PALATABILITY AND SELECTED RELATED CHARACTERISTICS OF THREE TYPES OF ROASTED PORCINE MUSCLE

by

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INTRODUCTION

Raising lard-type hogs began to be unprofitable in 1938 when the price of lard fell below the live hog price (Vrooman, 1952). This condition became extreme in 1949 when hog prices were more than 50% higher than the price of lard. Coupled with this lard-hog price relationship was an increasing preference by the consumer for a lean type of pork (Vrooman, 1952; Birmingham et al., 1954). To meet this situation, state and federal experiment stations developed several new strains of hogs that were heavily muscled, free from excess fat, well balanced and uniform in length and depth of body, and produced a large proportion of lean to fat.

Concurrently with development of the lean type hog, the processor began to notice porcine muscle that was pale, soft, and exudative (PSE). PSE muscle has been attributed to various factors such as breed, weight, and sex of the animal; ration fed; exercise; and processing procedures.

Extensive investigation has been carried out on the physical and chemical properties of porcine muscle. During the course of these investigations, 3 types of porcine muscle have come to be recognized; PSE, dark-firm-dry (DFD), and "normal." Extremely rapid glycolytic rates, which create low pH values at high muscle temperatures, are associated with the development of PSE muscle. If glycolysis is incomplete and rigor mortis takes place at a relatively high pH, or if glycolysis takes place slowly and rigor mortis occurs over a long period, the muscle

retains the DFD characteristics of living muscle. When glycolysis occurs at an intermediate rate (6-12 hr for complete production of lactic acid) and when 4-6 hr are required for the completion of rigor mortis, the grayish-pink, moderately firm, and moderately dry appearance of "normal" muscle is obtained (Briskey and Wismer-Pedersen, 1961; Briskey, 1963; Sayre and Briskey, 1963).

Although the physical and chemical properties of raw PSE, DFD, and "normal" porcine muscle have received considerable attention from workers in the field of animal science, little has been done to ascertain the acceptability of those 3 types of muscle from the standpoint of eating quality. Judge et al., (1960) reported that the tenderness of broiled chops increased as loins became less firm and as pH decreased. After determining what he referred to as loose water in porcine loins, Wismer-Pedersen (1959) submitted the loins to a taste panel, who found the meat acceptable over a wide range of loose water numbers. There was a slight decrease in scores for taste and texture of fried chops as the water holding capacity decreased. Briskey (1963) stated that Sayre and Briskey also found water-binding associated with tenderness. Muscles that had a low cooking loss were tender, whereas muscles that showed a high cooking loss lacked tenderness as determined by Warner-Bratzler shear values. The purpose of this study was to determine the palatability and selected related characteristics of PSE, DFD, and "normal" longissimus dorsi (LD) muscle in roasted pork loin.

REVIEW OF LITERATURE

Factors Influencing the Palatability and Related Characteristics of Porcine Muscle

Flavor, juiciness, and tenderness are the palatability factors most desired by the consumer. Chemical and physical characteristics of PSE and DFD pork muscle have been studied extensively and reviewed by Briskey (1964). However, few studies relative to the palatability of these types of pork muscle were found in the literature. Studies that have been conducted were concerned mainly with tenderness.

Breed and antemortem environment. In investigating the effect of breed and antemortem temperature and humidity upon the structure and tenderness of the LD muscle, Thomas et al. (1966) found that a high relative humidity (85%) tended to improve the structure (rated for firmness: soft, intermediate, firm) regardless of the environmental temperature. However, breed-treatment interaction indicated that the superior structure (firm) was brought about by the responses of Poland China pigs, whereas Hampshire pigs produced similar muscle structure regardless of environmental humidity. Allo-Kramer shear values indicated that pigs reared in a low humidity tended to have less tender muscle, and the effect of rearing environment on tenderness was more apparent when cooking temperatures of 68 and 72°C were used, whereas breed differences were evident at a cooking temperature of 60°C. Hiner et al. (1965) compared Duroc and Yorkshire pigs, and found that the

Durocs produced the more tender and juicier loins. Differences in type of muscle, if there were any, were not reported.

Judge et al. (1959) and Briskey (1964) reported the frequencies of PSE muscle in a number of breeds as:

Breed	Judge et al. %	Briskey %
Poland China	60.0	25.9
Hampshire	41.7	25.0
Duroc	----	14.0
Yorkshire	16.4	19.0

Post-mortem temperature. It has been postulated that the relationship between tenderness and shortening of muscle is a consequence of sarcomere shortening, and that the extent of shortening is inversely related to the degree of onset of rigor at the time of cold application (Beecher et al., 1965; Sink et al., 1965; Marsh and Leet, 1966). Briskey (1963) reported that a long delay phase and an extremely long onset phase resulted in dark, firm muscle that had virtually no shortening after completion of the rigor process.

Bate-Smith and Bendall (1949) found that the degree of shortening in rabbit muscle was dependent on the ultimate pH, and was markedly increased by raising the temperature from 17 to 37°C. Locker and Hagyard (1963) investigated shortening of raw bovine muscle at temperatures between 0 and 43°C. When strips of sternomandibularis muscle were tested, the maximum shortening occurred at 0°C. Shortening was at a minimum between 14 and 19°C, but increased above 19°C, although at a

slower rate than at the lower temperatures. Also, strips of LD muscle were studied on a limited scale, and were found to behave almost identically to the sternomandibularis muscle. The main exception for the LD was a consistent lag period before rapid shortening began at 2°C. Cook and Langsworth (1966a) examined the shortening of ovine muscle in the 0 to 40°C temperature range. These latter workers found that shortening of the LD was increased severely by temperatures near the freezing point. They also found (1966b) that cooking losses in unfrozen muscle increased with increasing cooling temperatures, whereas shear values decreased with increasing cooling temperatures from 0 to 10°C, remained constant from 10 to 30°C, and reached a minimum at 40°C.

It has been suggested that the tenderness of meat removed from the carcass in a pre-rigor condition is highly dependent upon the extent of the cold shortening that occurs after excision (Herring et al., 1965a; Marsh and Leet, 1966). Some muscles, including the LD, which is firmly anchored to the skeleton at one end only, are capable of shortening in the carcass under vertical suspension such as found in normal processing procedures because of tension release (Herring et al., 1965b; Marsh and Leet, 1966). Muscles firmly attached at both ends are capable of shortening in part of their length, if cold application does not reach the entire muscle evenly (Marsh and Leet, 1966).

Bovine psoas major muscles have longer sarcomeres than semitendinosus muscles. When those muscles were excised pre-

rigor and either held in a stretched-restrained state or left free to contract for 48 hr, or were excised 48 hr post-mortem, a number of effects were observed. Muscles excised shortly after death, quickly shortened 10 to 25% of their length as measured in the carcass. Shortening increased more in both excised free and stretched-restrained muscle held at 1°C than in those held at 5°C. Stretched-restrained semitendinosus muscles exhibited longer sarcomeres than when excised, whereas psoas major muscles tore during the stretching process before the initial sarcomere length could be obtained, and both muscles were less tender after being left free to contract. It was suggested that tenderness is influenced by the amount and kind of connective tissue, amount of marbling, and sarcomere length; and that sarcomere length is only an indication of molecular changes occurring in the actin and myosin of the muscle fiber (Herring et al., 1965a).

Beecher et al. (1965) pointed out that red muscle fibers are more resistant to the development of the PSE condition than are white muscle fibers and suggested that the longer sarcomere of the red muscle fiber could be a contributing factor. The longer sarcomere of the red muscle fiber may either contribute to or result from the slower post-mortem glycolytic rate (Infantee et al., 1964). Red muscles have high oxidative enzyme activity, whereas white muscles have high glycolytic activity.

Weiner et al. (1966) found that hams that were excised and pumped with cold (3°C) brine 1 hr post-mortem had lower total and drip cooking losses and lower shear values than hams excised

and chilled at 0 to 2°C for 48 hr before pumped with brine. It was suggested that the salts combined with calcium ions as they were released in the hams processed 1 hr post-mortem and thereby prevented the chelation of the calcium with actin and myosin. This action would decrease the shortening of muscles and account for the improved tenderness.

These same workers placed one lot of excised porcine loins in a blast freezer (-24 to -30°C) within 1 hr post-mortem, a second lot of excised loins was chilled at 0 to 2°C within 1 hr post-mortem, and a third lot (control) was chilled 48 hr at 0 to 2°C before being excised. Loins in lot II had significantly ($P = 0.05$) lower shear values than those in the controlled, whereas loins in lot I had significantly ($P = 0.01$) higher shear values than those in the control lot.

Borchert and Briskey (1965) investigated the effects of cooling porcine muscle with liquid nitrogen and by conventional means. They found the level of reducing sugar varied with the rate of cooling and suggested that this may be a basic difference between PSE and DFD muscle.

Miscellaneous factors. Carpenter et al. (1965) studied selected porcine loins that represented extreme color differences at both high and low levels of marbling. No consistent variation in tenderness could be attributed to color in 1-in. slices baked at 325°F to an internal temperature of 165°F. However, darker muscles were significantly juicier than lighter muscles, with the exception of heavy weight, light colored loins that were abundantly marbled. For flavor, there was no preference between

dark and light muscles except for slightly marbled, light weight loins for which the darker muscle was considered more desirable. The authors stated their data suggested that marbling improves the palatability of light colored muscle more than that of dark muscle. In dark muscle, the effects of marbling may be obscured by the larger quantities of juice retained during cooking.

Sayre et al. (1964) attributed a high cooking loss and low tenderness in PSE porcine muscle to evaporative losses during cooking. These workers found color significantly correlated with cooking evaporation ($P = 0.01$) and shear force ($P = 0.05$). Temperature and pH of the muscle during the onset of rigor mortis and gross morphology of the muscle 24 hr post-mortem were related to fluid losses and associated properties such as tenderness and cooking rate. No appreciable differences in protein and moisture and only slight differences in fat content were found in PSE, DFD, and dark exudative muscle.

Lewis et al. (1962) subjected 18 pigs to stress by periodic electrical stimulation for $5\frac{1}{2}$ hr before slaughter, and compared them with 18 similar pigs not under stress. For the animals subjected to stress, there was an increase in pH in the psoas major and quadriceps femoris muscles, but not in the LD. Briskey et al. (1959) suggested that animals became adjusted to stress continued over a period of time. However, Lewis et al. (1962) found that prolonged stress before slaughter significantly ($P = 0.01$) decreased total cooking, evaporation, and dripping loss from psoas major and quadriceps femoris and decreased ($P = 0.05$) the total cooking and dripping loss from

the LD. There were no significant differences in the flavor, tenderness, juiciness or shear values of LD muscle attributable to stress.

Wilson (1964) reported low quality (as judged by color, marbling, and firmness) charcoal-broiled pork rib chops higher in cooking losses, total moisture (as determined by the Brabender moisture tester), and Warner-Bratzler shear values ($\frac{1}{2}$-in. cores) than average quality rib chops, whereas average quality chops were more tender and had a higher pH. Juiciness scores and cooking time were not significantly related to quality.

Nutritional Value of Porcine Muscle

Cassens et al. (1963) found that neither breed nor treatment (sugar in the ration, or exercise just prior to slaughter) affected the concentration of zinc or myoglobin in LD or trapezius pork muscle. Previously Briskey et al. (1959) reported that total moisture, myoglobin, sodium, and potassium concentrations were not affected significantly by ration or exercise. Equally as important, Dahl (1962) found that distribution of 19 amino acids was almost identical in "normal" and PSE muscle.

Meyer et al. (1963) found that PSE pork had about twice as much niacin ($P = 0.005$) as DFD pork, both uncooked and cooked, whereas DFD muscle had higher thiamine content, and slightly higher riboflavin content in the raw state. These workers found PSE muscle had significantly ($P = 0.005$) higher cooking loss, and this higher cooking loss contributed to a higher nutrient loss either by destruction or in the drippings.

Niacin is a component of pyridine nucleotides. Meyer et al. (1963) suggested that the occurrence of PSE muscle could be the result of an increased rate of glycolysis brought about by large quantities of these oxidative coenzymes. However, these workers pointed out the need for studies to ascertain the variation, if any, of niacin levels in "normal" pork muscle tissue.

Lewis et al. (1962) found that the cooked muscles of stressed pigs contained more food nutrients/lb than the cooked muscles of rested pigs. They analyzed the LD, psoas major, and quadriceps femoris for moisture, protein, glycogen, lactic acid, phosphorus, sodium, potassium, calcium, and magnesium content.

Water-holding Properties of Cooked Muscle

The water-holding capacity of raw muscle used for meat has been widely investigated, and a variety of factors that influence the magnitude of the water-holding capacity have been proposed. Although there has been a paucity of work in the area of the water-holding capacity of cooked porcine muscle, results reported indicate that many of the same factors that influence the water-holding capacity of raw muscle are involved. Sherman (1961) explained the variations in fluid retention of porcine muscle in terms of colloidal transformations that occur. The most important factor appears to be solubilization of proteins, especially actomyosin, within the meat prior to heating. This process is influenced by pH, time and temperature of the aging

period, and the concentration of additives used. Hydration was not considered an important effect in improving fluid retention. However, Hamm and Deatherage (1960) found a relationship between the water-holding capacity of cooked beef LD and the degree of hydration, which was influenced by pH and the temperature of cooking.

Position of Shear Core

Studies that have reported Warner-Bratzler shear core values obtained from medial and lateral positions within porcine LD have given conflicting results. When the data of Pengilly and Harrison (1966) for ½-in. cores were analyzed without regard to section (anterior, middle, posterior positions), there was no difference between medial and lateral positions. Urbin et al. (1962) reported shear values for ½-in. cores from the medial position significantly greater than those from the lateral position of both uncooked and cooked LD chops. Converse results, shear values for 1-in. cores from the lateral position greater than those from the medial position, were reported for uncooked (Murphy and Carlin, 1961; Onate and Carlin, 1963) and cooked LD (Onate and Carlin, 1963).

EXPERIMENTAL PROCEDURE

Meat Used

Forty-eight pork loin roasts (818 to 1381 g) were available from animals that had received ante- and post-mortem treatments

designed to develop PSE, DFD, and "normal" muscle. These roasts were from 12 Poland China and 12 Duroc barrows that had been divided as follows into 3 lots of 8 animals each:

Animals	Antemortem treatment
Lot I - Control Poland China - No. 4, 8, 14, 23. Duroc - No. 3, 7, 13, 24.	Basal ration (Table 1).
Lot II - Sugar fed Poland China - No. 1, 10, 15, 20. Duroc - No. 6, 9, 16, 19.	Basal ration until 7 days before slaughter, then a 50-50 ration, by weight, of sucrose and the basal ration.
Lot III - Exercised Poland China - No. 5, 12, 18, 21. Duroc - No. 2, 11, 17, 22.	Basal ration until 48 hr before slaughter; exhaustive exercise immediately prior to slaughter.

Post-mortem treatment consisted of 2 chilling temperatures. Half of each carcass was assigned at random to coolers maintained at 30 and 42°F.

Processing of Roasts

Roasts consisting of the section of the loin from the first lumbar vertebra to the anterior end of the hipbone were wrapped in 0.0015-gauge aluminum foil, blast frozen and stored at -20°C for 7 to 9 months. Roasts were removed from the freezer approximately 20 hr before cooking, allowed to thaw in their wrapping at room temperature (approximately 24°C), unwrapped, and placed with the ribs down on racks in individual shallow pans (12 x 7.5 in.) with a right-angle thermometer inserted into the center

Table 1. Basal ration.

Ingredient	Percent
Sorghum grain	71.45
Soybean oil meal (44% protein)	16.2
Dehydrated alfalfa meal	8.8
Salt	0.5
Dicalcium phosphate	1.0
Limestone	1.0
Vitamin-antibiotic mix[a]	1.0
Trace mineral mix[b]	0.05

[a]Supplied the following per 100 lb: vitamin D, 15,000 I.U.; vitamin A, 100,000 I.U.; riboflavin, 200 mg; calcium pantothenate, 400 mg; niacin, 600 mg; choline chloride, 2000 mg; vitamin B_{12}, 500 mcg; and chlortetracycline, 500 mg.

[b]Supplied the following in ppm: manganese, 50; iron, 50; copper, 5; cobalt, 0.5; iodine, 1.5; zinc, 25; and calcium, 58.

of the LD (Fig. 1). Three roasts were cooked by dry heat at each evaluation period (Table 2) to an internal temperature of 75°C in a rotary gas oven at 350°F (Pengilly and Harrison, 1966).

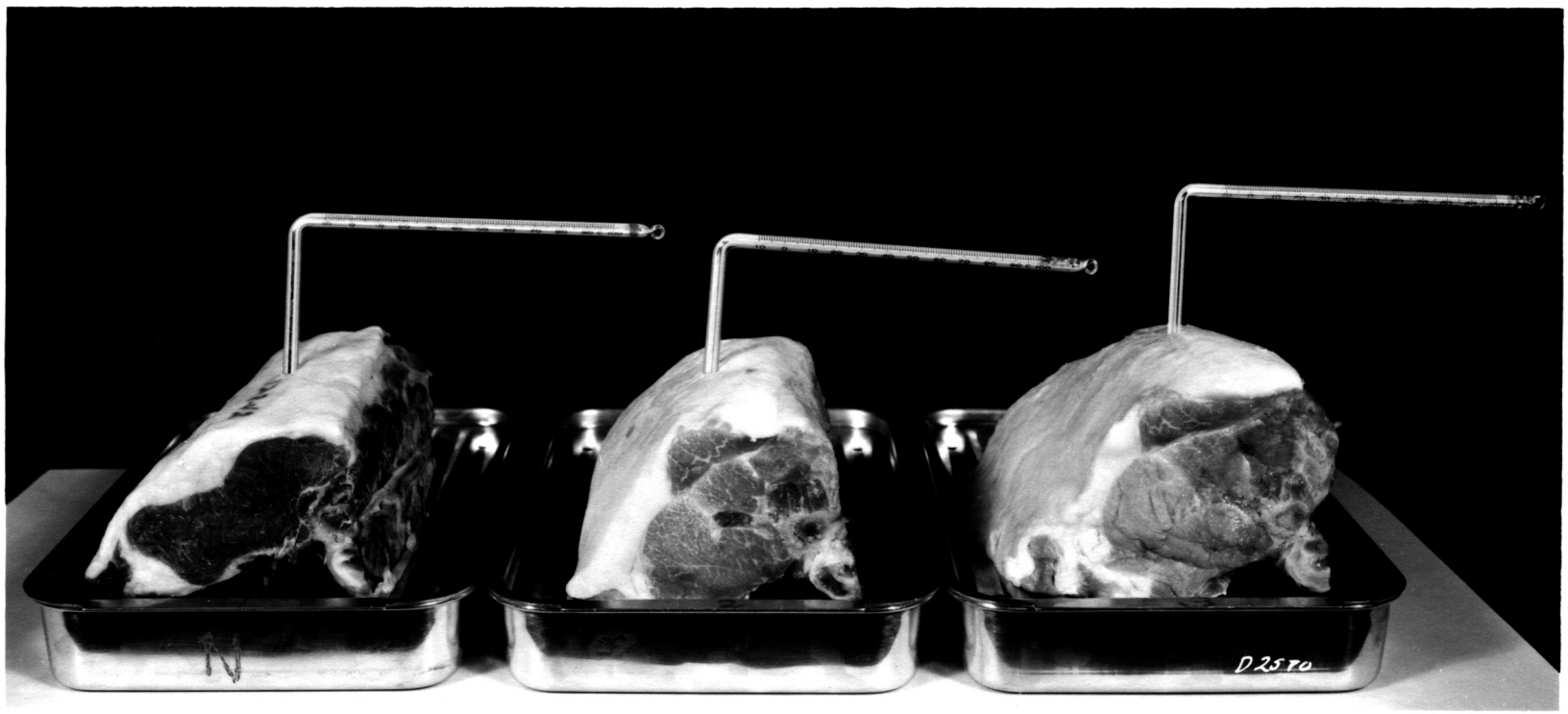
The LD was separated from the bone, all exterior fat and brown surface removed, and the muscle divided $2\frac{1}{2}$ in. from the anterior end into 2 pieces. Sampling is illustrated in Fig. 2.

Fig. 1. Appearance of loin prior to roasting.

A. DFD loin, anterior surface, first lumbar region.

B. "Normal" loin, posterior surface, anterior end of the hipbone.

C. PSE loin, posterior surface, anterior end of the hipbone.



A B C

Table 2. Design of the experiment.

Evaluation period	Roast code number[a]		
1	9-D-R-42	4-P-R-42	18-P-L-30
2	2-D-L-30	6-D-L-42	22-D-L-30
3	13-D-L-30	8-P-L-30	5-P-R-42
4	19-D-R-42	17-D-R-30	20-P-L-42
5	18-P-R-42	1-P-L-42	7-D-R-42
6	10-P-L-42	23-P-R-30	8-P-R-42
7	15-P-R-30	17-D-L-42	3-D-R-42
8	10-P-R-30	15-P-L-42	16-D-R-30
9	24-D-R-42	2-D-R-42	11-D-R-42
10	5-P-L-30	14-P-R-42	21-P-R-42
11	11-D-L-30	14-P-L-30	21-P-L-30
12	3-D-L-30	4-P-L-30	19-D-L-30
13	12-P-L-30	16-D-L-42	22-D-R-42
14	9-D-L-30	24-D-L-30	12-P-R-42
15	6-D-R-30	7-D-L-30	1-P-R-30
16	20-P-R-30	13-D-R-42	23-P-L-42

[a]Roast code number refers to animal number, breed, and post-mortem treatment: Animal number, 1-24; breed of animal, D - Duroc, P - Poland China; Post-mortem treatment, side of carcass, L - left, R - right; cooler temperatures, 30 and 42°F.

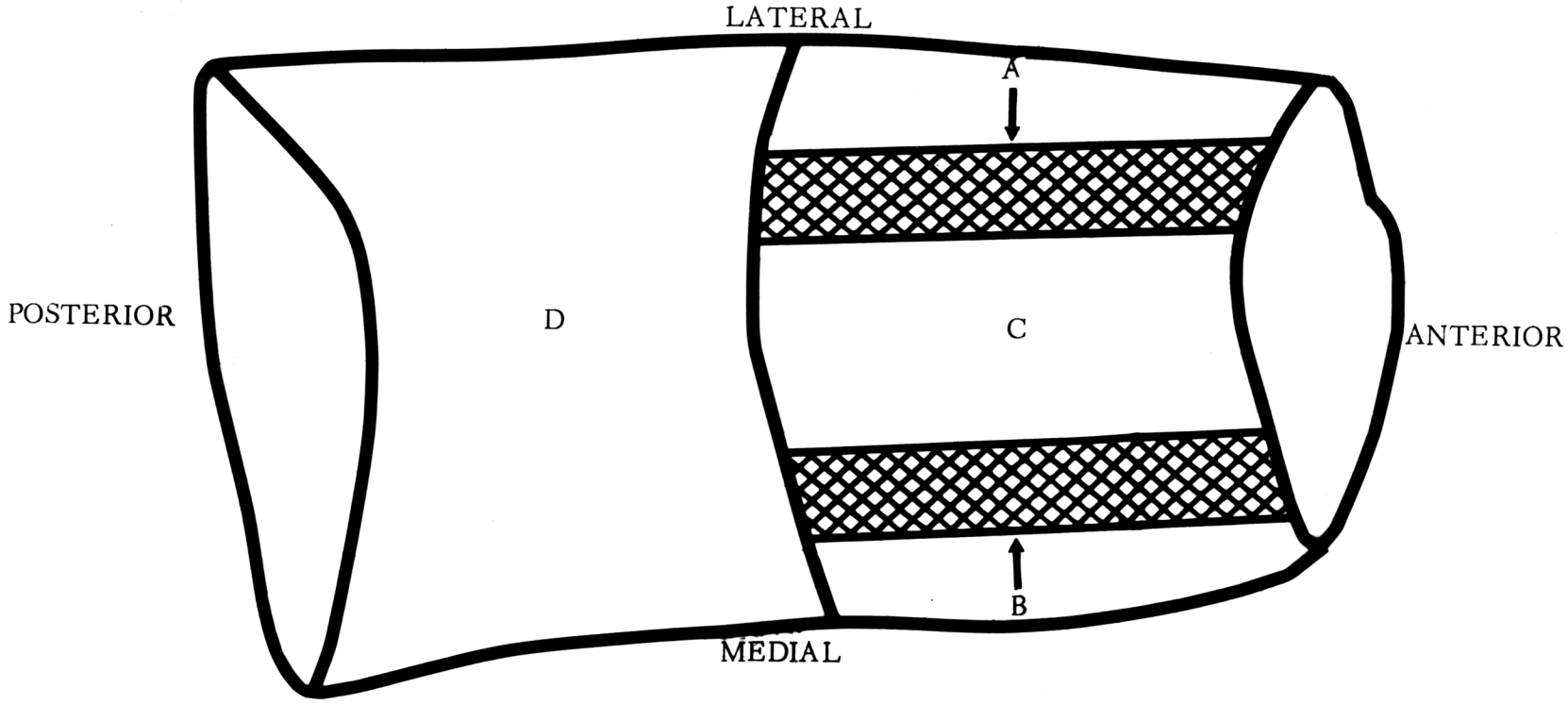
Fig. 2. Sampling plan for longissimus dorsi muscle.

A. Lateral shear core ($\frac{1}{2}$-in.).

B. Medial shear core ($\frac{1}{2}$-in.).

C. Organoleptic samples ($\frac{1}{2}$-in. cubes).

D. Press fluid, total moisture, and pH.


LATERAL
A
POSTERIOR
D
C
ANTERIOR
B
MEDIAL

Evaluation of Roasts

Total roasting time was noted, and roasting time on the basis of min/lb, and percentage total, volatile, and dripping roasting losses were calculated.

Shear values were obtained for 2 cores (½-in.) from the LD, one lateral and one medial. Each core was sheared 3 times on a Warner-Bratzler shearing apparatus equipped with a 25-lb dynamometer.

An experienced 8-member panel evaluated ½-in. cubes of the LD muscle for tenderness (based on chews), juiciness, and flavor on a 7-point scale. Juiciness and tenderness were scored on an intensity scale, whereas flavor was scored on degree of desirability (Fig. 5, Appendix).

Percentage total moisture was determined by drying duplicate 10-g samples of ground, cooked muscle in a C. W. Brabender semi-automatic moisture tester for 1 hr at 121°F.

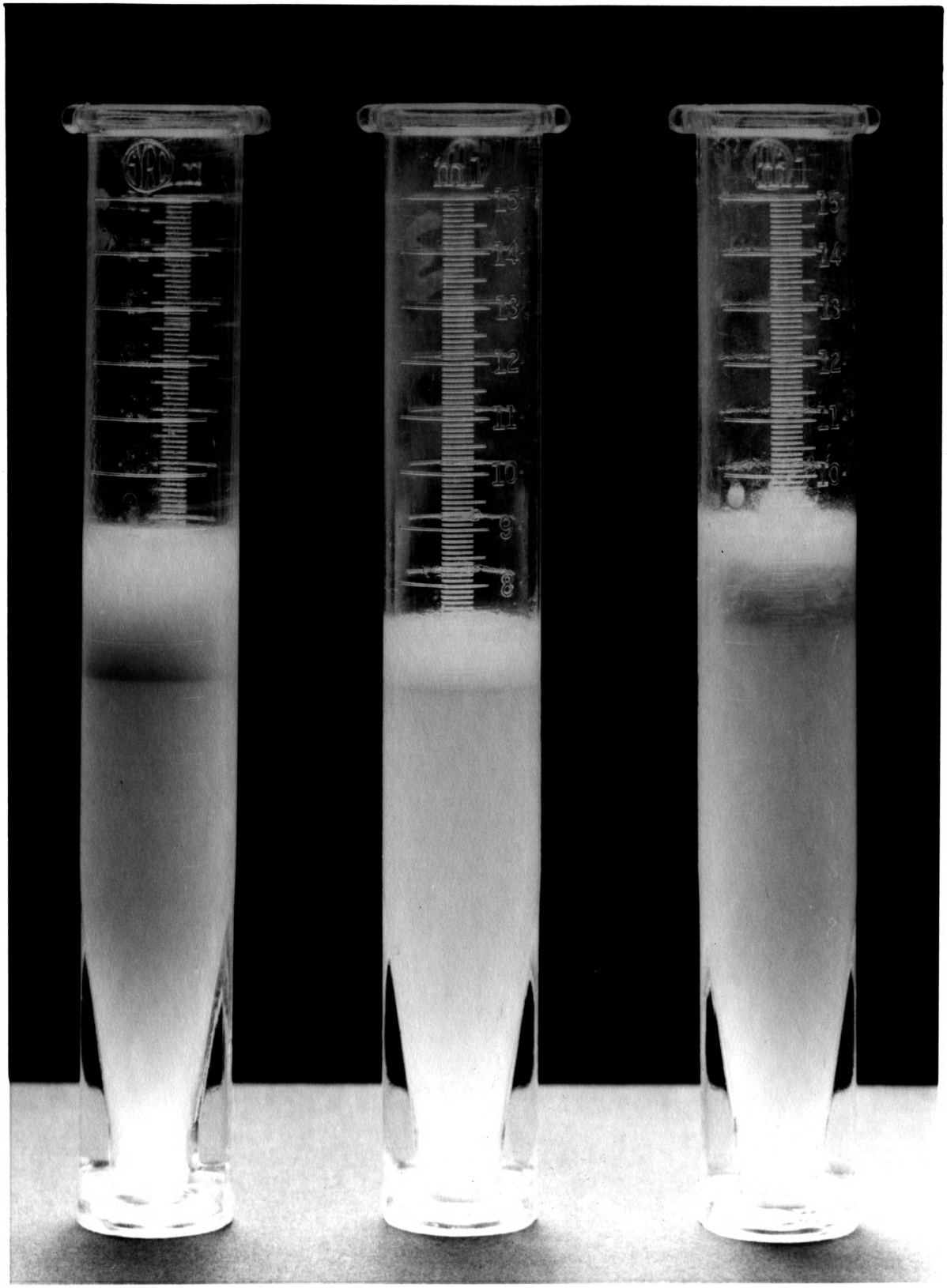
Press fluid was measured for duplicate 25-g samples of ground, cooked muscle packed in a cheesecloth-lined (2 layers 14.5 cm in diameter) cylinder of a Carver laboratory press by alternating the sample, roughly divided into thirds, with 4 circles of Whatman No. 1 filter paper (5.5 cm). The sample was pressed following a standardized 15-min time-pressure schedule with a maximum pressure of 4,000 psig. The expressed fluid (press fluid) was poured into weighed centrifuge tubes graduated in 0.1 ml (Fig. 3), capped with aluminum foil, and placed in a refrigerator until the following day, when the volume of total

Fig. 3. Appearance of fluid expressed by the Carver laboratory press.

A. Press fluid from PSE loin.

B. Press fluid from "normal" loin.

C. Press fluid from DFD loin.



A B C

fluid, serum, and fat were read.

To obtain the percentage moisture in the press fluid, the centrifuge tubes were placed in a freezer for 4-6 hr, the frozen fat was removed from the press fluid with a stainless steel laboratory spatula, and the sides of the centrifuge tube above the frozen serum wiped with a tissue that had been wrapped around the laboratory spatula. The tubes were allowed to stand at room temperature with the aluminum caps in place for 1 hr before being weighed on a Mettler Gram-atic Balance. The percentage moisture in the press fluid was calculated as follows:

$$\frac{\text{Wt (g) of serum expressed}}{\text{Wt of ground meat sample (25 g)}} \times 100 = \% \text{ moisture in press fluid}$$

Also, the percentage moisture remaining in the residue (press cake) from the ground meat sample was determined. The press cake was broken into 6 pieces, and the cheesecloth covering cut into pieces approximately $\frac{3}{4} \times \frac{1}{4}$ in. The partially divided press cake and cheesecloth were blended at high speed in a Kenmore blender for a total of 2 min with intermittent scraping down the sides of the blender jar as necessary. A sample (10-g) of the finely divided press cake and cheesecloth were dried in a C. W. Brabender semi-automatic moisture tester as described for ground, cooked muscle (Fig. 4).

Duplicate pH measurements were made on homogenates of ground, cooked muscle, using a Beckman pH meter, model 76. To prepare the homogenates, 5 g of muscle were blended with 50 ml distilled water for 2 min at high speed in a Waring Blender,

Fig. 4. Samples (10-g) of ground, cooked muscle and press cake in calibrated dishes used for total moisture determination in a C. W. Brabender semi-automatic moisture tester.

A. PSE porcine muscle.
   Upper
      Ground meat sample.
   Lower
      Press cake sample.

B. "Normal" porcine muscle.
   Upper
      Ground meat sample.
   Lower
      Press cake sample.

C. DFD porcine muscle.
   Upper
      Ground meat sample.
   Lower
      Press cake sample.

A B C

model PB-5. The homogenate was placed in a 250 ml beaker, adjusted to a temperature of 25°C, stirred with a magnetic stirrer for 30 sec, and the pH reading taken. The beaker was turned 180°, the homogenate stirred an additional 15 sec, and a second pH reading taken. The pH meter was standardized against a buffer of pH 6.86.

Analysis of Data

Data for each measurement made to evaluate the cooked meat were subjected to the following analysis of variance:

Source of Variation	D/F
Breed (B)	1
Post-mortem treatment (PTr)	1
Antemortem treatment (ATr)	2
B x PTr	1
ATr x PTr	2
B x ATr	2
B x ATr x PTr	2
Error	36
Total	47

When significant F-values occurred for sources with 2 D/F, least significant differences (LSD) at the 5% level were calculated. Correlation coefficients were determined within each antemortem treatment and with data for all treatments pooled for each measurement with every other measurement. Shear values for cores from medial and lateral positions in the LD were analyzed by Student's t-test.

RESULTS AND DISCUSSION

Loin roasts were evaluated by palatability scores and values for selected objective measurements. Mean data are in Tables 3, 5, and 6, and detailed data in Tables 7 to 20, Appendix. None of the measurements were affected significantly by post-mortem treatment (chilling temperatures of 30° and 42°F or -1.1° and 5.6°C), Tables 18 and 19, Appendix. Therefore, the data in Tables 3 and 6 are not separated according to post-mortem treatment.

In contrast to the data obtained in the present study, several workers found that carcass chilling temperature affected some characteristics of beef and ovine muscle. The shortening of beef muscle was related to tenderness and the extent of shortening to chilling temperature (Locker, 1960; Locker and Hagyard, 1963; Herring et al., 1965a). Shortening was more severe and the muscle less tender at 1° than at 5°C. Ovine muscle also had increased cooking loss and exudate with increasing post-mortem holding temperatures from 0° to 40°C.

Objective Measurements

Roasting time. Roasting time, both in total min and min/lb, was not affected significantly by breed or antemortem treatment. However, on the basis of min/lb, roasting time was affected ($P = 0.05$) by an interaction between breed and antemortem treatment (Table 3). Roasts from Duroc pigs fed sucrose required longer to cook (min/lb) than those from Poland China pigs receiving the same treatment. Within the Poland China breed, roasts

Table 3. Means, significance of F, and LSD attributable to breed, antemortem treatment, and the interaction between breed and antemortem treatment for roasting time and losses, pH, and Warner-Bratzler shear values.

Measurement	Breed and antemortem treatment						Probability level of F-value			LSD[a]
	Duroc			Poland China						
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised	B[b]	ATr[b]	B x ATr[b]	
Roasting time										
Total, min	77.9	75.7	74.2	70.3	74.0	73.2				---
Min/lb	35.7	36.2	35.0	33.4	33.2	36.4			*	2.60
Roasting losses, %										
Total	19.7	21.0	17.3	18.8	19.5	15.7	*	***		1.57
Volatile	11.7	12.8	11.0	11.5	11.7	9.5	*	**		1.02
Dripping	7.9	8.1	6.3	7.4	7.7	6.0		**		0.99
pH values										
24 hr, raw muscle[c]	5.69	5.60	5.87	5.64	5.45	6.17		***	*	0.22
Roasted, ground muscle	5.79	5.70	5.89	5.74	5.60	6.41	*	***	***	0.20
Shear values, lb/1/2-in. core	5.1	4.7	4.8	6.9	6.0	4.2	*	**	*	1.33

[a]LSD, least significant difference at the 5% level for ATr and B x ATr.

[b]B (breed) and ATr (antemortem treatment).

[c]Unpublished data from Bowers, J. (1966).

*, P = 0.05

**, P = 0.01

***, P = 0.001

from exercised animals required a longer time/lb than those from animals fed sucrose.

It was suggested (Sayre et al., 1964) that roasts that have a high evaporative loss have a decrease in cooking rate because of the cooling effect of evaporation. In this study, roasts from both breeds of exercised animals had significantly ($P = 0.05$) lower volatile roasting losses than roasts from sucrose fed animals, and required slightly less total roasting time. Roasts from Durocs on the basal ration also had significantly ($P = 0.05$) lower volatile losses, but required a slightly longer total roasting time than roasts from Durocs fed sucrose (Table 3).

Roasting losses. Differences in total and volatile roasting losses were attributable to breed ($P = 0.05$) and antemortem treatment (total, $P = 0.001$ and volatile, $P = 0.01$). Differences in dripping losses were attributable to antemortem treatment only ($P = 0.01$). Total and volatile losses within each antemortem treatment were significantly ($P = 0.05$) greater for roasts from Duroc than for those from Poland China animals. For both breeds, loss was greatest for roasts from animals fed the sucrose ration, least for those from exercised animals, and intermediate for roasts from animals on the basal ration. Meyer et al. (1963) reported weight losses from cooked gluteus medius PSE muscle significantly ($P = 0.005$) greater than losses from DFD muscle. Lewis et al. (1962) found stress significantly decreased total and dripping roasting losses from the LD, but did not significantly decrease evaporation loss. Also, they found that sugar feeding had no significant effect on roasting

losses. In this study, dripping losses were not affected significantly by breed; however, they followed the same trend as the total and volatile losses. When data for the 2 breeds were pooled, total, volatile, and dripping losses were greater for roasts from animals fed the basal ration than for those from exercised animals.

Correlation coefficients were computed to establish relationships between measurements used to evaluate the roasts (Table 20, Appendix). Coefficients for selected paired variates are reported in Table 4. In this manuscript, correlation coefficients are discussed in the terms suggested by Shindell's (1964) citation from Falkner. A coefficient between 0.00 and 0.39 is considered low, one between 0.40 and 0.79 is moderate, and one above 0.80 is considered high.

Correlation coefficients for total and volatile roasting losses vs shear values were low for roasts from animals fed both the basal and sucrose rations and when data were combined for roasts from all treatments, but were moderate for those from exercised animals. Coefficients for volatile roasting losses vs 24 hr pH were low for all antemortem treatments and for all treatments combined. Sayre et al. (1964) reported moderate correlations for volatile roasting losses vs both 24 hr pH and shear values for porcine LD.

pH values. Differences in 24 hr pH values for raw muscle were brought about by antemortem treatment ($P = 0.001$) and interaction between breed and antemortem treatment ($P = 0.05$);

Table 4. Correlation coefficients for selected paired variates.

Paired variates	Antemortem treatment			
	Treatments combined D/F = 46	Basal	Sucrose	Exercised
		D/F = 14		
	r	r	r	r
Total moisture (Brabender) vs total moisture (Carver press)	0.79***	0.58*	0.77***	0.82***
Total moisture (Brabender) vs serum in press fluid	0.65***	0.62**	0.75***	0.60*
Total moisture (Brabender) vs pH	0.64***	-0.51*	-0.02	0.78***
Total moisture (Brabender) vs juiciness scores	0.31*	0.06	0.04	0.39
Total moisture (Brabender) vs tenderness scores	0.19	-0.25	0.08	0.39
Total moisture (Carver press) vs serum in press fluid	0.84***	0.80***	0.88***	0.84***
Total moisture (Carver press) vs moisture in press cake	0.59***	0.13	0.55*	0.71**
Total moisture (Carver press) vs pH	0.50***	-0.23	-0.29	0.80***
Total moisture (Carver press) vs juiciness scores	0.33*	0.18	0.10	0.45
Total moisture (Carver press) vs tenderness scores	0.38**	0.08	0.24	0.62**
pH vs juiciness scores	0.46***	0.31	0.29	0.51*
pH vs serum in press fluid	0.33*	-0.21	-0.09	0.56*
pH vs tenderness scores	0.20	-0.18	-0.39	0.53*
pH vs shear values	-0.42**	0.15	-0.23	-0.60*
Juiciness scores vs serum in press fluid	0.34*	0.31	0.24	0.37
24 hr pH vs shear values	-0.19	0.11	-0.33	0.14
24 hr pH vs volatile roasting losses	-0.25	0.25	0.05	0.20
Total roasting losses vs shear values	0.20	-0.25	-0.28	0.52*
Volatile roasting losses vs shear values	0.19	-0.23	-0.24	0.48

*, P = 0.05
**, P = 0.01
***, P = 0.001

r values required for 3 levels of significance:

D/F	0.05	0.01	0.001
14	0.50	0.62	0.74
46	0.28	0.37	0.46

whereas breed (P = 0.05), antemortem treatment (P = 0.001), and interaction between these factors (P = 0.001) affected the pH values of the roasted, ground LD muscle (Table 3). Mean pH values were lowest for roasted LD from sucrose fed animals and highest for that from exercised animals. Mean pH values for roasted muscle from Poland China animals were lower than comparable values for roasted muscle from Duroc animals with the exception of that from exercised Poland China pigs.

Correlation coefficients for 24 hr pH vs shear values were low for all antemortem treatments and for all treatments combined. The correlation coefficients for pH of roasted muscle vs serum in press fluid and vs tenderness scores also were low with the exception of coefficients for exercised animals, which were moderate. Coefficients for pH vs juiciness scores and pH vs shear values were low for basal and sucrose fed animals and moderate for exercised animals and when treatments were combined. Coefficients for pH and total moisture (Brabender) were moderate except for sucrose fed animals, whereas coefficients for pH and total moisture (Carver press) varied. They were low for basal and sucrose fed animals, high for exercised animals, and moderate when treatments were combined (Table 4). Kauffman et al. (1964) reported increased muscle acidity was associated with greater quantities of expressible juice.

Shear values. Differences in shear values were attributable to breed and to interaction between breed and antemortem treatment at the 5% level, and to antemortem treatment at the 1% level (Table 3). For both breeds, LD from animals fed the basal ration had the highest shear values (least tender), whereas LD from sucrose fed Durocs and exercised Poland Chinas had the lowest shear values. Thomas et al. (1966) found tenderness as measured by the Allo-Kramer shear press related to breed. Briskey (1963) reported PSE muscle of heat-stressed animals less tender than normal muscle after moist-heat cookery. Lewis et al. (1962) reported that stress ($5\frac{1}{2}$ hr) had no significant effect on Warner-Bratzler shear values ($\frac{1}{2}$-in. core).

Mean data for lateral and medial shear cores for the LD are given in Table 5. When the raw data were analyzed by t-test,

Table 5. Treatment means for Warner-Bratzler shear values (lb/$\frac{1}{2}$-in. core) for scores from the lateral and medial positions in the LD muscle.

Breed and antemortem treatment					
Duroc			Poland China		
Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
		Lateral			
4.3	4.1	4.2	6.1	5.6	4.1
		Medial			
5.8	5.1	5.2	7.6	6.3	4.1

irrespective of breed or treatment, lateral shear values were significantly (P = 0.001) lower than medial values. This supports the findings of Urbin et al. (1962), but disagrees with those of Pengilly and Harrison (1966), Murphy and Carlin (1961), and Onate and Carlin (1963).

Total moisture. Total moisture as measured by the Brabender moisture tester was affected (P = 0.01) by both breed and antemortem treatment, and by interaction (P = 0.05) between these factors (Table 6). Mean values for total moisture were identical for muscle from sucrose fed Durocs and Poland Chinas and for Durocs on the basal ration. The LD of exercised animals (both Durocs and Poland Chinas) had the highest percentage moisture.

Correlation coefficients for total moisture as measured by the Brabender vs the Carver press were high for exercised animals and moderate for the other treatments and for all treatments combined. The relationship between total moisture, as measured by the Brabender, vs serum in the press fluid was moderate. When the Carver press was used to obtain total moisture this relationship was high. Although a larger portion of the total moisture, as measured by the Carver press, was retained by the press cake than was expressed as press fluid (Table 6), the relationship between total moisture (Carver press) vs moisture in the press cake was not as high as the relationship between total moisture (Carver press) and serum in the press fluid. The relationships between total moisture, as obtained by either the Brabender or the Carver press, and panel

Table 6. Means, significance of F, and LSD attributable to breed, antemortem treatment, and the interaction between breed and antemortem for total moisture, expressed moisture, press fluid, and organoleptic scores.

Measurement	Breed and antemortem treatment						Probability level of F-value			LSD[a]
	Duroc			Poland China						
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised	B[b]	ATr[b]	B x ATr[b]	
Total moisture, %										
Brabender	61.9	61.9	62.5	63.0	61.9	66.5	**	**	*	2.03
Carver Press	63.1	62.8	63.2	62.7	63.1	68.0				
Expressed moisture, %										
Press fluid	24.8	25.0	25.2	25.2	24.4	27.3				
Serum										
Press cake	38.3	37.8	38.0	37.5	38.7	40.7				
Press fluid, ml/25-g										
Total	7.9	8.0	8.2	7.8	7.7	8.3				
Serum	6.4	6.5	6.5	6.5	6.3	7.1				
Fat	1.5	1.5	1.7	1.3	1.4	1.2				
Flavor[c]	5.6	5.4	5.5	5.5	5.4	5.4				
Tenderness[c]	5.5	5.8	5.6	5.0	5.4	5.5	*			
Juiciness[c]	5.2	5.1	5.3	4.9	4.9	5.7				

[a]LSD, least significant difference at the 5% level for ATr and B x ATr.

[b]B (breed) and ATr (antemortem treatment).

[c]Range, 7 (very desirable flavor, very tender or juicy) to 1 (undesirable flavor, extremely tough or dry).

*, P = 0.05

**, P = 0.01

scores for juiciness were low except when the Carver press was used to obtain total moisture values for muscle from exercised animals. The relationship between total moisture and panel scores for tenderness followed the same pattern. Lewis (1963) did not find the juiciness score related to moisture in cooked LD muscle.

Subjective Measurements

Differences in flavor, tenderness, and juiciness scores attributable to antemortem treatment were not significant (Table 6). The low correlation coefficients for juiciness scores and serum in the press fluid (Table 4) support the findings of Kauffman et al. (1964). These workers reported a low correlation (r = -0.35) between expressible juice and panel scores for juiciness.

Tenderness scores were affected (P = 0.05) by breed (Table 6). Mean values for Poland Chinas given all treatments were lower than those for Durocs. Animals fed the basal ration were less tender than those given other treatments. It appears that the treatment desirable for attaining the most tender LD muscle is dependent upon the breed of the animal.

SUMMARY

Roasts from the posterior third of the loin were obtained from 12 Duroc and 12 Poland China pigs that had received ante- and post-mortem treatments designed to develop PSE, DFD, and "normal" muscle. A completely randomized design was used to

evaluate 3 roasts at each of 16 periods. Each section of loin was roasted at 350°F to an internal temperature of 75°C and evaluated by palatability scores and measurements for selected related characteristics of the LD muscle.

Roasting time and losses were noted. Measurements on cooked LD included: scores for tenderness, juiciness, and flavor; Warner-Bratzler shear and pH values; percentage total moisture; volume of press fluid; and percentage moisture in the press fluid and press cake. Data for each measurement were subjected to analysis of variance. When significant F-values occurred, least significant differences at the 5% level were calculated. Shear values for cores from medial and lateral positions in the LD were analyzed by Student's t-test.

None of the measurements were affected significantly by post-mortem treatment (carcass cooling temperature). There was no marked organoleptic preference for one type of muscle. No significant differences attributable to antemortem treatment (basal ration, sugar-fed, exercised pigs) were found for flavor, tenderness, or juiciness. Regardless of antemortem treatment, all roasts from Poland China pigs were less tender than those from Duroc pigs.

Antemortem treatment did not significantly affect the following: total moisture (Carver press), expressed moisture (press fluid serum and press cake), volume of press fluid (total, serum, and fat), and total roasting time. There were significant differences in shear values, pH values (roasted muscle), and total

moisture (Brabender) attributable to breed, antemortem treatment, and interaction between breed and antemortem treatment. Significant differences in roasting losses (total and volatile) were attributable to breed and antemortem treatment, whereas significant differences in dripping losses were attributable to antemortem treatment alone. Significant differences in pH of the raw muscle 24 hr post-mortem were attributable to antemortem treatment and to interaction between breed and antemortem treatment. Differences in roasting time, in min/lb, were attributable to interaction between breed and antemortem treatment.

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APPENDIX

Name _____ Date _____

Sample Number	Juiciness	Flavor	Tenderness Based on Chews	
			Number	Score
1				
2				
3				

Descriptive terms for scoring:

Juiciness

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

Tenderness

7. Very tender
6. Tender
5. Moderately tender
4. Acceptable
3. Slightly tough
2. Tough
1. Extremely tough

Flavor

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

Comments:

Fig. 5. Score card for pork loin roasts.

Table 7. Internal temperature of roasts prior to roasting and flavor scores.

Post-mortem treatment, cooler temperature, °F	Breed and antemortem treatment					
	Duroc			Poland China		
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
	Internal temperature, °C					
30	17.0	18.0	19.0	18.0	21.0	22.0
	23.0	23.0	19.0	21.0	16.0	22.0
	21.0	21.0	22.0	19.0	20.0	17.0
	20.0	21.0	15.0	22.0	22.0	21.0
Av.	20.3	20.8	18.8	20.0	19.8	20.5
42	20.0	22.0	20.0	21.0	23.0	18.0
	21.0	18.0	22.0	20.0	19.0	21.0
	24.0	23.0	23.0	22.0	21.0	23.0
	22.0	22.0	22.0	21.0	17.0	21.0
Av.	21.8	21.3	21.8	21.0	20.0	20.8
	Flavor scores, 7 (very desirable) to 1 (very undesirable)					
30	6.0	5.5	6.0	5.8	5.0	5.5
	6.0	4.7	4.8	5.3	5.9	4.8
	5.3	5.2	5.9	5.4	5.4	6.0
	6.0	5.6	5.0	6.3	5.4	4.8
Av.	5.8	5.2	5.4	5.7	5.4	5.3
42	5.0	5.9	6.0	5.8	5.3	5.4
	6.0	5.5	5.1	4.9	5.5	5.9
	5.9	5.1	5.6	5.1	5.1	5.4
	4.9	6.0	5.8	5.0	5.8	5.2
Av.	5.4	5.6	5.6	5.2	5.4	5.5

Table 8. Volume of total (serum and fat) press fluid (Carver Press) and juiciness scores.

Post-mortem treatment, cooler temperature, °F	Breed and antemortem treatment					
	Duroc			Poland China		
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
	Total press fluid, ml/25 g					
30	7.3	8.4	6.4	6.4	7.1	7.3
	8.2	7.8	6.0	6.7	8.2	8.8
	7.1	8.7	8.9	8.5	8.2	8.5
	9.1	7.4	9.3	8.8	8.5	7.8
Av.	7.9	8.1	7.7	7.6	8.0	8.1
42	8.1	8.7	8.0	8.0	7.8	7.9
	7.8	6.6	8.8	7.2	6.1	7.9
	8.5	7.8	9.6	7.7	7.3	8.4
	7.2	8.2	8.1	8.5	8.0	9.2
Av.	7.9	7.8	8.6	7.9	7.3	8.4
	Juiciness scores, 7 (very juicy) to 1 (extremely dry)					
30	4.8	5.1	4.7	4.5	3.7	4.8
	5.4	4.3	4.5	5.0	5.1	6.0
	5.5	4.5	6.5	5.0	5.1	5.4
	6.0	5.7	5.7	5.6	5.8	6.3
Av.	5.4	4.9	5.4	5.0	4.9	5.6
42	5.5	5.4	5.1	5.5	5.5	6.6
	6.3	5.8	5.6	4.5	3.5	4.6
	4.4	5.5	5.1	3.9	5.1	5.3
	3.3	5.1	5.0	5.1	4.9	6.3
Av.	4.9	5.3	5.2	4.8	4.8	5.7

Table 9. Volume of serum and fat in press fluid (Carver Press).

Post-mortem treatment, cooler temperature, °F	Breed and antemortem treatment					
	Duroc			Poland China		
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
			Serum, ml/25 g			
30	5.7	7.3	5.0	5.5	5.7	5.9
	7.2	6.9	5.4	5.2	7.1	7.6
	6.1	6.3	7.2	7.3	7.5	8.1
	7.1	6.1	6.3	6.9	7.2	6.8
Av.	6.5	6.7	6.0	6.2	6.9	7.1
42	6.0	6.1	6.7	6.5	4.9	6.1
	6.4	4.7	6.7	6.8	5.4	6.7
	6.8	6.8	6.8	6.0	6.5	8.0
	6.0	7.3	7.4	7.6	6.0	7.4
Av.	6.3	6.2	6.9	6.7	5.7	7.1
			Fat, ml/25 g			
30	1.6	1.1	1.4	0.9	1.4	1.4
	1.0	0.9	0.6	1.5	1.1	1.2
	1.0	2.4	1.7	1.2	0.7	0.4
	2.0	1.3	3.0	1.9	1.3	1.0
Av.	1.4	1.4	1.7	1.4	1.1	1.0
42	2.1	2.6	1.3	1.5	2.9	1.8
	1.4	1.9	2.1	0.4	0.7	1.2
	1.7	1.0	2.8	1.7	0.8	0.4
	1.2	0.9	0.7	0.9	2.0	1.8
Av.	1.6	1.6	1.7	1.1	1.6	1.3

Table 10. Shear values and tenderness scores (based on chews).

Port-mortem treatment, cooler temperature, °F		Breed and antemortem treatment					
		Duroc			Poland China		
		Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
		Shear values, lb/½-in. core					
30		4.4	6.2	4.6	5.6	6.1	5.6
		4.6	5.2	4.1	8.9	5.9	2.8
		4.4	4.4	5.5	5.3	6.1	4.9
		5.5	3.1	4.1	5.7	6.5	2.8
	Av.	4.7	4.7	4.6	6.4	6.2	4.0
42		7.4	4.8	7.0	6.8	6.5	3.4
		5.2	2.9	4.0	6.3	5.5	6.5
		4.8	4.8	3.9	6.1	5.3	4.6
		4.2	5.8	4.7	10.5	5.9	2.5
	Av.	5.4	4.6	4.9	7.4	5.8	4.3
		Tenderness scores, 7 (very tender) to 1 (extremely tough)					
30		5.8	5.9	5.0	5.1	4.6	4.3
		5.7	5.9	5.5	4.5	6.3	6.3
		5.7	6.0	5.3	5.6	4.4	5.9
		5.0	6.1	6.0	5.6	6.1	6.1
	Av.	5.5	6.0	5.4	5.2	5.4	5.6
42		5.0	5.3	5.6	4.8	5.1	5.8
		6.0	6.0	5.5	4.6	5.3	4.3
		4.9	5.6	6.1	5.3	5.8	5.1
		5.9	5.4	6.0	4.1	5.5	6.3
	Av.	5.4	5.6	5.8	4.7	5.4	5.4

Table 11. Roasting time in total minutes and minutes per pound.

Post-mortem treatment, cooler temperature, °F		Breed and antemortem treatment					
		Duroc			Poland China		
		Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
				Total min			
30		87.0	79.0	75.0	80.0	86.0	60.0
		66.0	74.0	77.0	65.0	76.0	73.0
		78.0	86.0	64.0	70.0	66.0	86.0
		76.0	76.0	78.0	66.0	60.0	78.0
	Av.	76.8	78.8	73.5	70.3	72.0	74.3
42		87.0	80.0	76.0	70.0	74.0	80.0
		80.0	75.0	81.0	72.0	87.0	65.0
		68.0	64.0	70.0	71.0	67.0	71.0
		81.0	71.0	72.0	68.0	76.0	72.0
	Av.	79.0	72.5	74.8	70.3	76.0	72.0
				Min/lb			
30		30.7	38.2	30.9	34.5	36.3	33.1
		35.7	37.2	33.2	33.9	32.3	32.0
		35.1	32.1	30.6	36.1	28.7	39.6
		36.0	37.6	37.1	32.5	31.6	36.8
	Av.	34.4	36.3	33.0	34.3	32.2	35.4
42		39.4	35.4	34.7	31.1	37.8	35.9
		38.1	34.9	38.6	33.0	35.5	40.9
		35.6	36.6	36.8	34.0	29.5	38.8
		34.8	37.0	37.5	31.8	34.2	34.0
	Av.	37.0	36.0	36.9	32.5	34.3	37.4

Table 12. Percentage total roasting losses.

Post-mortem treatment, cooler temperature, °F	Breed and antemortem treatment					
	Duroc			Poland China		
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
30	20.5	20.3	17.9	21.2	24.3	18.6
	18.8	20.9	19.8	20.5	18.0	13.8
	18.9	22.9	13.6	18.0	14.3	17.6
	20.5	21.5	18.6	16.8	17.2	14.3
Av.	19.7	21.4	17.5	19.1	18.5	16.1
42	20.7	19.7	18.7	18.0	21.3	15.1
	20.7	21.7	18.2	18.9	20.9	17.2
	16.7	18.7	16.5	20.9	18.9	16.3
	20.5	22.3	14.9	16.0	20.9	12.0
Av.	19.7	20.6	17.1	18.5	20.5	15.2

Table 13. Percentage volatile and dripping losses during roasting.

Post-mortem treatment, cooler temperature, °F		Breed and antemortem treatment					
		Duroc			Poland China		
		Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
				Volatile			
30		11.8	12.9	11.5	13.9	14.7	11.4
		11.3	12.2	13.5	12.8	11.1	7.7
		11.9	13.2	8.3	10.4	9.8	9.5
		11.4	12.5	10.6	10.7	10.0	7.9
	Av.	11.6	12.7	11.0	12.0	11.4	9.1
42		11.8	13.6	11.0	9.6	11.5	9.4
		11.6	12.5	12.1	12.3	12.7	11.2
		11.1	12.0	9.3	11.8	10.1	10.8
		12.5	12.9	11.6	9.9	13.1	7.6
	Av.	11.8	12.8	11.0	10.9	11.9	9.8
				Dripping			
30		8.6	7.1	6.2	7.3	9.6	6.9
		7.3	8.6	6.6	7.6	6.7	5.9
		6.9	9.5	5.0	7.4	4.2	8.0
		8.9	8.7	8.1	5.9	7.1	6.2
	Av.	7.9	8.5	6.5	7.1	6.9	6.8
42		8.8	6.0	7.7	8.5	9.4	5.7
		9.0	9.1	6.0	6.5	7.9	5.5
		5.3	6.1	7.0	9.0	8.6	5.3
		7.9	9.1	3.1	6.2	7.7	4.2
	Av.	7.8	7.6	6.0	7.6	8.4	5.2

Table 14. Total moisture measured by the Brabender moisture tester and the Carver press.

Post-mortem treatment, cooler temperature, °F	Breed and antemortem treatment					
	Duroc			Poland China		
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
	Total moisture, %, Brabender					
30	61.5	63.9	61.8	63.2	59.3	61.7
	63.7	62.8	64.1	61.4	63.2	67.5
	61.6	59.9	62.6	63.4	65.3	67.8
	61.9	61.4	59.5	62.8	62.3	67.9
Av.	62.2	62.0	62.0	62.7	62.5	66.2
42	60.9	59.6	62.0	62.0	57.5	66.5
	62.4	60.2	61.8	64.6	63.2	63.6
	61.8	63.8	62.3	61.7	63.7	68.1
	61.4	63.2	65.6	64.3	60.4	68.9
Av.	61.6	61.7	62.9	63.2	61.2	66.8
	Total moisture, %, Carver press					
30	59.1	65.8	57.8	60.1	60.5	58.6
	67.2	63.9	61.0	60.4	66.5	72.8
	62.9	64.7	62.2	65.4	68.1	71.4
	65.6	64.7	63.6	64.5	67.4	70.2
Av.	63.7	64.8	61.1	62.6	65.6	68.3
42	59.9	56.8	63.9	58.3	54.4	64.2
	63.9	56.8	63.6	63.5	60.7	64.5
	63.0	62.6	64.1	62.2	64.9	69.6
	63.8	66.9	68.9	67.0	61.1	72.3
Av.	62.5	60.8	65.1	62.8	60.3	67.7

Table 15. Moisture expressed (press fluid serum) from cooked, ground LD and moisture in press cake.

Post-mortem treatment, cooler temperature, °F	Breed and antemortem treatment					
	Duroc			Poland China		
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
	Press fluid serum, %/25 g ground muscle					
30	19.58	28.77	18.89	21.10	21.87	22.90
	28.09	27.00	20.67	20.25	27.64	29.29
	23.45	24.84	27.77	28.91	29.05	31.34
	28.59	24.38	25.24	27.62	28.47	26.24
Av.	24.93	26.25	23.14	24.47	26.76	27.44
42	23.87	22.74	26.65	24.66	19.03	23.60
	25.48	18.33	26.22	26.13	20.42	26.11
	25.84	25.53	26.65	24.10	24.71	30.18
	23.57	28.27	29.54	29.10	23.62	28.94
Av.	24.70	23.72	27.27	26.00	21.95	27.21
	Press cake, %					
30	39.5	37.0	38.9	39.0	38.6	35.7
	39.1	36.9	40.3	40.1	38.9	43.5
	39.4	39.9	34.4	36.5	39.0	40.1
	37.0	40.3	38.4	36.9	38.9	44.0
Av.	38.8	38.5	38.0	38.1	38.9	40.8
42	36.0	34.1	37.2	33.6	35.4	40.6
	38.4	38.5	37.4	37.4	40.3	38.4
	37.2	37.1	37.4	38.1	40.2	39.4
	39.5	38.6	39.4	37.9	37.5	43.4
Av.	37.8	37.1	37.9	36.8	38.4	40.5

Table 16. pH values of raw muscle at 24 hr post-mortem[a] and pH values of cooked, ground muscle homogenates.

Post-mortem treatment, cooler temperature, °F	Breed and antemortem treatment					
	Duroc			Poland China		
	Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
	pH, raw muscle					
30	5.80	5.60	5.90	5.70	5.30	6.65
	5.85	5.45	6.25	5.75	5.45	6.40
	5.45	5.70	5.80	5.40	5.50	5.90
	5.65	5.60	5.70	5.65	5.60	5.75
Av.	5.69	5.59	5.91	5.63	5.46	6.18
42	5.70	5.65	5.85	5.65	5.40	6.60
	5.85	5.50	6.00	5.80	5.40	6.50
	5.55	5.65	5.75	5.50	5.40	5.85
	5.60	5.60	5.70	5.65	5.50	5.70
Av.	5.68	5.60	5.83	5.65	5.43	6.16
	pH, cooked, ground muscle homogenate					
30	5.75	5.70	5.80	5.63	5.61	5.90
	5.69	5.58	5.82	5.90	5.43	6.55
	6.00	5.58	5.71	5.77	5.89	6.88
	5.80	5.66	6.05	5.70	5.62	6.57
Av.	5.81	5.63	5.85	5.75	5.64	6.48
42	5.91	5.89	5.84	5.75	5.72	6.30
	5.69	5.80	6.03	5.69	5.61	5.89
	5.82	5.79	6.01	5.78	5.48	6.30
	5.60	5.61	5.79	5.71	5.41	6.83
Av.	5.76	5.77	5.92	5.73	5.56	6.33

[a]Bowers, J. 1966. Unpublished data.

Table 17. Shear values based on lateral and medial position.

Post-mortem treatment, cooler temperature, °F		Breed and antemortem treatment					
		Duroc			Poland China		
		Basal	Sucrose	Exercised	Basal	Sucrose	Exercised
		Lateral values, lb/½-in. core					
30		3.3	5.5	4.1	4.6	6.6	6.0
		4.0	4.5	3.6	7.5	5.3	4.0
		4.0	4.1	4.8	5.0	5.8	4.4
		4.6	2.2	3.7	5.3	7.1	2.5
	Av.	4.0	4.1	4.1	5.6	6.2	4.2
42		5.3	4.7	5.6	6.8	5.9	4.7
		4.9	2.5	4.1	6.3	3.9	5.7
		4.6	4.0	3.5	5.4	4.4	3.3
		3.5	5.5	4.5	8.2	6.0	2.5
	Av.	4.6	4.2	4.4	6.7	5.1	4.1
		Medial values, lb/½-in. core					
30		5.4	6.8	5.1	6.5	5.6	5.1
		5.1	5.8	4.6	10.2	6.5	1.5
		4.8	4.7	6.2	5.5	6.3	5.3
		6.3	3.9	4.5	6.0	5.9	3.1
	Av.	5.4	5.3	5.1	7.1	6.1	3.8
42		9.4	4.8	8.4	6.8	7.1	2.0
		5.5	3.2	3.9	6.2	7.0	7.3
		4.9	5.5	4.2	6.8	6.1	5.8
		4.9	6.0	4.8	12.8	5.8	2.4
	Av.	6.2	4.9	5.3	8.2	6.5	4.4

Table 18. Analysis of variance for objective measurements.

Source[a]	D/F	F-value	
		Total moisture, %	
		Brabender	Carver press
B	1	8.60 **	ns
PTr	1	ns	↓
ATr	2	7.66 **	
B x PTr	1	ns	
ATr x PTr	2	ns	
B x ATr	2	4.39 *	
B x ATr x PTr	2	ns	
Error	36		
Total	47		

		Expressed moisture, %	
		Press fluid serum	Press cake
B	1	ns	ns
PTr	1	↓	↓
ATr	2		
B x PTr	1		
ATr x PTr	2		
B x ATr	2		
B x ATr x PTr	2		
Error	36		
Total	47		

Table 18. (continued)

Source[a]	D/F	F-value		
		Press fluid, ml/25-g		
		Total	Serum	Fat
B	1	ns	ns	ns
PTr	1			
ATr	2			
B x PTr	1			
ATr x PTr	2			
B x ATr	2			
B x ATr x PTr	2			
Error	36			
Total	47			
		Roasting time		
		Total, min		Min/lb
B	1	ns		ns
PTr	1			
ATr	2			
B x PTr	1			
ATr x PTr	2			
B x ATr	2			3.40 *
B x ATr x PTr	2			ns
Error	36			
Total	47			

Table 18. (concluded)

Source[a]	D/F	F-value		
		Roasting losses, %		
		Total	Volatile	Dripping
B	1	4.61 *	5.50 *	ns
PTr	1	ns	ns	ns
ATr	2	12.93 ***	7.89 **	7.39 **
B x PTr	1	ns	ns	ns
ATr x PTr	2	↓	↓	↓
B x ATr	2	↓	↓	↓
B x ATr x PTr	2	↓	↓	↓
Error	36			
Total	47			

		pH values		Shear values, lb/½-in. core
		24 hr	Roasted	
B	1	ns	4.71 *	5.12 *
PTr	1	ns	ns	ns
ATr	2	21.98 ***	26.81 ***	5.61 **
B x PTr	1	ns	ns	ns
ATr x PTr	2	ns	ns	ns
B x ATr	2	4.57 *	11.93 ***	3.87 *
B x ATr x PTr	2	ns	ns	ns
Error	36			
Total	47			

[a]B (breed), PTr (post-mortem treatment), and ATr (antemortem treatment).
ns, not significant
*, P = 0.05
**, P = 0.01
***, P = 0.001

Table 19. Analysis of variance for subjective measurements.

Source	D/F	F-value		
		Flavor[b]	Tenderness[b]	Juiciness[b]
B	1	ns	4.47 *	ns
PTr	1		ns	
ATr	2			
B x PTr	1			
ATr x PTr	2			
B x ATr	2			
B x ATr x PTr	2			
Error	36			
Total	47			

[a]B (breed), PTr (post-mortem treatment), and ATr (antemortem treatment).

[b]Range, 7 (very desirable flavor, very tender or juicy) to 1 (undesirable flavor, extremely tough or dry).

ns, not significant

*, P = 0.05
**, P = 0.01
***, P = 0.001

Table 20. Correlation coefficients among 18 measurements for 3 antemortem treatments.

Factor	Factor																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Line
1		0.79	0.60	0.16	0.65	-0.61	0.58	0.64	-0.25	0.31	-0.11	0.19	-0.15	0.02	-0.70	-0.59	-0.59	0.34	A
		0.58	0.56	0.13	0.62	-0.72	-0.06	-0.51	0.22	0.06	-0.03	-0.25	-0.44	-0.25	-0.47	-0.19	-0.48	0.19	B
		0.77	0.72	0.03	0.75	-0.89	0.38	-0.02	0.16	0.04	0.04	0.08	-0.44	-0.34	-0.63	-0.51	-0.57	0.11	C
		0.82	0.54	0.08	0.60	-0.58	0.76	0.78	-0.50	0.39	-0.25	0.39	0.22	0.17	-0.63	-0.51	-0.42	-0.02	D
2			0.85	0.50	0.84	-0.42	0.59	0.50	-0.22	0.33	-0.10	0.38	-0.14	0.09	-0.57	-0.56	-0.41	0.12	A
			0.84	0.56	0.80	-0.26	0.13	-0.23	-0.00	0.18	0.06	0.08	-0.44	0.19	-0.44	-0.32	-0.37	-0.09	B
			0.90	0.37	0.88	-0.70	0.55	-0.29	0.22	0.10	0.05	0.24	-0.37	-0.43	-0.44	-0.43	-0.31	0.26	C
			0.83	0.50	0.84	-0.31	0.71	0.80	-0.47	0.45	-0.29	0.62	0.29	0.35	-0.63	-0.60	-0.29	-0.28	D
3				0.73	0.98	-0.29	0.07	0.31	0.03	0.36	0.08	0.19	-0.30	0.13	-0.54	-0.52	-0.40	0.03	A
				0.82	0.96	-0.06	-0.44	-0.18	0.09	0.33	0.11	-0.10	-0.48	0.17	-0.62	-0.66	-0.30	-0.20	B
				0.64	0.99	-0.55	0.14	-0.13	0.37	0.26	0.09	0.18	-0.46	-0.28	-0.52	-0.39	-0.48	0.38	C
				0.71	0.99	-0.21	0.19	0.52	-0.07	0.36	0.06	0.40	0.06	0.43	-0.51	-0.50	-0.24	-0.36	D
4					0.70	0.42	-0.18	0.31	-0.07	0.51	0.14	0.24	-0.19	0.14	-0.45	-0.52	-0.24	0.01	A
					0.81	0.47	-0.57	0.02	0.05	0.42	0.36	-0.06	-0.32	0.15	-0.55	-0.77	-0.11	-0.20	B
					0.63	0.28	-0.40	0.06	0.32	0.48	0.22	0.13	-0.26	-0.17	-0.30	-0.13	-0.36	0.62	C
					0.67	0.53	-0.03	0.35	-0.22	0.54	-0.05	0.48	-0.00	0.29	-0.46	-0.59	-0.04	-0.40	D
5						-0.35	0.09	0.33	0.02	0.34	0.09	0.16	-0.30	0.08	-0.57	-0.54	-0.44	0.05	A
						-0.14	-0.43	-0.21	0.08	0.31	0.15	-0.13	-0.46	0.00	-0.72	-0.73	-0.38	-0.14	B
						-0.58	0.10	-0.09	0.38	0.24	0.10	0.12	-0.47	-0.30	-0.55	-0.39	-0.54	0.37	C
						-0.27	0.22	0.56	-0.09	0.37	0.05	0.36	0.06	0.41	-0.52	-0.51	-0.25	-0.33	D
6							-0.34	-0.02	-0.12	0.23	0.07	0.12	0.13	0.08	0.14	-0.00	0.24	-0.05	A
							-0.31	0.35	-0.03	0.25	0.37	0.10	0.16	0.25	0.15	-0.20	0.38	-0.12	B
							-0.54	0.18	-0.14	0.21	0.11	-0.00	0.31	0.19	0.36	0.34	0.28	0.19	C
							-0.28	-0.17	-0.18	0.28	-0.12	0.20	-0.07	-0.09	-0.00	-0.18	0.24	-0.15	D
7								0.47	-0.46	0.07	-0.32	0.43	0.20	-0.04	-0.25	-0.25	-0.16	0.17	A
								-0.04	-0.18	-0.30	-0.10	0.31	0.15	0.01	0.39	0.66	-0.06	0.21	B
								-0.42	-0.21	-0.26	-0.07	0.21	0.03	-0.44	-0.00	-0.24	0.21	-0.14	C
								0.74	-0.74	0.33	-0.59	0.59	0.44	0.07	-0.46	-0.43	-0.20	-0.04	D
8									-0.42	0.46	-0.17	0.20	0.10	0.25	-0.59	-0.61	-0.37	0.43	A
									0.15	0.31	-0.14	-0.18	0.03	0.26	0.01	-0.05	0.05	-0.36	B
									-0.23	0.29	0.01	-0.39	-0.14	0.14	-0.25	-0.00	-0.42	0.32	C
									-0.60	0.51	-0.34	0.53	0.45	0.23	-0.47	-0.64	0.05	-0.09	D
9									-0.23	0.08	-0.67	-0.24	-0.13	0.20	0.19	0.15	-0.19		A
									0.14	-0.42	-0.82	-0.33	-0.21	-0.25	-0.23	-0.10	0.11		B
									-0.13	-0.01	-0.41	-0.16	-0.14	-0.28	-0.24	-0.24	-0.33		C
									-0.54	0.74	-0.69	-0.36	0.13	0.52	0.48	0.22	0.14		D
10										0.15	0.32	-0.18	0.06	-0.52	-0.61	-0.25	0.26		A
										0.51	0.03	-0.03	0.26	-0.13	-0.38	0.17	0.28		B
										0.33	0.36	-0.69	-0.08	-0.45	-0.48	-0.31	0.52		C
										-0.33	0.54	0.22	-0.14	-0.72	-0.79	-0.19	-0.16		D
11											-0.05	-0.09	-0.00	0.00	0.04	-0.06	0.02		A
											0.38	-0.10	-0.06	-0.12	-0.20	-0.02	0.25		B
											0.08	0.04	-0.01	-0.13	0.08	-0.27	0.31		C
											-0.42	-0.21	0.08	0.16	0.16	0.01	-0.10		D
12												0.26	0.11	-0.10	-0.22	0.06	-0.12		A
												0.40	0.29	0.32	0.16	0.28	-0.02		B
												-0.13	0.05	0.05	-0.15	0.21	0.41		C
												0.56	-0.02	-0.46	-0.51	-0.05	-0.53		D
13													0.30	0.43	0.36	0.40	-0.13		A
													0.29	0.63	0.41	0.54	0.15		B
													0.34	0.68	0.77	0.41	-0.19		C
													0.30	0.18	0.03	0.35	-0.25		D
14														0.20	0.21	0.11	0.08		A
														0.35	0.23	0.25	-0.05		B
														0.62	0.64	0.39	0.05		C
														0.18	0.17	0.07	-0.08		D
15															0.86	0.83	-0.35		A
															0.74	0.77	0.28		B
															0.82	0.86	-0.12		C
															0.83	0.67	0.21		D
16																0.43	-0.25		A
																0.14	0.25		B
																0.43	0.05		C
																0.14	0.20		D
17																	-0.34		A
																	0.19		B
																	-0.27		C
																	0.08		D
18																			

Key
All treatments combined = A
Basal ration = horizontal line B
Sucrose ration = horizontal line C
Exercised = horizontal line D

Factor
1 = Total moisture, Brabender, %
2 = Total moisture, Carver, %
3 = Press fluid serum, %
4 = Press fluid, total, ml/25 g
5 = Press fluid, serum, ml/25 g
6 = Press fluid, fat, ml/25 g
7 = Press cake moisture, %
8 = pH values, roasted muscle
9 = Shear values, lb/1/2-in. core
10 = Juiciness scores
11 = Flavor scores
12 = Tenderness scores
13 = Total roasting time, min
14 = Roasting time, min/lb
Roasting loss, %
15 = Total
16 = Volatile
17 - Dripping
18 = pH values, 24 hr

r values required for 3 levels of significance

D/F	0.05	0.01	0.001
14	0.50	0.62	0.74
46	0.28	0.37	0.46

PALATABILITY AND SELECTED RELATED CHARACTERISTICS OF THREE TYPES OF ROASTED PORCINE MUSCLE

by

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B. S., Kansas State University, 1964

AN ABSTRACT OF A MASTER'S THESIS

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Lean type hogs have been developed in accordance with consumer demand for less lard and a larger proportion of muscle to fat. Concurrently with development of the lean type hog, the processor began to notice porcine muscle that was pale, soft, and exudative (PSE). Extensive investigation has been carried out on the physical and chemical properties of porcine muscle. During the course of these investigations, 3 types of porcine muscle have come to be recognized; PSE, dark-firm-dry (DFD), and "normal." Although the physical and chemical properties of raw PSE, DFD, and "normal" porcine muscle have received considerable attention, little has been done to ascertain the palatability and related characteristics of those 3 types of muscle.

Roasts from the posterior third of the loin were obtained from 12 Duroc and 12 Poland China pigs that had received ante- and post-mortem treatments designed to develop PSE, DFD, and "normal" muscle. A completely randomized design was used to evaluate 3 roasts at each of 16 periods. Each section of loin was roasted at 350°F to an internal temperature of 75°C and evaluated by palatability scores and measurements for selected related characteristics of the LD muscle.

Roasting time and losses were noted. Measurements on cooked LD included: scores for tenderness, juiciness, and flavor; Warner-Bratzler shear and pH values; percentage total moisture; volume of press fluid; and percentage moisture in the press fluid and press cake. Data for each measurement were subjected to analysis of variance. When significant F-values occurred, least

significant differences at the 5% level were calculated. Shear values for cores for medial and lateral positions in the LD were analyzed by Student's *t*-test.

None of the measurements were affected significantly by post-mortem treatment. There was no marked organoleptic preference for one type of muscle. No significant differences attributable to antemortem treatment were found for flavor, tenderness, or juiciness. Regardless of antemortem treatment, all roasts from Poland China pigs were less tender than those from Duroc pigs.

Antemortem treatment did not significantly affect the following objective measurements: total moisture (Carver press), expressed moisture (press fluid serum and press cake), volume of press fluid (total, serum, and fat), and total roasting time. There were significant differences in shear values, pH values (roasted muscle), and total moisture (Brabender) attributable to breed, antemortem treatment, and interaction between breed and antemortem treatment. Significant differences in roasting losses (total and volatile) were attributable to breed and antemortem treatment, whereas significant differences in dripping losses were attributable to antemortem treatment alone. Significant differences in pH of the raw muscle 24 hr post-mortem were attributable to antemortem treatment and to interaction between breed and antemortem treatment. Differences in roasting time, in min/lb, were attributable to interaction between breed and antemortem treatment.