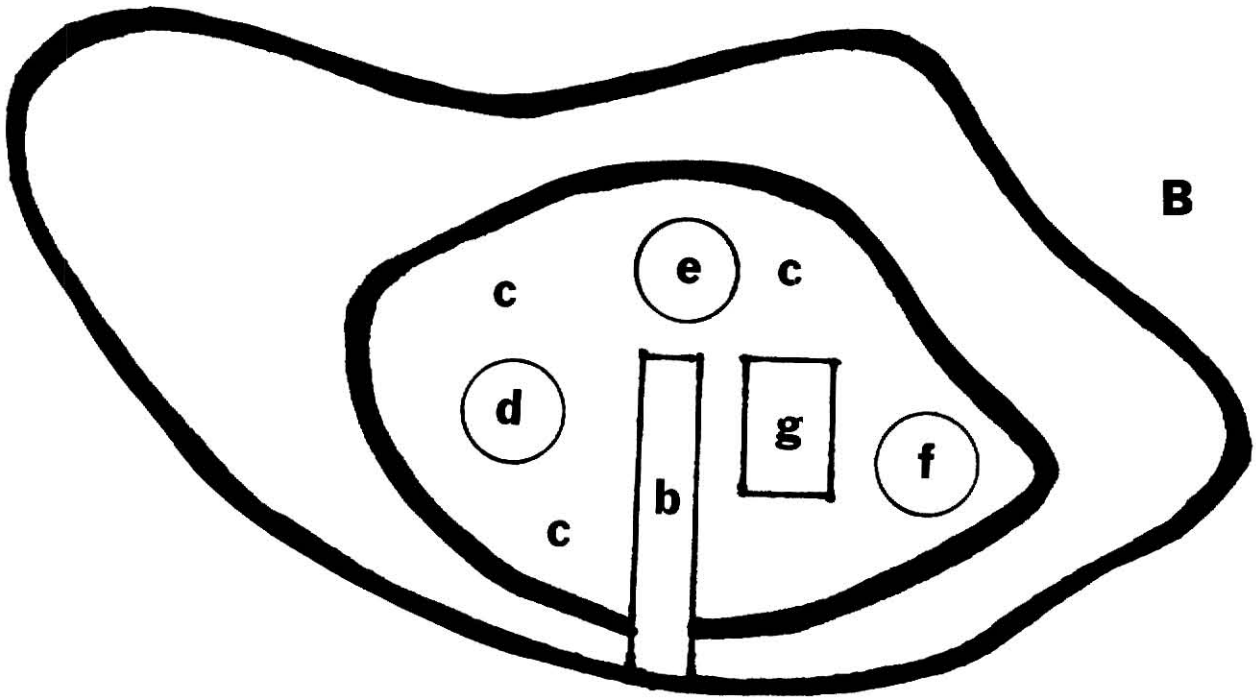
b. Thermometer hole.

c. pH, total moisture, ether extract, Gardner color-difference.

d,e,f. Warner-Bratzler shear and water holding capacity.

g. Histological evaluations.


A
c
a
a
a
c
c
a
a
b
a


B
c
e
c
d
g
f
b
c

fixed in physiological saline and 10% formalin solution and were held at 25°C until samples were sectioned, stained and mounted (approximately 120 days). The order of preparing sections for histological study was the same as that followed for cooking the chops.

A CTD International microtome was used to section a specimen of muscle tissue (approximately 1.0 X 1.0 X 0.5 cm.). A small amount of Cryoform, an embedding matrix, was placed on the microtome tissue holder. The tissue to be sectioned was placed on the holder, and the holder was inserted into the Cryostat Microtome. A commercial preparation of freon gas, Cryokwik, was used to initiate freezing of the tissue before quick freezing in the microtome. Sections, 10 μ thick, were cut longitudinally at a working temperature of -20°C for cooked tissue and -30°C for raw tissue. Each section was transferred directly to a microscope slide containing a thin layer of albumin fixative by lightly touching the slide to the section while it was still on the knife blade. A minimum of 48 sections were prepared from each specimen. Twenty-four sections were stained with alum hematoxylin and Sudan IV as described by Wu (1977) to differentiate the muscle fibers and fat, respectively (Appendix, p. 60). After the section was stained, a cover glass was mounted on the slide with glycerin jelly. The other 24 sections were stained using a procedure modified from Reid (1970) to differentiate muscle fibers and connective tissue (Appendix, p. 61). After each section was stained, a cover glass was mounted on the slide with Permount.

Five sections were selected randomly from the 24 sections stained with alum hematoxylin and Sudan IV. A three-member laboratory panel evaluated the five sections. An ocular micrometer was placed in the eyepiece of a Bausch and Lomb microscope with magnification of 430X to

measure the width and sarcomere lengths of 25 fibers (Forms I, II, III, and IV, Appendix, pp. 63 to 69) from each of 56 samples (24 raw tissue, 32 cooked tissue X 5 sections X 25 fibers = 7000 fibers).

Quantity and distribution of fat and quantity and type of collagenous tissue in 280 sections were estimated by the three-member panel. Slides were projected using a Bausch and Lomb microprojector, and each section was focused on a surface 60 cm. from the slide, giving a magnification of 44X. Scores for quantity and distribution of fat were assigned on a scale of 7-1 with 7 representing a large amount of fat or fat present in all areas of the section, and 1 representing no fat or fat present in a few areas. Scores for quantity of fibrous or granular collagenous connective tissue were assigned on a scale of 7-1 with 7 representing a large amount of fibrous or granular connective tissue in the section, and 1 representing no fibrous or granular connective tissue present (Form V, Appendix, p. 70).

Data for each measurement were analyzed by analysis of variance (AOV) to study differences among cooking treatment combinations for a randomized complete block design, blocked on the loin. The AOV was:

| Source of Variation | D/F |
|---|---|
| Loin | 7 |
| Type of Oven (O) | 1 |
| Type of Heat (H) | 1 |
| O X H | 1 |
| Error | 21 |
| Total | 31 |

All measurements, except quantity of granular connective tissue, were used to compare changes from raw to cooked specimens. The AOV was:

| Source of Variation | D/F |
|---|---|
| Loin | 7 |
| Treatment Combinations | 4 |
| Type of Oven (O) | 1 |
| Type of Heat (H) | 1 |
| O X H | 1 |
| Raw vs. Cooked | 1 |
| Error | 24 |
| Total | 39 |

Also, correlation coefficients were calculated for selected histological measurements and sensory, physical or chemical data from phase I of the project. Relationships were studied for:

Muscle fiber width vs

- Initial tenderness score
- Final tenderness score
- Warner-Bratzler shear value

Distribution of fat vs

- Initial tenderness score
- Final tenderness score
- Juiciness score

Quantity of collagenous connective tissue, fibrous or granular vs

- Initial tenderness score
- Final tenderness score
- Warner-Bratzler shear value
- Juiciness score

Sarcomere length vs

- Initial tenderness score
- Final tenderness score
- Warner-Bratzler shear value

Quantity of fat vs

- Initial tenderness score
- Final tenderness score
- Juiciness score
- Flavor intensity score
- Ether extract

# RESULTS AND DISCUSSION

Histological characteristics of LD muscle tissue from pork chops cooked by dry or moist heat were not affected significantly by type of oven, type of heat, or by interaction of type of oven X type of heat, except that muscle fiber sarcomere length was affected ($P < 0.05$) by type of heat (Tables 1, 2, and 3).

## Fat

Mean scores for quantity of fat in LD muscle increased with each heat treatment, mean scores increased ($P < 0.05$) from raw to cooked tissue for all treatment combinations except for CM (Table 4). Mean fat quantity scores for tissue cooked in the conventional oven differed ($P < 0.05$) between dry and moist heat with the mean score for CD increasing over that for the raw tissue by 11.4% more than the increase for CM tissue. The increase in fat quantity scores for tissue cooked in the microwave oven was not affected by type of heat. With moist heat, mean fat quantity scores for tissue cooked in the microwave oven (MM) increased 11.4% more than those for tissue cooked in the conventional oven (CM). Woolsey and Paul (1969) reported that more crude fat was extracted from cooked than from raw tissue. They stated that heating caused denaturation of protein and subsequent release of lipid previously complexed with protein. Chambers (1979) stated that if such changes in fat do occur during cooking, the released fat would stain and increase the quantity of fat observed histologically. In this study, it appears that dry heat enhanced the denaturation of the protein complex and the dispersion of the fat more

Table 1 - Means, standard errors,[a] and F-values for selected measurements by type of oven

| Measurement | Type of oven[b] | | F-value |
|---|---|---|---|
| | Conventional | Microwave | |
| Fat, relative quantity[c] | 5.0 (±0.24) | 5.3 (±0.24) | 0.42 |
| Fat distribution[d] | 4.2 (±0.23) | 4.5 (±0.23) | 0.44 |
| Quantity of fibrous collagenous connective tissue[e] | 3.8 (±0.14) | 3.8 (±0.14) | 0.01 |
| Quantity of granular collagenous connective tissue[f] | 5.2 (±0.25) | 4.6 (±0.25) | 2.61 |
| Fiber width, μ | 46.4 (±1.44) | 46.2 (±1.44) | 0.01 |
| Sarcomere length, μ | 1.7 (±0.04) | 1.6 (±0.04) | 0.63 |

[a]Values in parentheses are standard errors of the means.

[b]Dry and moist heat data combined.

[c]Range 7-1, large amount to none present.

[d]Range 7-1, present in all areas to present in few areas.

[e]Range 7-1, large amount to none present

[f]Range 7-1, large amount to none present.

Table 2 - Means, standard errors,[a] and F-values for selected measurements by type of heat[b]

| Measurement | Type of heat | | F-value |
|---|---|---|---|
| | Dry | Moist | |
| Fat, relative quantity[c] | 5.3 (±0.24) | 5.0 (±0.24) | 0.69 |
| Fat distribution[d] | 4.4 (±0.23) | 4.3 (±0.23) | 0.10 |
| Quantity of fibrous collagenous connective tissue[e] | 3.7 (±0.14) | 3.8 (±0.14) | 0.41 |
| Quantity of granular collagenous connective tissue[f] | 4.7 (±0.25) | 5.1 (±0.25) | 1.17 |
| Fiber width, μ | 45.4 (±1.44) | 47.3 (±1.44) | 0.87 |
| Sarcomere length, μ | 1.7 (±0.04) | 1.6 (±0.04) | 5.68* |

[a]Values in parentheses are standard errors of the means.

[b]Conventional and microwave oven data combined.

[c]Range 7-1, large amount to none present.

[d]Range 7-1, present in all areas to present in few areas.

[e]Range 7-1, large amount to none present.

[f]Range 7-1, large amount to none present.

* ($P < 0.05$)

Table 3 - Means, standard errors,[a] and F-values for selected measurements by type of oven and type of heat

| Measurement | Type of oven | Type of heat | | F-value |
|---|---|---|---|---|
| | | Dry | Moist | |
| Fat relative quantity[b] | Conventional | 5.3 (±0.34) | 4.8 (±0.34) | 0.76 |
| | Microwave | 5.3 (±0.34) | 5.3 (±0.34) | |
| Fat distribution[c] | Conventional | 4.5 (±0.33) | 4.0 (±0.33) | 0.87 |
| | Microwave | 4.4 (±0.33) | 4.6 (±0.33) | |
| Quantity of fibrous collagenous connective tissue[d] | Conventional | 3.8 (±0.21) | 3.8 (±0.21) | 1.14 |
| | Microwave | 3.6 (±0.21) | 4.0 (±0.21) | |
| Quantity of granular collagenous connective tissue[e] | Conventional | 4.8 (±0.35) | 5.6 (±0.35) | 1.77 |
| | Microwave | 4.7 (±0.35) | 4.6 (±0.35) | |
| Fiber width, μ | Conventional | 44.5 (±2.04) | 48.4 (±2.04) | 0.91 |
| | Microwave | 46.3 (±2.04 | 46.2 (±2.04) | |
| Sarcomere length, μ | Conventional | 1.8 (±0.06) | 1.6 (±0.06) | 0.35 |
| | Microwave | 1.7 (±0.06) | 1.6 (±0.06) | |

[a]Values in parentheses are standard errors of the means.

[b]Range 7-1, large amount to none present.

[c]Range 7-1, present in all areas to present in few areas.

[d]Range 7-1, large amount to none present.

[e]Range 7-1, large amount to none present.

Table 4 - Means, F-value and standard errors[a] for selected histological characteristics

| Measurement | Treatment[b] | | | | | F-value |
|---|---|---|---|---|---|---|
| | Raw | CD | MD | CM | MM | |
| Fat, relative quantity[c] | 4.4m (±0.14) | 5.3n (±0.24) | 5.3n (±0.24) | 4.8m (±0.24) | 5.3n (±0.24) | 5.29* |
| Percent change[d] | | +20.5 | +20.5 | +9.1 | +20.5 | |
| Fat distribution[e] | 3.7m (±0.14) | 4.5n (±0.24) | 4.4n (±0.24) | 4.0m (±0.24) | 4.6n (±0.24) | 3.62* |
| Percent change[d] | | +21.6 | +18.9 | + 8.1 | +24.3 | |
| Quantity of fibrous collagenous connective tissue[f] | 4.5 (±0.28 | 3.8 (±0.49) | 3.6 (±0.49) | 3.8 (±0.49) | 4.0 (±0.49) | 1.09 |
| Percent change[d] | | -15.6 | -20.0 | -15.6 | -11.1 | |
| Quantity of granular collagenous connective tissue[g,h] | 1.0 | 4.8 | 4.7 | 5.6 | 4.6 | |
| Percent change[d] | | +380.0 | +370.0 | +460.0 | +360.0 | |
| Fiber width, μ | 49.5m (±0.75) | 44.5n (±1.30) | 46.3n (±1.30) | 48.4m (±1.30) | 46.2n (±1.30) | 3.57* |
| Percent change[d] | | -10.1 | -6.5 | -2.2 | -6.7 | |

Table 4 - (concluded)

| Measurement | Treatment[b] | | | | | F-value |
|---|---|---|---|---|---|---|
| | Raw | CD | MD | CM | MM | |
| Sarcomere length, μ | 1.8m (±0.02) | 1.8m (±0.03) | 1.7n (±0.03) | 1.6n (±0.03) | 1.6n (±0.03) | 16.25*** |
| Percent change[d] | | 0.0 | -5.6 | -11.1 | -11.1 | |

[a]Values in parentheses are standard error of the mean.

[b]CD- Conventional, dry; MD- Microwave, dry; CM-Conventional, moist; MM- Microwave, moist.

[c]Range 7-1, large amount to none present.

[d]Values show percentage change differences from raw to cooked samples.

[e]Range 7-1, present in all areas to present in few areas.

[f]Range 7-1, large amount to none present.

[g]Range 7-1, large amount to none present.

[h]Data were not analyzed statistically.

[m,n]Means for a measurement bearing different letters differ significantly ($P \leq 0.05$).

* ($P \leq 0.05$)

*** ($P \leq 0.001$)

than did moist heat. Chambers (1979) postulated that a difference in the mobility of the fat in meat cooked by conventional methods or in a microwave oven may be observed, because the microwave oven heats the meat faster than conventional heating. That may be one reason for the observance of a greater quantity of fat in MM tissue than in CM tissue. Apgar et al. (1959) reported greater ($P < 0.05$) fat content (Modified Babcock method) in porcine LD muscle from pork roasts cooked by microwaves than in the LD of conventionally-cooked roasts.

Similar to fat quantity score, the mean score for fat distribution increased more (13.5%) for CD tissue than it did for CM tissue. Also with moist heat, microwave cooking appeared to have greater effect on mobility of the fat than did conventional cooking.

Connective tissue

There were no significant changes observed for quantity of fibrous collagenous tissue when the raw tissue was compared with tissue from muscle cooked by any of the four treatment combinations (Table 4). Mean scores for granular connective tissue indicated the greatest noticeable change from raw to cooked tissue for any of the histological measurements (Table 4). Those data were not analyzed statistically, because no granular tissue was observed in the raw tissue (a score of 1, Table 4). However, a medium quantity of granular connective tissue was observed histologically in muscle cooked by all treatment combinations (Table 4). Lowe (1955) and Strandine (1949) reported that less dense or indistinct fasciculi appeared to be the principal source of granular connective tissue. Indistinct fibers that may have been present but not noticeable in the raw tissue is a possible explanation for the granular tissue

appearing after cooking (Table 4). Skelton et al. (1963) stated that more total connective tissue in cooked meat than in raw meat may be attributable to swelling and redistribution of connective tissue during heating. They explained that as the collagenous tissue swells, it becomes granular and fills the spaces between muscle fibers, and there appears to be more collagenous tissue in cooked than in raw meat. Also, they stated that as muscle fibers shrink, spaces between the fibers increase and swollen collagenous tissue fills them. Redistribution of the collagenous tissue may cause the granular tissue to appear in more parts of the sections studied and give the appearance of large amounts of granular tissue.

Muscle fiber width

Mean muscle fibers widths decreased ($P < 0.05$) from raw to cooked tissue with all treatment combinations studied, except for CM (Table 4). The CD treatment caused the greatest decrease (10.1%) and CM treatment caused the least decrease (2.2%) of muscle fiber width (Table 4). Reid (1971) reported similar results for cooking bovine LD muscle to 75°C by dry and moist heat in a conventional oven. She observed smaller ($P < 0.01$) fiber diameters in muscle cooked by dry heat than in muscle cooked by moist heat. In this study, there was little difference between MD and MM for the change (0.2%) from raw to cooked tissue (Table 4).

The width of a large number of fibers was measured, because a large range in fiber width was anticipated. Width of individual muscle fibers ranged from 12 to 127.5 μ for raw tissue and from 10 to 130 μ for cooked tissue. Bourne (1960) reported a considerable range in the "diameter" of fibers in different voluntary muscles, with 10 to 100 μ commonly being accepted. Khan (1971) reported a range of 24.08 to 49.71 μ for the width

of fibers for raw tissue and a range of 23.30 to 43.49 μ for cooked tissue from one bovine LD muscle. He measured fiber width by the same method as the one used for this study. Joubert (1955) found a range in fiber diameter of 28 to 73 μ for raw bovine LD muscle.

Sarcomere length

Mean sarcomere length of fibers in CD tissue did not differ from that of fibers in raw tissue; whereas, mean sarcomere length of fibers in CM tissue was 11.1% less than that of fibers in raw tissue. With the microwave oven, the difference between dry and moist heat for change in sarcomere length from raw to cooked tissue was only 5.5% (Table 4). With dry heat, the sarcomere length of fibers in MD tissue was 5.6% less than that of fibers in raw tissue. With moist heat, the percentage change in sarcomere length from raw to cooked tissue was not affected by type of oven (Table 4).

Relationships between paired variates

Correlation coefficients were calculated within each oven/heat treatment combination to study relationships of histological characteristics to selected sensory, physical, and chemical measurements. Shindell (1964) classified correlation coefficients from 0.00 to 0.39 as low correlations, those from 0.40 to 0.79 as moderate correlations, and coefficients from 0.80 to 1.00 as high correlations. Relationships for this study are discussed using that classification.

Fat quantity score was correlated moderately with juiciness ($r = -0.72^*$) and flavor ($r = -0.76^*$) scores for MD chops. With CD, CM, and MM, correlations for the fat quantity score vs juiciness and flavor scores

were low (Table 5). Those low correlation coefficients indicate that both juiciness and flavor were dependent on factors other than fat quantity. Carpenter et al. (1963) reported a positive, but a low correlation ($r = 0.38^{**}$) between pork flavor intensity and histologically observed fat quantity.

The correlation coefficients for quantity of fat vs ether extract were moderate for CD ($r = 0.63$) and MD ($r = 0.59$), respectively (Table 5). As fat quantity increased, ether extract also increased for CD and MD pork. That relationship was expected, because ether extract is a chemical measure of fat quantity.

For CD, a moderate correlation coefficient ($r = 0.48$) occurred for quantity of fat score vs initial tenderness score. A negative, moderate correlation coefficient was observed between quantity of fat and Warner-Bratzler shear values for pork given the same treatment. Correlation coefficients for quantity of fat and both initial tenderness scores and WB shear values were low for MD and MM (Table 5). Ramsbottom et al. (1945) stated that the amount of connective tissue associated with intramuscular fat may explain why it is impossible to always show a positive relationship between high fat quantity and tenderness.

Fat distribution appeared to have some influence on the juiciness and tenderness of pork cooked by dry heat (Table 5). A moderate, negative, correlation occurred between fat distribution and both juiciness ($r = -0.65$) and final tenderness scores ($r = -0.41$) for MD chops. Juiciness and tenderness decreased as fat was observed in more areas in the muscle tissue. Chambers (1979) stated that when fat was present in a few areas it might be more agglomerated than when it is evenly distributed throughout the muscle, which could cause the mouth to detect more fat at one time

Table 5 - Correlation coefficients for selected paired variates on the basis of oven/heat treatment combinations

| Paired variates - DF=6 | Heat treatments[a] CD | MD | CM | MM |
|---|---|---|---|---|
| Relative quantity fat vs | | | | |
| Initial tenderness score | 0.48 | 0.12 | 0.37 | 0.16 |
| Final tenderness score | -0.03 | -0.23 | 0.23 | 0.20 |
| Warner-Bratzler shear | -0.53 | -0.15 | 0.11 | -0.22 |
| Juiciness score | 0.21 | -0.72* | 0.18 | 0.15 |
| Flavor intensity score | -0.05 | -0.76* | -0.30 | 0.19 |
| Ether extract | 0.63 | 0.59 | -0.06 | -0.16 |
| Fat distribution vs | | | | |
| Initial tenderness score | 0.64 | -0.11 | -0.06 | 0.40 |
| Final tenderness score | -0.01 | -0.41 | -0.23 | 0.43 |
| Warner-Bratzler shear | -0.43 | 0.34 | 0.28 | 0.03 |
| Juiciness score | 0.15 | -0.65 | -0.16 | 0.45 |
| Quantity fibrous collagenous connective tissue vs | | | | |
| Initial tenderness score | -0.31 | -0.43 | 0.58 | -0.12 |
| Final tenderness score | 0.10 | -0.49 | 0.28 | -0.13 |
| Warner-Bratzler shear | 0.38 | 0.34 | -0.04 | 0.40 |
| Juiciness score | -0.24 | 0.17 | 0.66 | 0.09 |
| Quantity granular collagenous connective tissue vs | | | | |
| Initial tenderness score | 0.06 | 0.04 | -0.31 | 0.76* |
| Final tenderness score | 0.33 | 0.05 | -0.27 | 0.33 |
| Warner-Bratzler shear | -0.24 | -0.17 | -0.10 | 0.06 |
| Juiciness score | 0.67 | -0.26 | -0.66 | 0.29 |
| Muscle fiber width vs | | | | |
| Initial tenderness score | 0.09 | 0.64 | -0.37 | 0.35 |
| Final tenderness score | 0.07 | 0.82* | -0.37 | 0.20 |
| Warner-Bratzler shear | -0.21 | -0.89** | 0.22 | -0.91** |

Table 5 - (Concluded)

| Paired variates - DF=6 | Heat treatments | | | |
|---|---|---|---|---|
| | CD | MD | CM | MM |
| Sarcomere length vs | | | | |
| Initial tenderness score | 0.47 | 0.44 | 0.46 | 0.17 |
| Final tenderness score | 0.09 | 0.33 | 0.54 | 0.10 |
| Warner-Bratzler shear | -0.82* | -0.17 | 0.18 | 0.28 |

[a]CD- Conventional, dry; MD-Microwave, dry; CM- Conventional, moist; MM- Microwave, moist.

* $P \leq 0.05$, 4 = 0.707

** $P \leq 0.01$, r = 0.834

and give the impression of greater juiciness. For CD chops, correlation coefficients were moderate between fat distribution and initial tenderness score ($r = 0.64$) or WB shear values ($r = -0.43$). WB shear values decreased as fat was observed in more areas in the muscle. The relationship was moderate for initial ($r = 0.40$) and final ($r = 0.43$) tenderness vs fat distribution for MM. Initial and final tenderness increased as fat appeared in more areas. Carpenter et al. (1963) and Hiner et al. (1955) found an increase in intramuscular fat to be accompanied by a decrease in coarseness of connective tissue, which might aid in ultimate alteration of collagenous tissue during cooking.

Quantity of fibrous connective tissue correlated moderately with initial ($r = -0.43$) and final ($r = -0.49$) tenderness scores for MD chops. As quantity of fibrous connective tissue decreased, initial and final tenderness increased. A moderate correlation ($r = 0.58$) occurred between quantity of fibrous connective tissue and initial tenderness scores for CM chops (Table 5). The initial impression of tenderness decreased as quantity of fibrous connective tissue decreased.

Paul (1972) stated that, generally, tenderness should increase (thus WB shear values should decrease) with a decrease in fibrous collagenous tissue. In this study, that was true for pork cooked by all oven/heat treatment combinations except CM. For CM pork, fibrous collagenous connective tissue did not appear to be related to tenderness (Table 5).

Hamm (1960) pointed out that collagen in meat may contribute considerably to an increase in the water-holding capacity of meat, and it may increase juiciness of the muscle. In this study, moderate correlation ($r = 0.66$) was observed between quantity of fibrous collagenous tissue and

juiciness scores for CM shops (Table 5). Juiciness scores decreased as quantity of fibrous connective tissue decreased.

Generally, granular connective tissue had little relation to tenderness of pork cooked by any of the four oven/heat treatments (Table 5). For MM, the quantity of granular collagenous tissue correlated moderately with initial tenderness scores having an r value of 0.76*. However, all other r values for quantity of granular collagenous tissue and tenderness measurements were low.

For CD chops, a moderate correlation coefficient (r = 0.67) occurred for quantity of granular connective tissue score vs juiciness score. Conversely, for CM chops, juiciness score vs quantity of granular collagenous tissue correlated negatively (r = -0.66). As the granular connective tissue increased, juiciness decreased. Granular connective tissue may have helped to increase WHC and juiciness in chops cooked by CD more than it did in chops cooked by CM.

Generally, for chops cooked in the microwave oven, the narrower the muscle fiber widths, the less tender the meat (initial, final and WB shear). High correlations (MD, r = -0.89**; MM, r = -0.91**) were observed between muscle fiber width and WB shear values, but for chops cooked in a conventional oven, low correlations (CD, r = -0.21; CM, r = 0.22) occurred for muscle fiber width vs WB shear value (Table 5). For chops cooked by MD, the score for muscle fiber width decreased as initial and final tenderness scores decreased with correlation coefficients of r = 0.64 and r = 0.82*, respectively. Correlation coefficients for muscle fiber width vs both initial and final tenderness scores for MM chops were r = 0.35 and r = 0.20, respectively. Hostetler and Landmann (1968) explained that when proteins of myofilaments denature, immobile

water is freed, and diameter of the fiber is decreased; thus, hydration may be a factor involved in decreased tenderness of muscle. Chambers (1979) observed the opposite effect; in his study, tissue from beef round steaks cooked in the microwave oven had narrower muscle fibers than tissue from steaks cooked in a conventional oven, but conventionally-cooked steaks were tenderer than those cooked by microwaves.

Sarcomere length in muscle fibers was related moderately to initial tenderness scores for CD ($r = 0.47$), CM ($r = 0.46$), and MD ($r = 0.44$) pork chops. Sarcomere lengths were related moderately to final tenderness scores only for CM chops ($r = 0.54$). As sarcomere length decreased, tenderness decreased. All correlation coefficients for sarcomere length and WB shear values were low, except for CD ($r = 0.82*$). Montgomery et al. (1977) observed increased ($P < 0.05$) sarcomere lengths with increased tenderness of hot-processed pork roasts pre-cooked by conventional roasting when compared to hot-processed pork roasts pre-cooked in the microwave oven.

# SUMMARY

Selected histological characteristics of thirty-two pork loin chops cooked by dry heat (modified roasting) or by moist heat (oven-film bag) in a conventional or a microwave oven were studied. Samples were removed from the LD muscle of four randomly selected cooked chops from each loin. Data for sensory, chemical, and physical characteristics were available to study relationships between those characteristics and histological characteristics. Data were analyzed by analysis of variance for a randomized complete-block design, blocked on the loin, to study influences of type of oven, type of heat, and interactions of type of oven X type of heat on the histological properties of the muscle. Histological characteristics of raw porcine LD muscle were compared to those of porcine LD muscle cooked by the four oven/heat treatment combinations. Correlation coefficients were calculated for selected paired variates within oven/heat treatment groups.

Differences in histological characteristics attributable to type of oven, type of heat, or to interaction of type of oven X type of heat were not significant, except that muscle fiber sarcomere length was affected by type of heat. Differences between type of heat were attributable to the differences between dry and moist heat in both ovens with the difference for the conventional oven being slightly greater than that for the microwave oven.

Mean scores for quantity of fat and fat distribution indicated that microwave cooking had a slightly greater effect on mobility of the fat than did conventional cooking. Low correlation coefficients for juiciness or

flavor vs quantity of fat indicated that juiciness and flavor of the pork chops were dependent on factors other than fat quantity. However, moderate correlations for fat distribution and initial tenderness score or WB shear values indicated that more even fat distribution had some influence on the tenderness of pork cooked by CD and MM.

There were no significant changes in fibrous connective tissue when the raw tissue was compared with tissue cooked by any of the four oven/heat treatment combinations. For all treatment combinations except CM, correlation was moderate for fibrous connective tissue and WB shear values; WB shear values decreased with a decrease in fibrous connective tissue. Fibrous connective tissue did not appear to be related to WB shear values for CM pork. Moderate correlation was observed between quantity of fibrous connective tissue and juiciness scores for CM chops; a decrease in juiciness occurred with a decrease of fibrous connective tissue.

Mean scores for granular connective tissue indicated the greatest change from raw to cooked tissue for any of the histological measurements. More granular connective tissue appeared in CM pork than in tissue cooked by CD, MD or MM. Granular connective tissue had little relation to tenderness measurements of pork cooked by any of the four oven/heat treatments, except for the initial tenderness score for MM tissue. More granular connective tissue appeared to have helped to increase WHC and juiciness in chops cooked by CD more than in chops cooked by CM.

Mean muscle fiber widths decreased from raw to cooked tissue for all treatment combinations studied except for CM. Generally, for chops cooked in the microwave oven, the narrower the muscle fibers, the less tender the meat (initial and final panel scores and WB shear values).

A decrease in mean fiber sarcomere length was observed from raw to cooked tissue for all treatment combinations except for CD. Decreased sarcomere lengths in fibers in CM pork loin chops appeared to be related to decreased tenderness.

Generally, correlation coefficients indicated that the histological study did not consistently explain the attributes of pork loin chops measured by a sensory panel or by objective measurements related to the sensory attributes.

# CONCLUSIONS

Under the conditions of this study, it was concluded that:

1. Histological characteristics should not be used exclusively to predict the sensory qualities of pork loin chops.
2. Generally, histological characteristics of conventionally-cooked pork loin chops tend to help explain more about the sensory, physical, or chemical properties of those chops than is explained by the histological characteristics of microwave-cooked chops.
3. LD muscle from pork loin chops cooked by dry or moist heat in a conventional or microwave oven to an end point temperature of 75°C does not differ significantly in histological estimates of fat quantity, fat distribution, quantity of fibrous connective tissue, quantity of granular connective tissue, or muscle fiber width.
4. Histological estimates for changes from raw to cooked tissue indicate that fewer significant changes occur in pork LD muscle with the CM treatment than occur with the other three oven/heat treatment combinations.

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## ACKNOWLEDGMENTS

The author wishes to express sincere appreciation to Dr. Dorothy L. Harrison, Professor of Foods and Nutrition and Major Professor, for her assistance and guidance throughout the research and in preparing the manuscript and for her encouragement throughout the period of graduate study. The writer wishes to thank Dr. Arthur D. Dayton, Professor and Head, Department of Statistics, for the experimental design and analysis of data; Dr. Carole S. Setser, Assistant Professor, Department of Foods and Nutrition, and Dr. Donald H. Kropf, Professor, Department of Animal Sciences and Industry, for serving on the writer's advisory committee.

Appreciation is expressed to Kwang-Ok Kim, Jolene Neufeld and Ruth Vilander for evaluating microscope sections and to fellow students for their encouragement throughout the project.

Special thanks are given to my husband, Marion, and children, Cindy, Brian and Susie; for their patience and support throughout the period of my graduate study.

# APPENDIX

# MATERIALS AND METHODS FOR COOKING PORTION OF THE PROJECT

## Experimental design and cooking

The experimental design for cooking was a randomized complete block, blocked on the loin. There were 16 evaluation periods with four chops (2 from each of two treatments) cooked at each period. Each pork loin provided chops for one replication of each treatment.

Pairs of adjacent chops were assigned randomly to cooking treatments. Before each cooking period, chops designated by the experimental design were defrosted in the foil wrap 5 hours at approximately 25°C and 18 hours at approximately 4°C, then unwrapped and weighed. Chops for each treatment were weighed as a pair.

Thermometers (-20° to 105°C, 15 cm long) were inserted with the bulb (approximately 1.3 cm long) in the geometric center of the LD muscle. Temperature was recorded on removal from the oven and after post-oven temperature rise. Glass thermometers with mercury in the column were used for conventionally cooked chops, and glass thermometers with a non-polar organic liquid in the column were used for microwave cooked chops.

Cooking time and post-oven temperature rise were determined in preliminary work. The CM, MD and MM chops were removed from the ovens at a mean temperature of 71°, 73° and 70°C respectively, and allowed to rise in temperature for approximately 2-4 minutes, to achieve a final internal temperature of 75°C. CD chops were cooked to 75°C; preliminary work indicated no post-oven temperature rise for that treatment.

For contentional modified roasting (CD), each chop was placed on a wire rack 12.7 cm high set in a shallow pan. Chops were cooked in an electric rotary hearth oven at 177°C. For microwave roasting (MD), each

chop was placed on a Pyrex casserole lid (diameter, 15.5 cm) in a 22.8 cm Pyrex pie plate, placed in the center of the rotary hearth in the microwave oven (Sharp R-8200), and cooked at the roast setting (approximately 422 watts, p. 55).

For moist heat cooking, each chop was placed in an oven film bag and closed with a twister tie or with masking tape for microwave-cooked chops. Five holes were punctured in each bag with a skewer, to allow steam to escape and to prevent the bag from breaking. The thermometer was inserted through the bag into the position described earlier. For CM, the entire system for each chop was placed on a low rack in a shallow roasting pan and cooked in an electric rotary hearth oven at 177°C. For MM, the entire system for each chop was placed on a Pyrex casserole lid (diameter, 15.5 cm) in a 22.8 cm Pyrex pie plate in the center of the rotary hearth in the microwave oven and cooked at the roast setting (approximately 422 watts).

## Sensory evaluation

Flavor, juiciness and tenderness of 1.3 X 2.0 cm cores of cooked meat were evaluated by a 7-member laboratory panel using a 5-1 point intensity scale (p. 50). Instructions for evaluation were given to panel members during preliminary work (p. 51).

Cores were presented to panel members in the top of half-pint double boilers set over warm water (approximately 65°C), and the entire system was placed on an electric hot tray at low heat (approximately 35°C). All sensory evaluation took place within 20 minutes after preparation of samples.

Form 1. Score Card for Sensory Evaluation of Porcine Longissimus Dorsi Muscle

Panel Member _____ Date _____

| Sample | Flavor | Juiciness | Tenderness | | | Comments |
|---|---|---|---|---|---|---|
| | | | Initial score | No. of chews | Score based on chews | |
| | | | | | | |
| | | | | | | |

Flavor

5 Intense meat flavor
4 Moderate meaty flavor
3 Slight meaty flavor
2 Perceptible meaty flavor
1 No meaty flavor

Juiciness

5 Juicy
4 Moderately juicy
3 Neither juicy nor dry
2 Slightly dry
1 Dry

Tenderness

5 Tender
4 Moderately tender
3 Neither tender nor tough
2 Slightly tough
1 Tough

# INSTRUCTIONS TO JUDGES FOR SENSORY EVALUATION OF PORCINE LONGISSIMUS DORSI MUSCLE

For scoring sensory characteristics, each judge is to select two cores of meat at random from each double boiler. Use one core for assessing flavor and juiciness, and one core for evaluating tenderness and counting chews.

## Scoring For Flavor And Juiciness

Record a score for flavor and another for juiciness within a range of 5 to 1 that describes your impression of the sample. Refer to the score card for descriptive terms for specific scores within the range of 5 to 1. Record the score describing your impression of flavor and juiciness at the beginning of the chewing process.

## Scoring For Tenderness

### Initial score

Record a score for tenderness within a range of 5 to 1 that describes your initial impression of the sample. Refer to the score card for descriptive terms for specific scores within the range of 5 to 1.

### Chew count

Count the number of times you chew the 1.3-cm core of meat before swallowing. Chew until the core is masticated completely, then swallow. Record the number of chews required to masticate the core. Record a score from 5 to 1 that describes your impression of the tenderness of the core. Refer to the score card for descriptive terms within the range of 5 to 1.

Use the number of chews to help you standardize your tenderness scores from day to day. Set up for yourself a range of the number of chews for each score from 5 to 1. For example, if you chew 25 to 35 times, record a score of 4 if that score represents your impression of tenderness; then, if you chew 35 to 45 times, record a score of 3; continuing to reduce the score by a given number of increased chews. Each judge sets his own range of chews for a given score.

## Comments

Comments about the samples and/or explaining your reason for giving a particular score are helpful. Please comment on any aspect of a sample that you believe affects its overall sensory qualities.

Take your time to score each sample. Water is provided for rinsing your mouth between samples.

## Shear value

Tenderness was measured on cooked samples by shearing 1.3 cm cores on a Warner-Bratzler (W-B) shearing apparatus equipped with a 22.7 kg dynamometer. Three cores were taken from each cooked chop, one from each end and one from the center of the LD muscle. Duplicate measurements were taken on each core and over-all shear value was the average for the three shear cores.

## Ether extract

Percentage of ether extract in samples of both raw and cooked meat was measured in triplicate by the analytical laboratory of the Department of Animal Science and Industry at Kansas State University. A modified AOAC method (AOAC, 1976) was used for the analysis.

Table 6 - Experimental design for cooking

| Cooking period | Loin | Replication | Chop[a] position | Treatment[b] |
|---|---|---|---|---|
| 1 | I | 1 | 7,8 | 3 |
| | | | 3,4 | 1 |
| 2 | | | 9,10 | 2 |
| | | | 1,2,5 | 4 |
| 3 | II | 2 | 8,9 | 2 |
| | | | 4,5 | 4 |
| 4 | | | 1,2,3 | 3 |
| | | | 11,12 | 1 |
| 5 | III | 3 | 9,10 | 2 |
| | | | 5,7 | 3 |
| 6 | | | 3,4 | 1 |
| | | | 8,11 | 4 |
| 7 | IV | 4 | 8,9 | 3 |
| | | | 4,5 | 2 |
| 8 | | | 10,11 | 1 |
| | | | 2,3 | 4 |
| 9 | V | 5 | 4,5 | 4 |
| | | | 7,8 | 1 |
| 10 | | | 9,10 | 2 |
| | | | 2,3 | 3 |
| 11 | VI | 6 | 3,4 | 2 |
| | | | 7,8 | 4 |
| 12 | | | 9,10 | 3 |
| | | | 11,12 | 1 |

Table 6 - (Concluded)

| Cooking period | Loin | Replication | Chop[a] position | Treatment[b] |
|---|---|---|---|---|
| 13 | VII | 7 | 7,8 | 2 |
| | | | 4,5 | 4 |
| 14 | | | 1,2,3 | 1 |
| | | | 9,10 | 3 |
| 15 | VIII | 8 | 3,4 | 3 |
| | | | 7,8 | 1 |
| 16 | | | 11,12 | 4 |
| | | | 9,10 | 2 |

[a]Chops were randomly selected from loin.

[b]Treatments randomly assigned to chops.

1 Conventional oven, dry heat, CD
2 Conventional oven, moist heat, CM
3 Microwave oven, dry heat, MD
4 Microwave oven, moist heat, MM

Purpose: To Determine Cooking Power in the Sharp Carousel Microwave Oven (Model No. R 8200)

Determination of cooking power. Cooking power was determined for four settings of the variable cooking control: defrost, simmer, roast, and full power.

Distilled water (454 g, 18°C) was heated in a one liter Pyrex glass beaker for 60 sec.

For each setting, the water temperature was measured at the beginning and end of the one-minute heating period. The thermometer was plunged into the water to the immersion mark and the water was stirred five times clockwise and five times counterclockwise, then the temperature of the water was read. The procedure was repeated three times for each setting.

Calculation of cooking watts/hour. The basic equation for sensible heat gain of distilled water centrally placed in the microwave oven is:

$$\text{Cooking watts/hour} = \frac{454 \text{ g } H_2O \times \Delta t \text{ in } °C \text{ (1 min. heating)} \times 60}{3.413}$$

where $H_2O$ is distilled water at 18°C, $\Delta t$ is temperature in degrees Celsius during a heating period of one minute, 60 is the number of minutes in one hour, 3.413 is the number of BTU in one watt.

Cooking power determined with ground beef patties present in the oven. A Pyrex pie pan was inverted and placed in the microwave oven. Two 150 g patties of thawed, uncooked ground beef were placed on two stirring rods on the pie pan to prevent the ground beef from resting in the fat drippings.

Distilled water, 454 g at 18°C, in a Pyrex glass beaker was placed in the center of the pie pan. The water and ground beef were heated 60 sec.

Four settings of the variable cooking control were used: defrost, simmer, roast, and full power./See statement above.

For each setting, the water and ground beef temperatures were measured at the beginning and end of the one minute heating period. For the water, the thermometer was plunged into the water to the immersion mark and the water was stirred five times clockwise and five times counter-clockwise, and the temperature of the water was read. For the ground beef, a thermometer with a non-organic liquid in the column indicating the temperature was inserted into the center of the ground beef and read. Each setting was repeated three times.

The data obtained from the above procedures were:

Table 7 - Data for $H_2O$

| Setting | Trial | Beg. temp. (°C) | End temp. (°C) | Δ temp. (°C) | Cooking power watts/hour[a] |
|---|---|---|---|---|---|
| Defrost | 1 | 18 | 26 | 8 | 246.1 |
| | 2 | 18 | 27 | 9 | 263.7 |
| | 3 | 18 | 25 | 7 | 193.4 |
| | Avg. | | | | 234.4 |
| Simmer | 1 | 18 | 31 | 12 | 351.6 |
| | 2 | 18 | 31 | 12 | 351.6 |
| | 3 | 18 | 28 | 10 | 298.9 |
| | Avg. | | | | 334.0 |
| Roast | 1 | 18 | 32 | 13 | 439.5 |
| | 2 | 18 | 31 | 12 | 421.9 |
| | 3 | 18 | 32 | 14 | 404.3 |
| | Avg. | | | | 421.9 |
| Full Power | 1 | 18 | 37 | 19 | 580.1 |
| | 2 | 18 | 36 | 18 | 550.0 |
| | 3 | 18 | 36 | 18 | 562.6 |
| | Avg. | | | | 564.2 |

[a]See formula, p. 55.

Table 8 - Data for ground beef and water, data for ground beef patties

| Setting | Trial | Pattie | Beg. temp. (°C) | End temp. (°C) | Δ temp. (°C) |
|---|---|---|---|---|---|
| Defrost | 1 | 1 | 18 | 24 | 6 |
| | | 2 | 18 | 24 | 6 |
| | 2 | 1 | 17 | 23 | 6 |
| | | 2 | 17 | 23 | 6 |
| | 3 | 1 | 16 | 22 | 6 |
| | | 2 | 16 | 21 | 5 |
| Simmer | 1 | 1 | 14 | 26 | 12 |
| | | 2 | 16 | 27 | 11 |
| | 2 | 1 | 17 | 25 | 8 |
| | | 2 | 17 | 27 | 10 |
| | 3 | 1 | 16 | 25 | 9 |
| | | 2 | 17 | 27 | 10 |
| Roast | 1 | 1 | 16 | 34 | 18 |
| | | 2 | 16 | 31 | 15 |
| | 2 | 1 | 17 | 35 | 18 |
| | | 2 | 16 | 31 | 15 |
| | 3 | 1 | 17 | 34 | 16 |
| | | 2 | 17 | 28 | 11 |
| Full Power | 1 | 1 | 17 | 36 | 9 |
| | | 2 | 16 | 37 | 21 |
| | 2 | 1 | 17 | 45 | 28 |
| | | 2 | 17 | 38 | 21 |
| | 3 | 1 | 17 | 40 | 23 |
| | | 2 | 16 | 40 | 24 |

Table 9 - Data for ground beef and water trials, data for water

| Setting | Trial | Beg. temp. (°C) | End temp. (°C) | Δ temp. (°C) | Cooking power watts/hour[a] |
|---|---|---|---|---|---|
| Defrost | 1 | 18 | 22 | 4 | 123.1 |
| | 2 | 18 | 23 | 5 | 140.6 |
| | 3 | 18 | 20 | 2 | 70.3 |
| | Avg. | | | | 111.3 |
| Simmer | 1 | 18 | 23 | 5 | 158.2 |
| | 2 | 18 | 27 | 6 | 175.8 |
| | 3 | 18 | 23 | 4 | 140.6 |
| | Avg. | | | | 158.2 |
| Roast | 1 | 18 | 27 | 9 | 281.3 |
| | 2 | 18 | 27 | 9 | 263.7 |
| | 3 | 18 | 27 | 9 | 263.7 |
| | Avg. | | | | 269.6 |
| Full Power | 1 | 18 | 28 | 10 | 334.0 |
| | 2 | 18 | 27 | 18 | 316.4 |
| | 3 | 18 | 31 | 12 | 351.6 |
| | Avg. | | | | 334.0 |

[a]See formula, p. 55.

## MUSCLE FIBERS AND FAT STAINING AND MOUNTING PROCEDURE[a]

1. Dip tissue in ethyl alcohol, 50%
2. Stain in Alum Hematoxylin[b] - 2 minutes
3. Rinse in tap water - 1 minute
4. Rinse in tap water - 1 minute
5. Stain in Sudan IV solution[c]

   Raw tissue - 2 minutes

   Cooked tissue - 3 minutes
6. Dip in ethyl alcohol, 50%
7. Dip in ethyl alcohol, 70%
8. Dip in ethyl alcohol, 95%
9. Rinse in tap water

Muscle fibers stain blue, and fat stains red.

---

[a]Procedure modified from Wu (1977).

[b]Manufactured by: Fischer Scientific Co. Chemical Manufacturing Division, Fairlawn, New Jersey 07410

[c]Formula for stain is in Appendix, p. 62.

### Mounting the cover glass

Glycerine jelly is used as the mounting medium. After staining, the slides are dried with disposable paper wipers, care being taken to avoid damage to the muscle tissue section. One drop of warm glycerine jelly (stored at 50°C in a paraffin warming oven) is dropped onto the section. A cover slip is placed on the glycerine jelly-covered sections.

## COLLAGENOUS CONNECTIVE TISSUE STAINING PROCEDURE[a]

1. Rinse in tap water
2. Stain in a saturated solution of picric acid - 2 minutes
3. Rinse in tap water - 2 times
4. Stain in Picro-ponceau[b] - 20 seconds
5. Dip in 70% alcohol
6. Dip in 95% alcohol
7. Dip in absolute alcohol
8. Clear in xylene - 2 times
9. Mount with Permount

Collagenous tissue stains red, degraded collagenous tissue does not stain.

---

[a]Procedure modified from Reid (1970).

[b]Formula for Picro-ponceau solution is in Appendix, p. 62.

*Mounting the cover glass*

Permount is used as the mounting medium. After staining, the slides are dried with disposable paper wipers, care being taken to avoid damage to the muscle tissue section. The tissue must be allowed to dry so that there is no cloudy appearance after the cover glass is applied. One drop of Permount is dropped onto the section. A cover glass is placed on the Permount-covered section.

# FORMULAS FOR HISTOLOGICAL STAINS

Sudan IV solution:

1.0 g Sudan IV
50 ml ethyl alcohol, 70%
50 ml acetone

Mix thoroughly. Keep the saturated solution in a tightly stoppered bottle and filter before using. Make fresh after 250-300 sections have been stained.

Picro-ponceau solution

10 ml aqueous Ponceau S, 1%
86 ml aqueous picric acid, saturated
4 ml acetic acid, 1%

Mix thoroughly.

Form I. Instructions for Microscopic Measurement of Fiber Width

An ocular micrometer, a clear disc on which is engraved a tiny scale, is placed in the eyepiece of the Bausch and Lomb microscope. This disc is marked in equal units with the center unit further divided into five smaller units.

The ocular disc is compared to a stage micrometer to determine the width of each ocular unit. The stage micrometer is a slide with a measurement line divided into 0.01 mm units. The slide is inserted onto the stage of the microscope under high power (43X objective and 10X eyepiece). The dynazoom knob on the microscope should by set on 1 to give a magnification of 430X. Match a line of the scale on the stage micrometer with a line on the squared scale of the ocular (eyepiece) micrometer. Count the number of ocular and stage units until another line on the ocular micrometer matches another line on the stage micrometer. Determine the distance covered by the ocular units. Each unit equals 0.012 mm (12 μ), and one small ocular units equals 0.0025 mm (2.5 μ).

Replace the stage micrometer with the slide to be studied. The width of the muscle fibers can be obtained by counting the number of units corresponding to the width of a fiber and multiplying that number by the size of the unit of measure.

Example: muscle fiber width = 1 large ocular unit and 3 small ocular units.

$$(1 \times 0.012 \text{ mm}) + (3 \times 0.0025 \text{ mm}) = 0.0195 \text{ mm } (19.5 \mu)$$

The eyepiece can be turned in the tube, turning the ocular scale. Fibers may be measured in this way even if they do not lie in a perfectly vertical or horizontal direction. For each section, select 25 fibers, measure, calculate the width in mm, and record it on the score sheet.

Do not remove the ocular micrometer from the eyepiece of the microscope after it is calibrated. If the disc is removed from the eyepiece, the calibrations for unit determinations need to be repeated for each magnification used. If the disc is turned over, the calibration readings are changed.

Procedure modified from Wu (1977).

Form II. Score Card for Histological Evaluation of Fiber Width

Panel members _____ Date _____

| Measurement | Section Number 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|
| Muscle fibers | | | | | | |
| width, μ | | | | | | |
| Fiber I | | | | | | |
| Fiber II | | | | | | |
| Fiber III | | | | | | |
| Fiber IV | | | | | | |
| Fiber V | | | | | | |
| Fiber VI | | | | | | |
| Fiber VII | | | | | | |
| Fiber VIII | | | | | | |
| Fiber IX | | | | | | |
| Fiber X | | | | | | |
| Fiber XI | | | | | | |
| Fiber XII | | | | | | |
| Fiber XIII | | | | | | |
| Fiber XIV | | | | | | |
| Fiber XV | | | | | | |
| Fiber XVI | | | | | | |
| Fiber XVII | | | | | | |
| Fiber XVIII | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Fiber XIX | | | | | | |
| Fiber XX | | | | | | |
| Fiber XXI | | | | | | |
| Fiber XXII | | | | | | |
| Fiber XXIII | | | | | | |
| Fiber XXIV | | | | | | |
| Fiber XXV | | | | | | |
| Average | | | | | | |

Form III. Instructions for Microscopic Measurement of Sarcomere Length

The ocular micrometer is placed in the eyepiece of the microscope in the same manner as that for measuring fiber width. The same unit determinations will be used to measure sarcomere length. One large ocular unit equals 0.012 mm (12 μ), and one small ocular unit equals 0.0025 mm (2.5 μ).

The number of sarcomeres in one ocular unit will be counted, and the size of the ocular unit will be divided by the number of sarcomeres.

Example: sarcomere length = $\frac{0.012 \text{ mm (size of ocular unit)}}{7 \text{ sarcomeres}} = 0.0017 \text{ (1.7 } \mu\text{)}$

The eyepiece may be turned in the tube to line up the sarcomeres in the ocular unit. For each section, 25 areas of sarcomere lengths will be selected at random, measured, and width calculated in mm and recorded on the score sheet.

As before, the ocular micrometer should not be removed from the eyepiece of the microscope.

Form IV. Score Card for Histological Evaluation of Sarcomere Length

Panel members _____ Date _____

| Measurement | Section Number 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|
| Sarcomere Length, μ | | | | | | |
| I | | | | | | |
| II | | | | | | |
| III | | | | | | |
| IV | | | | | | |
| V | | | | | | |
| VI | | | | | | |
| VII | | | | | | |
| VIII | | | | | | |
| IX | | | | | | |
| X | | | | | | |
| XI | | | | | | |
| XII | | | | | | |
| XIII | | | | | | |
| XIV | | | | | | |
| XV | | | | | | |
| XVI | | | | | | |
| XVII | | | | | | |
| XVIII | | | | | | |
| XIX | | | | | | |
| XX | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| XXI | | | | | | |
| XXII | | | | | | |
| XXIII | | | | | | |
| XXIV | | | | | | |
| XXV | | | | | | |
| Average | | | | | | |

Form V. Score Card for Histological Evaluation of Quantity and Distribution of Fat and Quantity and Type of Collagenous Tissue

Panel Member _____ Date _____

| Measurement | Section Number 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|
| Fat | | | | | | |
| Relative Quantity[a] | | | | | | |
| Fat Distribution[b] | | | | | | |

| Quantity[a] | Distribution[b] |
|---|---|
| 7 Large | 7 Present in all areas |
| 5 Medium | 5 Present in many areas |
| 3 Small | 3 Present in moderate no. of areas |
| 1 None | 1 Present in few areas |

| Measurement | Section Number 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|
| Collagenous Tissue | | | | | | |
| Quantity[a] | | | | | | |
| Fibrous | | | | | | |
| Granular | | | | | | |

| Quantity[a] |
|---|
| 7 Large |
| 5 Medium |
| 3 Small |
| 1 None |

Table 10 - Analysis of variance including mean squares and F-values for selected histological characteristics

| Source | df | Mean squares and F-values[a] | | | | | |
|---|---|---|---|---|---|---|---|
| | | FRQ[b] | FD[c] | QFCC[d] | QGCC[e] | FW[f] | SL[g] |
| Loin | 7 | 1.63<br>(2.06) | 1.45<br>(1.69) | 0.238<br>(0.34) | 1.21<br>(1.51) | 56.31<br>(2.30) | 0.1022<br>(5.58) |
| Treatment | 4 | 2.54<br>(3.22) | 1.68<br>(1.95) | 2.097<br>(2.97) | 54.28<br>(67.85) | 48.64<br>(1.99) | 0.1654<br>(9.04) |
| Oven | 1 | 0.38<br>(0.48) | 0.38<br>(0.44) | 0.003<br>(0.01) | 2.59<br>(2.61) | 0.34<br>(0.01) | 0.0200<br>(0.63) |
| Heat | 1 | 0.63<br>(0.69) | 0.09<br>(0.11) | 0.138<br>(0.41) | 1.16<br>(1.17) | 29.07<br>(0.87) | 0.1800<br>(5.68) |
| Oven/heat | 1 | 0.69<br>(0.76) | 0.75<br>(0.87) | 0.383<br>(1.14) | 1.75<br>(1.77) | 30.23<br>(0.91) | 0.0113<br>(0.35) |
| Raw vs Cooked | 1 | 8.44<br>(10.68) | 5.49<br>(6.38) | 7.865<br>(11.12) | 211.62<br>(264.53) | 134.91<br>(5.52) | 0.4505<br>(24.62) |
| Error | 28 | 0.79 | 0.86 | 0.707 | 0.80 | 24.45 | 0.0183 |

[a]F-values are figures in parentheses.

[b]Fat relative quantity; range 7-1, large amount to none present.

[c]Fat distribution; range 7-1, present in all areas to present in few areas.

[d]Quantity fibrous collagenous connective tissue; range 7-1, large amount to none present.

[e]Quantity granular collagenous connective tissue; range 7-1, large amount to none present.

[f]Fiber width, μ.

[g]Sarcomere length, μ.

Table 11 - Histological evaluation scores for raw samples[a]

| Replication | | Measurement | | | | | |
|---|---|---|---|---|---|---|---|
| Loin | Chop | FRQ[b] | FD[c] | QFCC[d] | QGCC[e] | FW[f] (μ) | SL[g] (μ) |
| I | 0 | 4.2 | 3.0 | 3.5 | 1.0 | 56.9 | 1.7 |
| I | 6 | 3.1 | 3.4 | 3.0 | 1.0 | 46.7 | 1.8 |
| I | 13 | 5.0 | 3.5 | 6.5 | 1.0 | 62.3 | 1.6 |
| II | 0 | 5.8 | 5.9 | 5.9 | 1.0 | 51.9 | 1.8 |
| II | 6 | 4.5 | 5.0 | 3.7 | 1.0 | 49.4 | 1.7 |
| II | 13 | 4.3 | 4.9 | 3.7 | 1.0 | 52.2 | 1.8 |
| III | 0 | 5.7 | 5.0 | 7.0 | 1.0 | 46.6 | 1.7 |
| III | 6 | 5.8 | 3.9 | 5.1 | 1.0 | 41.1 | 1.7 |
| III | 13 | 6.1 | 5.3 | 3.1 | 1.0 | 52.1 | 1.7 |
| IV | 0 | 3.5 | 3.7 | 4.6 | 1.0 | 46.0 | 2.0 |
| IV | 7 | 3.9 | 2.6 | 6.2 | 1.0 | 47.7 | 2.0 |
| IV | 13 | 3.3 | 2.2 | 5.3 | 1.0 | 55.7 | 2.1 |
| V | 0 | 4.2 | 4.6 | 3.9 | 1.0 | 45.3 | 1.7 |
| V | 6 | 3.5 | 3.7 | 3.4 | 1.0 | 42.5 | 1.8 |
| V | 13 | 5.4 | 4.2 | 7.0 | 1.0 | 52.2 | 1.8 |
| VI | 0 | 3.4 | 3.4 | 6.2 | 1.0 | 47.2 | 2.0 |
| VI | 6 | 3.0 | 1.8 | 4.2 | 1.0 | 47.5 | 2.0 |
| VI | 13 | 4.7 | 3.8 | 6.7 | 1.0 | 55.6 | 1.9 |
| VII | 0 | 3.5 | 3.4 | 3.0 | 1.0 | 44.9 | 2.3 |
| VII | 6 | 3.9 | 2.1 | 3.0 | 1.0 | 49.0 | 1.9 |
| VII | 13 | 5.5 | 5.0 | 3.7 | 1.0 | 45.4 | 1.9 |

Table 11 - (Concluded)

| Replication | | Measurement | | | | | |
|---|---|---|---|---|---|---|---|
| Loin | Chop | FRQ[b] | FD[c] | QFCC[d] | QGCC[e] | FW[f] (μ) | SL[g] (μ) |
| VIII | 0 | 4.7 | 3.9 | 3.0 | 1.0 | 46.3 | 1.8 |
| VIII | 6 | 3.0 | 1.9 | 3.0 | 1.0 | 52.2 | 1.7 |
| VIII | 13 | 4.7 | 3.1 | 4.3 | 1.0 | 50.6 | 1.7 |
| Mean | | 4.4 | 3.7 | 4.5 | 1.0 | 49.5 | 1.8 |

[a]Average values for three panel members.

[b]Fat, relative quantity; range 7-1, large amount to none present.

[c]Fat distribution; range 7-1, present in all areas to present in few areas.

[d]Quantity fibrous collagenous connective tissue; range 7-1, large amount to none present.

[e]Quantity granular collagenous connective tissue; range 7-1, large amount to none present.

[f]Fiber width, μ.

[g]Sarcomere length, μ.

Table 12 - Histological evaluation scores for cooked samples[a]

| Heat treatment | Replication | | Measurement | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Loin | Chop | FRQ[b] | FD[c] | QFCC[d] | QGCC[e] | FW[f] (μ) | SL[g] (μ) |
| Conventional dry | I | 3 | 5.3 | 3.9 | 3.1 | 4.9 | 47.7 | 1.8 |
| | II | 12 | 5.9 | 4.3 | 3.4 | 5.0 | 39.6 | 2.1 |
| | III | 4 | 6.6 | 5.5 | 3.9 | 3.9 | 39.7 | 1.6 |
| | IV | 10 | 5.0 | 3.3 | 3.4 | 5.9 | 45.1 | 1.8 |
| | V | 7 | 4.8 | 3.7 | 4.6 | 5.4 | 47.3 | 1.7 |
| | VI | 11 | 5.0 | 5.3 | 3.9 | 5.8 | 56.6 | 2.0 |
| | VII | 2 | 5.9 | 5.8 | 3.1 | 3.5 | 40.9 | 1.7 |
| | VIII | 7 | 4.1 | 3.8 | 5.3 | 3.9 | 39.2 | 1.5 |
| | Mean | | 5.3 | 4.5 | 3.8 | 4.8 | 44.5 | 1.8 |
| Conventional moist | I | 10 | 4.3 | 3.5 | 3.1 | 7.0 | 48.8 | 1.5 |
| | II | 8 | 5.8 | 4.6 | 4.2 | 5.3 | 43.0 | 1.6 |
| | III | 10 | 4.5 | 3.7 | 4.1 | 5.3 | 50.1 | 1.5 |
| | IV | 4 | 5.5 | 4.1 | 3.9 | 4.9 | 50.0 | 1.7 |
| | V | 10 | 3.9 | 3.3 | 3.7 | 5.1 | 48.4 | 1.6 |
| | VI | 3 | 4.3 | 4.1 | 3.7 | 6.3 | 41.1 | 1.8 |
| | VII | 7 | 5.8 | 5.1 | 3.4 | 6.7 | 47.8 | 1.5 |
| | VIII | 9 | 3.9 | 3.9 | 3.9 | 4.5 | 57.7 | 1.5 |
| | Mean | | 4.8 | 4.0 | 3.8 | 5.6 | 48.4 | 1.6 |
| Microwave dry | I | 8 | 4.2 | 2.9 | 3.9 | 4.1 | 60.1 | 1.4 |
| | II | 3 | 7.0 | 6.3 | 3.9 | 6.5 | 44.3 | 1.8 |
| | III | 7 | 6.9 | 5.9 | 3.0 | 3.0 | 40.8 | 1.6 |
| | IV | 9 | 5.0 | 3.3 | 3.5 | 5.1 | 47.7 | 2.0 |
| | V | 2 | 6.0 | 4.7 | 3.5 | 4.6 | 45.5 | 1.5 |
| | VI | 9 | 4.1 | 3.7 | 3.0 | 5.1 | 50.8 | 2.0 |
| | VII | 9 | 4.5 | 3.9 | 5.0 | 3.3 | 38.8 | 1.5 |
| | VIII | 3 | 4.3 | 4.2 | 3.0 | 5.8 | 42.0 | 1.7 |
| | Mean | | 5.3 | 4.4 | 3.6 | 4.7 | 46.3 | 1.7 |

Table 12 - (Concluded)

| Heat treatment | Replication | | Measurement | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Loin | Chop | FRQ[b] | FD[c] | QFCC[d] | QGCC[e] | FW[f] (μ) | SL[g] (μ) |
| Microwave moist | I | 5 | 5.0 | 4.5 | 3.4 | 3.1 | 52.4 | 1.4 |
| | II | 5 | 5.1 | 4.9 | 3.8 | 5.8 | 51.5 | 1.5 |
| | III | 11 | 4.3 | 3.3 | 4.3 | 3.8 | 45.6 | 1.5 |
| | IV | 2 | 6.1 | 4.2 | 3.7 | 5.5 | 49.6 | 1.8 |
| | V | 5 | 6.9 | 5.5 | 4.2 | 4.1 | 47.5 | 1.6 |
| | VI | 7 | 5.9 | 5.4 | 3.9 | 5.3 | 42.7 | 1.7 |
| | VII | 5 | 4.3 | 3.4 | 3.7 | 4.9 | 37.2 | 1.7 |
| | VIII | 11 | 4.5 | 5.3 | 4.6 | 4.3 | 43.2 | 1.4 |
| | Mean | | 5.3 | 4.6 | 4.0 | 4.6 | 46.2 | 1.6 |

[a]Average values for three panel members.

[b]Fat relative quantity; range 7-1, large amount to none present.

[c]Fat distribution; range 7-1, present in all areas to present in few areas.

[d]Quantity fibrous collagenous connective tissue; range 7-1, large amount to none present.

[e]Quantity granular collagenous connective tissue; range 7-1, large amount to none present.

[f]Fiber width, μ.

[g]Sarcomere length, μ.

# HISTOLOGICAL CHARACTERISTICS OF PORK LOIN CHOPS COOKED BY DRY OR MOIST HEAT IN A CONVENTIONAL OR MICROWAVE OVEN

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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1980

Microwave ovens are increasing in popularity, because of a large decrease in price from the original, and because of various technical improvements in the oven. Most of the research in which meat was cooked in domestic microwave ovens during the first decade in which they were available and compared with meat cooked in conventional ovens indicated that microwave-cooked meat had greater cooking losses, and was less tender and juicy than conventionally-cooked meat. However, some recent research has indicated that moderate to low cooking power, techniques for minimizing irregular heating patterns, and allowance for post-heating temperature rise have helped to produce microwave-cooked meat that is comparable in cooking and sensory properties to conventionally-cooked meat. Histological methods have been used widely to observe the changes occurring in cooked meat structure in relation to sensory, physical and chemical changes. More information is needed on the histological characteristics of pork cooked by dry or moist heat in a conventional or microwave oven.

Selected histological characteristics of thirty-two pork loin chops cooked by dry heat (modified roasting) or by moist heat (oven-film bag) in a conventional or a microwave oven were studied. Samples were removed from the LD muscle of four randomly selected cooked chops from each loin. Data for sensory, chemical, and physical characteristics were available to study relationships between those characteristics and histological characteristics. Data were analyzed by analysis of variance for a randomized complete-block design, blocked on the loin to study influences of type of oven, type of heat, and interactions of type of oven X type of heat on the histological properties of the muscle. Histological characteristics of raw porcine LD muscle were compared to those of porcine LD muscle cooked by the four oven/heat treatment combinations. Correlation coefficients

were calculated for selected paired variates on the basis of oven/heat treatment.

Differences in histological characteristics attributable to type of oven, type of heat, or to interaction of type of oven X type of heat were not significant, except that muscle fiber sarcomere length was affected by type of heat.

Mean scores for quantity of fat and fat distribution indicated that microwave cooking had a slightly greater effect on mobility of the fat than did conventional cooking. Low correlation coefficients for juiciness or flavor vs quantity of fat indicated that juiciness and flavor of the pork chops were dependent on factors other than fat quantity. However, moderate correlations for fat distribution and initial tenderness score or WB shear values indicated that fat distribution had some influence on the tenderness of pork cooked by CD and MM.

There were no significant changes in fibrous connective tissue when the raw tissue was compared with tissue cooked by any of the four oven/heat treatment combinations. For all treatment combinations except CM, correlation was moderate for fibrous connective tissue and WB shear values; WB shear values decreased with a decrease in fibrous connective tissue. Fibrous connective tissue did not appear to be related to WB shear values for CM pork. Moderate correlation was observed between quantity of fibrous connective tissue and juiciness scores for CM chops; a decrease in juiciness occurred with a decrease of fibrous connective tissue.

Mean scores for granular connective tissue indicated the greatest change from raw to cooked tissue for any of the histological measurements. More granular connective tissue appeared in CM pork than in tissue cooked

by CD, MD, MM. Granular connective tissue had little relation to tenderness measurements of pork cooked by any of the four oven/heat treatments, except for the initial tenderness score for MM tissue. Quantity of granular connective tissue may have helped to increase WHC and juiciness in chops cooked by CD more than in chops cooked by CM.

Mean muscle fiber widths decreased from raw to cooked tissue for all treatment combinations studied except for CM. Tissue cooked by CD had narrower muscle fiber widths than tissue cooked by CM. Generally, for chops cooked in the microwave oven, the narrower the muscle fibers, the less tender the meat (initial and final panel scores and WB shear values).

A decrease in mean fiber sarcomere length was observed from raw to cooked tissue for all treatment combinations except CD. Decreased sarcomere lengths in fibers in CM pork loin chops appeared to be related to decreased tenderness.

Generally, correlation coefficients indicated that the histological study did not help to explain the attributes of pork loin chops that were measured by a sensory panel or by objective measurements related to the sensory attributes.