EFFECTS OF MICROWAVE COOKING RATE ON
PALATABILITY OF PORK LOIN CHOPS

by

RANDY CLINTON HINES, B.S.

A THESIS

IN

MEAT SCIENCE

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

MASTER OF SCIENCE

Approved

August, 1979

AC
805
T3
1979
No. 71
cop. 2

ACKNOWLEDGMENTS

I am deeply indebted to Dr. C. Boyd Ramsey for his direction of this thesis, and to the other members of my committee, Dr. Robert A. Long, Dr. Leland F. Tribble and Dr. James R. Clark, for their helpful criticism. I would also like to express my appreciation to my fellow graduate students for their assistance in conducting this research.

TABLE OF CONTENTS

ACKNOWLEDGMENTS	ii
LIST OF TABLES	iv
LIST OF FIGURES	v
CHAPTER	
I. INTRODUCTION	1
II. LITERATURE REVIEW	2
III. EFFECTS OF MICROWAVE COOKING RATE ON PALATABILITY OF PORK LOIN CHOPS	6
Summary	6
Introduction	7
Experimental Procedure	8
Cooking	10
Sampling	17
Sensory Panel	18
Statistical Analyses	20
Results and Discussion	20
Cooking Time	20
Cooking Losses	22
Sensory Panel Scores	22
Proximate Analyses	25
LITERATURE CITED	28

LIST OF TABLES

Table	Page
1. Least squares means for the effects of animal and cooking method on cooking times and losses.	21
2. Least squares means for the effects of animal and cooking method on palatability.	23
3. Least squares means for the effects of animal and cooking method on moisture, protein and ether extractable components.	26

LIST OF FIGURES

Figure	Page
1. Anatomical locations of the six sets of three chops.	9
2. Microwave oven with cooking rate selection bar.	11
3. Placement of chops on microwave cooking tray.	13
4. Rotation pattern of microwave cooking tray to positions 1 through 8.	14
5. Denatured egg white showing cooking pattern of the Amana RR-7 Radar Range.	15
6. Denatured egg white showing cooking pattern of the Amana RR-9 Radar Range.	16
7. Locations of sensory panel (2.5 cm) and W-B shear (1.3 cm) cores.	19

CHAPTER I

INTRODUCTION

Microwave ovens with variable cooking rate controls, temperature controls, programmable defrost-cook cycles, and various other features recently have been developed. These advances in technology have made microwave ovens even more popular than formerly in homes.

Only Korschgen et al. (1976) have reported results of research in which procedures for cooking meat with microwaves were varied. On-off cycles were used in cooking beef, pork and lamb roasts. Turning the magnetron on and off by hand controls (sometimes called "stand-by cooking") involves the same principle as the automatic variable cooking rate controls in the modern microwave ovens. As the off cycle is lengthened, the cooking rate is decreased. Little research has been conducted on improving cooking procedures for pork chops. Decreasing the rate of oven roasting of beef roasts (Marshall et al., 1960; Schoman, 1960) and pork roasts (Carlin et al., 1965; Jones, 1978) has been shown to decrease cooking shrinkage and increase meat palatability. Similar effects might be found with decreased cooking rate of pork chops in microwave ovens.

Kersh (1978) and Jones (1978) found that the animal from which pork loin chops or roasts were obtained was one of the largest sources of variance in their cooking studies. This effect should be further studied.

CHAPTER II

LITERATURE REVIEW

Cooking method is one of the major factors which affects meat palatability. Considerable research on microwave (or electronic) cooking of beef, pork and lamb has been conducted. Research results are variable among animal species and meat cuts in regard to cooking losses, tenderness and juiciness.

Apgar (1959) used pork patties, roasts and chops in a comparison of electronically and conventionally cooked pork. Higher cooking losses and lower juiciness scores were found for conventionally cooked chops. Tenderness scores tended to be higher for the conventionally cooked chops. No differences due to cooking method in total cooking losses of the pork roasts were noted.

Korschgen et al. (1976) used a 115 V microwave oven, a 220 V microwave oven and a conventional oven to cook beef, pork and lamb roasts. Pork and lamb roasts showed no differences ($P>.05$) in total cooking losses between conventional and electronic cooking; however, total cooking losses were greater for electronically cooked beef roasts. Warner-Bratzler (W-B) shear values for beef and lamb muscle did not differ due to cooking method. However, pork had lower shears on interior cores than for exterior cores of roasts cooked in the 115 V microwave oven. The highest shear values were recorded from roasts cooked in the 220 V microwave oven. Flavor scores from interior muscle samples were similar for all three species and both cooking methods. Tenderness was not significantly different between the 115 V microwave and conventionally cooked pork roasts. Juiciness scores were not

significantly different between cooking methods or species, but scores tended to be higher for the interior of beef samples cooked in the conventional oven.

Kylen et al. (1964) found that both beef and pork roasts were less juicy and less tender when cooked in an electronic oven than in a conventional oven. Cooking losses for pork roasts cooked in an electronic oven were not different ($P > .05$) from those for conventionally cooked pork roasts. Beef roasts cooked in the conventional oven were lower in total cooking losses than beef roasts cooked in an electronic oven. These results agree with the work of Carpenter et al. (1968) and Marshall (1960).

Deethardt et al. (1973) found a lower volatile loss but a higher drip loss from electronically cooked pork loin roasts than from conventionally cooked roasts. Total cooking losses were similar between cooking methods. In their study, microwave ovens with and without browning units were used. Lower flavor scores were recorded for muscle cooked in the microwave oven containing a browning unit, but no significant differences were found among electronic, convection and conventional cooking methods for meat texture, juiciness and tenderness.

The thicker meat cuts (roasts) generally are similar in tenderness whether cooked by conventional or microwave methods (Apgar et al., 1959; Deethardt et al., 1973; Kylen et al., 1964). However, thinner cuts of meat (steaks and chops) which have been cooked electronically are less tender than those cuts cooked by conventional methods (Carpenter and King, 1965; Carpenter et al., 1968).

Cooking times and internal temperatures of meat have varied among studies. Deethardt et al. (1973) reported internal temperatures of 77 C and less cooking time required for pork roasts cooked electronically as compared to roasting in conventional ovens. Apgar et al. (1959) cooked pork chops and roasts to an 88 C internal temperature to alleviate pink color which was present at lower internal temperatures. Total cooking times for electronically cooked meats have been less than for conventional cooking methods as reported by Apgar et al. (1959), Headley and Jacobson (1960), Bramblett et al. (1970) and Marshall (1960).

Broiling in a conventional oven is a method many consumers use for cooking cuts of meat low in connective tissue. Kersh (1978) found that broiled chops which were .6, 1.3, 1.9 or 2.5 cm in thickness were more tender than those cooked by pan-frying or microwaves. All chops were cooked to a 77 C internal temperature as suggested by Holmes et al. (1966), Weir et al. (1963), Bowers and Goertz (1966) and Carlin et al. (1965).

Microwave cooking of meats has the advantage over conventional methods of being faster, although acceptability of these products is lower because of color, aroma or flavor problems (Apgar et al., 1959; Kylen et al., 1964; Kersh, 1978; Deethardt et al., 1973). Penner and Bowers (1973) found microwave reheated pork to be more desirable than conventionally reheated pork. These results are consistent with work by Causey and Fenton (1951), but inconsistent with research by Sigler et al. (1977) in which chops reheated by broiling were more acceptable than chops reheated in microwave ovens.

Holmes et al. (1966) found increased juiciness and higher cooking losses for 1.9 cm pork chops when compared to 1.3 cm chops. Conflicting results by Kersh (1978) showed no differences in cooking losses among 1.3, 1.9 and 2.5 cm chops.

The objectives of this study were to determine the effects of animals and four rates of microwave cooking on cooking time, uniformity of doneness, palatability and proximate composition of pork loin chops.

CHAPTER III
EFFECTS OF MICROWAVE COOKING RATE ON PALATABILITY
OF PORK LOIN CHOPS

Summary

Twelve loins from six pork carcasses provided 216 1.9 cm chops which were used to study the effects of broiling and four microwave oven cooking rates on cooking and palatability traits. The four microwave oven control settings and the respective power outputs (Watts) were low (205), medium (270), roast (350) and high (505). Two Amana Radar Ranges (RR-7 and RR-9), calibrated to be equal in output, were used for the microwave cooking. Broiling, which served as a control, was done in an electric range oven.

Cooking time for sets of three chops was 57.4 min/kg for broiling and decreased from 49.4 to 18.4 min/kg as microwave cooking rate increased from low to high. The chop sets averaged 517.6 g in raw weight. Drip loss did not differ ($P>.05$) among cooking methods, but evaporative and total losses were highest for broiling and second highest for the low microwave setting.

Sensory panel flavor score was highest ($P<.05$) for broiled chops but did not differ among microwave speeds. Juiciness score was highest for the chops cooked at the low microwave setting and did not differ among the other cooking treatments. Tenderness tended to vary inversely with microwave cooking speed. Broiled chops were comparable in tenderness to those cooked at the low microwave setting. Overall acceptability was lowest for chops cooked at the high micro-

wave setting and did not differ ($P > .05$) among the other treatments.

Pigs from which the chops were obtained were a significant source of variance in all of the traits studied except flavor score, cooking time and protein content. The animal X cooking method interaction was significant only for cooking losses and proximate composition. In an overall evaluation, the high microwave setting tended to produce the least desirable cooked product while the low microwave setting and broiling tended to produce the more desirable products.

Introduction

Cooking method is one of the major factors which determines meat palatability. Microwave (or electronic) cooking is becoming more popular in the home due to increased speed of cooking, convenience and savings of energy when compared to conventional cooking methods. Microwave cooking research has produced conflicting results. Apgar et al. (1959) compared electronically and conventionally cooked pork patties, roasts and chops. Conventionally cooked chops had greater ($P < .05$) cooking losses and lower juiciness scores. However, Korschgen et al. (1976) found greater ($P < .05$) cooking losses for electronically cooked beef roasts but no differences in total cooking losses between conventionally and electronically cooked pork and lamb roasts. Carpenter et al. (1968) and Marshall (1960) also found lower cooking losses for beef cooked in conventional ovens when compared to beef cooked electronically.

Kylen et al. (1964) found that both beef and pork roasts were less juicy and tender when cooked by microwaves than by conventional

roasting. Similar tenderness results were found for beef steaks (Carpenter et al., 1968) and lamb chops (Carpenter and King, 1965).

Total cooking time was much less for microwave prepared meats (Headley and Jacobson, 1960; Bramblett, 1970; Apgar et al., 1959). Acceptability of meats cooked by microwaves has been low due to color, aroma or flavor problems (Apgar et al., 1959; Kylen et al., 1964; Deethardt et al., 1973). However, pork reheated by microwaves has been very acceptable (Penner and Bowers, 1973).

Jones (1978) found oven roasting of pork loin roasts at temperatures below those presently recommended gave a desirable cooked product and reduced cooking losses. Such information is needed for microwave cooked meats.

The objectives of this study were to determine the effects of animal variation on cooking and palatability traits and to determine the effects of four microwave cooking rates on cooking time, uniformity of doneness, palatability and proximate composition of pork loin chops.

Experimental Procedure

Twelve loins from six carcasses which were scored "3" for quality in the Wisconsin system (University of Wisconsin Special Bulletin No. 9, 1963) were selected from about 60 pork carcasses of unknown history. The loins were bought from a local meat packer and shipped to the Texas Tech University Meats Laboratory. The tenderloin muscles were removed from each loin and discarded. The loins were frozen at -30 C with the skin intact. After about 48 hr in the freezer, a loin end roast was removed from each loin between the last two

lumbar vertebrae. Beginning at this anatomical location, 1.9 cm chops were sliced anteriorly from each loin with a band saw until 18 chops were obtained.

Chop thickness was determined after contacting the personnel in several local supermarkets and meat markets. A "thick" pork chop was reported to be about 1.9 cm in thickness. Loins were sliced frozen because uniformity of thickness was much easier to obtain. Three chops were needed for each treatment to produce enough product for evaluation. A total of six treatment groups from each loin containing three consecutive chops were wrapped in freezer paper and numbered according to location within the loin (figure 1). Each set of chops, representing a particular treatment, then was returned to the freezer and held at -30 C until evaluated. Freezer storage time for all chops ranged from 2 to 12 weeks.

Figure 1. Anatomical locations of the six sets of three chops.

Assignment of cooking treatments to chop sets was done by rotating treatments among the six positions within the loin, with each set of three chops being assigned one of the five cooking treatments. All five treatments were represented in each loin, with "broil" being assigned two locations in each loin. This procedure produced a control sample for each sensory panel session. Treatments were rotated among the anatomical locations in the six pairs of loins to reduce any variation possibly caused by anatomical location within the loin.

A total of 72 chop sets were obtained from the six pairs of loins. The original model consisted of 24 broiled treatments and 48 microwave treatments - 12 for each of the four microwave settings. An error in assigning cooking method to chop sets resulted in 10, 13, 12 and 13 replications for microwave "high", "roast", "medium" and "low", respectively, instead of the intended 12 replications.

Cooking. The cooking treatments consisted of four microwave settings (high, roast, medium and low) in two microwave ovens, and broiling in the oven of a conventional electric range. Microwave cooking was conducted in either an Amana RR-7 or RR-9 Radar Range. Wattage output at each of the four settings in both ovens was determined by measuring the rise in temperature of 473 ml of distilled water when heated 1 minute. The formula, $W = \Delta T^{\circ}\text{C} \times 31.6$, where W = wattage output and $\Delta T^{\circ}\text{C}$ = temperature rise in centigrade of the distilled water, was applied (Van Zante, 1973). Microwave ovens were calibrated to be equal in wattage output at each of the four settings by adjusting the cooking rate selection gliding bar (figure 2). The metric scale below the cooking selection bar served

Figure 2. Microwave oven with cooking rate selection bar (see arrow).

as a guide for determining the setting. The wattage outputs for both ovens at each of the four settings were "high", 505; "roast", 350; "medium", 270; and "low", 205. The microwave ovens varied the cooking power by using different on-off cycles of the magnetron at the four settings of the controls.

Each set of chops was thawed at 3 C for about 16 hr and trimmed to about .6 cm subcutaneous fat thickness before being cooked. The chops used for broiling were placed on a wire rack in an aluminum pan. Placement of the meat inside the conventional electric oven was about 20 cm from the heating element. The conventional oven was preheated for 5 min before chops were placed in the oven. The chops were turned after the top side browned and were cooked to an internal temperature of 77 C.

Chops used for all of the microwave treatments were placed on a round fluted tray designed for use in microwave ovens (figure 3). The bone portions of the chops were turned toward the center of the tray to allow exposure of the muscle to more area within the oven. The tray was rotated to eight positions within the oven (figure 4) to achieve a more uniform chop doneness.

The decision to use eight cooking positions for each set of chops was based on the variability in cooking rate in petri dishes within each microwave oven. Photographs of egg white (figures 5 and 6) represent the cooking patterns of the two microwave ovens. The white areas in each figure are areas of greater microwave bombardment indicated by the denatured egg white. The dark areas within each dish where the egg white has not been denatured indicate a lesser amount of microwave penetration. This variation in cooking pattern indi-

Figure 3. Placement of chops on microwave cooking tray.

Figure 4. Rotation pattern of microwave cooking tray to positions 1 through 8.

Figure 5. Denatured egg white showing cooking pattern of the Amana RR-7 Radar Range.

Figure 6. Denatured egg white showing cooking pattern of the Amana RR-9 Radar Range.

cated the necessity of rotating the trays and chops to achieve greater uniformity of cooking.

Estimated total cooking times for each cooking rate were determined through preliminary studies. Time at each position was determined by dividing estimated total cooking time of the chop set by eight. This procedure theoretically allowed for equal time at each of the eight positions when an internal temperature of 77 C was reached. The chops were turned before the fifth rotation.

An exact internal temperature of 77 C was difficult to achieve. Chops which were cooked at faster rates tended to rise more in temperature after cooking power was turned off than those cooked at slower rates. The oven was turned off before a final internal temperature of 77 C was reached and a short period was allowed for the temperature to rise. If the temperature did not reach 77 C, power was again supplied at short intervals to achieve the desired internal temperature. The temperature rise after cooking was difficult to predict in the chops cooked by microwaves. Chops cooked on "high" and "roast" rose in temperature from 1 to several degrees while those cooked on "low" and "medium" rose only slightly or none. Internal meat temperature varied from 1 to 3 C in the final product.

Cooking losses and cooking times for each cooking treatment were recorded. Time required for rotation of the trays in the microwave ovens was not included in cooking time.

Sampling. The sensory panel received samples from the same location within the longissimus muscle of each chop. Chop sequence for each treatment group was maintained so that not only sample location within the chop was constant but also the samples were

taken from the same chop within chop sets each time. Receiving samples from the same anatomical location within each chop set helps to reduce variation that can occur in tenderness from dorsal to lateral locations (Carpenter and King, 1965).

Two 2.5 cm cores and one 1.3 cm core were taken from the longissimus muscle of each chop. The 2.5 cm cores were evaluated by the sensory panel. The samples were served on warm plates. Sensory panel members were supplied with a knife and fork and instructed to evaluate the same size of sample at each setting.

The 1.3 cm cores, taken between the 2.5 cm cores, were used for W-B shear value determination (figure 7). The remaining sections of the longissimus muscle were placed in plastic bags, frozen and later ground for analyses of moisture, ether extract and nitrogen according to A.O.A.C. (1970) procedures.

Sensory panel. Evaluation of the cooked samples was conducted by a six-member trained panel. Panel members were selected and trained as described by Cross et al. (1978). The panel consisted of four men and two women. A total of 24 sessions with three samples per session was necessary for evaluation of the 216 chops. At each session, samples from one broiled chop and two microwave cooked chops were evaluated. Samples were rated for flavor, juiciness, tenderness and overall acceptability on a nine-point hedonic scale where 1 = dislike extremely and 9 = like extremely for flavor and overall acceptability; 1 = extremely dry and 9 = extremely juicy for juiciness; and 1 = extremely tough and 9 = extremely tender for tenderness.

Figure 7. Locations of sensory panel (2.5 cm) and W-B shear (1.3 cm) cores.

Samples were served under a dim red light to reduce bias due to appearance or color caused by the lack of browning on the surface of microwave chops and the browning of the broiled chops.

Statistical analyses. Data were analyzed by the method of least squares (Harvey, 1960). Sources of variance were animal, cooking method and their interaction. Anatomical locations on the loin from which the chops were cut, carcass side and microwave oven (RR-7 vs. RR-9) were deleted from the original model because they were not significant ($P > .05$) sources of variance. Duncan's mean separation test was used when a significant main effect was found (Steel and Torrie, 1960). The predetermined acceptable level of probability was 5% and is used throughout this discussion.

Results and Discussion

Cooking time. The number of three-chop sets per animal and treatment, and least-squares means for animal and cooking method effects on cooking times are presented in table 1. Least-squares means for total cooking time and cooking time/kg of the chop sets, which averaged 517.6 g in raw weight, did not differ significantly among animals. Cooking method had large effects on both total cooking time and cooking time/kg of chops. Broiled chops required the greatest cooking time (30.1 min) and cooking time decreased from 26.0 to 9.6 min as the microwave cooking rate was increased from low to high. Similar treatment differences were evident when cooking time was expressed on a per kilogram of chop basis. Microwave cooking, which has the advantage of being faster than conventional methods, was only 1.2 times faster on the "low" setting when com-

TABLE 1. LEAST-SQUARES MEANS FOR THE EFFECTS OF ANIMAL AND COOKING METHOD ON COOKING TIMES AND LOSSES

Source of variance	Number of chop sets	Cooking time, min	Cooking time, min/kg	Cooking losses, %		
				Drip	Evaporation	Total
Animal						
1	12	20.8 ^a	39.5 ^a	12.5 ^a	19.1 ^{ab}	31.6 ^a
2	12	21.6 ^a	42.0 ^a	13.2 ^a	20.8 ^{bc}	33.9 ^{ab}
3	12	20.2 ^a	39.2 ^a	14.4 ^a	21.6 ^c	35.1 ^b
4	12	23.5 ^a	43.6 ^a	13.8 ^a	19.8 ^{abc}	33.6 ^{ab}
5	12	21.9 ^a	41.1 ^a	13.1 ^a	19.3 ^{ab}	32.4 ^{ab}
6	12	20.1 ^a	41.1 ^a	8.2 ^b	17.8 ^a	26.1 ^c
Cooking method						
Broil	24	30.1 ^a	57.4 ^a	11.9 ^a	26.0 ^a	38.0 ^a
Microwave						
High	10	9.6 ^b	18.4 ^b	11.9 ^a	16.4 ^b	28.3 ^{bc}
Roast	13	13.8 ^c	27.0 ^c	13.4 ^a	16.1 ^b	29.4 ^{bc}
Medium	12	16.6 ^d	33.5 ^d	12.6 ^a	15.0 ^b	27.6 ^c
Low	13	26.0 ^e	49.4 ^e	13.3 ^a	18.5 ^c	31.0 ^b
SD ^f		3.4	5.1	2.5	2.2	3.3

a,b,c,d,e Means in a column within main effect with different superscripts are different ($P < .05$).

^f Standard deviation derived from square root of error mean square; degrees of freedom = 42.

pared to broiling in a conventional oven. But microwave cooking on the "high" setting was 3.1 times faster than conventional broiling (18.4 vs. 37.4 min/kg).

Cooking losses. Chops from animals 1 through 5 did not differ significantly in cooking losses. However, chops from animal 6 had the lowest drip, evaporative and total cooking losses. Total losses ranged from 26.1 for animal 6 to 35.1% for animal 3. The reason for these cooking loss differences is not known. Differences in muscle quality and fat covering of the chops were minimal.

Cooking method had no significant effect on drip loss, with the means ranging from 11.9 to 13.3%. However, evaporative losses were greatest for the broiled chops (26.0%) and second highest for the chops cooked at the low microwave oven setting (18.5%). The high, roast and medium settings did not produce significant differences in evaporation loss. Total cooking losses were almost 7% higher for broiled chops than for any of the microwave cooked chops. These results are in contrast to those of Carpenter et al. (1968), but are in agreement with work by Apgar et al. (1959). The only significant difference in losses among the microwave treatments was between the two lowest rates (27.6 vs. 31.0%). Losses did not vary directly with differences in microwave cooking rate.

The animal X method interactions for drip loss and evaporative loss were significant but animal X method interaction for total cooking loss was not significant.

Sensory panel scores. Least-squares means for animal and cooking method effects on sensory panel scores are presented in table 2. Flavor scores were not significantly different among chops from the

TABLE 2. LEAST SQUARES MEANS FOR THE EFFECTS OF ANIMAL AND COOKING METHOD ON PALATABILITY

Source of variance	Sensory panel scores				W-B shear, kg
	Flavor	Juiciness	Tenderness	Overall acceptability	
Animal					
1	6.6 ^a	6.2 ^a	6.2 ^{ab}	6.3 ^{ab}	3.8 ^a
2	6.6 ^a	6.0 ^a	6.4 ^a	6.4 ^{ab}	3.2 ^b
3	6.6 ^a	6.3 ^a	5.9 ^b	6.1 ^{ab}	3.8 ^a
4	6.8 ^a	6.4 ^a	6.3 ^{ab}	6.5 ^a	3.9 ^a
5	6.4 ^a	6.1 ^a	5.4 ^c	5.9 ^b	4.6 ^c
6	6.8 ^a	7.0 ^b	7.6 ^d	7.2 ^c	2.3 ^d
Cooking method					
Broil	7.0 ^a	6.1 ^a	6.5 ^a	6.6 ^a	3.5 ^a
Microwave					
High	6.5 ^b	6.1 ^a	5.8 ^b	5.9 ^b	3.5 ^a
Roast	6.5 ^b	6.5 ^{ab}	6.3 ^{ac}	6.4 ^a	3.6 ^a
Medium	6.3 ^b	6.2 ^a	6.1 ^{bc}	6.3 ^{ab}	3.6 ^a
Low	6.5 ^b	6.8 ^b	6.6 ^a	6.6 ^a	4.0 ^a
SD ^e	.5	.6	.6	.6	.5

a,b,c,d Means in a column within main effect with different superscripts are different (P<.05).

^eStandard deviation derived from square root of error mean square; degrees of freedom = 42.

six pigs; however, juiciness scores were highest (7.0) for animal 6, which had the lowest cooking losses. Chops from animal 6 had the highest tenderness (7.6) and overall acceptability (7.2) scores. The chops from animal 5 tended to be scored lowest in tenderness (5.4) and overall acceptability (5.9). W-B shear values tended to substantiate the sensory panel tenderness scores with the average shear force of chops from animal 5 being almost twice as great as that of animal 6 (4.6 vs. 2.3). These results suggest a need for selection in swine for greater tenderness.

Broiled chops were scored about .5 point higher for flavor than were any of the microwave cooked chops. Microwave cooked chops did not differ significantly in flavor. Browning of the surface of the broiled chops probably produced a large part of the flavor differences, whereas, the lack of browning by the microwaves reduced the flavor desirability of the chops cooked by microwaves.

Tenderness scores were significantly lower for the chops cooked at the microwave high and medium settings than at the broil or microwave low setting. The broiled and microwave low treatments did not differ significantly in tenderness score (6.5 vs. 6.6). W-B shear means ranged from 3.5 to 4.0 kg among cooking treatments, but none of the differences were significant.

Least-squares means for overall acceptability were identical for microwave low and broiled chops (6.6). These means were significantly higher than only the microwave high treatment. These results indicate that the slowest microwave cooking rate tended to produce a superior product as determined by the sensory panel. The high setting tended to produce the least desirable cooked product

but differences generally were small between palatability values produced by adjacent microwave oven settings. Broiled chops clearly were superior in flavor but inferior in juiciness when compared to the chops cooked at the low microwave setting.

Microwave cookery of meat produced distinctive flavor disadvantages, but this study indicates that overall acceptability of microwave cooked pork chops can be improved by reducing the microwave cooking rate. More research should be conducted to improve acceptability of meats cooked by microwaves.

Proximate analyses. Moisture content of the cooked longissimus muscle varied significantly among animals, ranging from 51.1 to 61.7% (table 3). Animal 6, which was scored highest by the sensory panel for juiciness, tenderness and overall acceptability, had the most moisture (61.7%) and least ether extractable components (9.4%) in its muscle. Animals 3 and 4 tended to have the least moisture and most ether extractable components. Protein content ranged from 29.3 to 29.7% and was not significantly different among the muscles from the six animals. The muscle from animal 6 was low in fat content but still ranked first in palatability. If such animals could be identified and used as breeding herd replacements, pork could be produced which is lower in caloric content but very acceptable in palatability. More research effort should be directed toward this goal.

None of the differences in protein, moisture or ether extract of the chops among cooking methods were significant. Likewise, no trends among the microwave cooking rates were evident. Thus, cooking method did not affect the composition of the cooked muscle. Animal X method interactions were significant for all muscle com-

TABLE 3. LEAST-SQUARES MEANS FOR THE EFFECTS OF ANIMAL AND COOKING METHOD ON MOISTURE, PROTEIN AND ETHER EXTRACTABLE COMPONENTS

Source of variance	Moisture	Protein ^a	Ether extract
Animal			
1	54.2 ^b	29.6 ^b	14.1 ^b
2	53.3 ^b	29.3 ^b	14.5 ^{bc}
3	51.1 ^c	29.7 ^b	16.6 ^{cd}
4	52.7 ^{bc}	29.3 ^b	17.3 ^d
5	54.0 ^b	29.4 ^b	14.4 ^b
6	61.7 ^d	29.4 ^b	9.4 ^e
Cooking method			
Broil	53.7 ^b	29.6 ^b	14.7 ^b
Microwave			
High	55.6 ^b	29.3 ^b	13.0 ^b
Roast	54.6 ^b	29.0 ^b	15.2 ^b
Medium	56.4 ^b	29.0 ^b	13.0 ^b
Low	53.4 ^b	30.1 ^b	15.4 ^b
SD ^f	2.5	1.8	2.6

^aKjeldahl nitrogen X 6.25.

^{b,c,d,e}Means in a column within main effect with different superscripts are different (P<.05).

^fStandard deviation derived from square root of error mean square; degrees of freedom = 42.

position components measured, indicating that the response of animals to different cooking methods was variable.

LITERATURE CITED

- A.O.A.C. 1960. Official Methods of Analysis (9th Ed). Association of Official Analytical Chemists, Washington, D. C.
- Apgar, J., N. Cox, I. Downey and F. Fenton. 1959. Cooking pork electronically. Effect on cooking losses and quality. J. Amer. Diet. Assoc. 35:1260.
- Bowers, J. R. and G. E. Goertz. 1966. Effect of internal temperature on eating quality of pork chops. J. Amer. Diet. Assoc. 48:116.
- Bramblett, V. D., M. D. Judge and R. B. Hanington. 1970. Effect of temperature and cut on quality of pork roasts. J. Amer. Diet. Assoc. 52:132.
- Carlin, A. F., D. M. Bloemer and D. K. Hotchkiss. 1965. Relation of oven temperature and final internal temperature to quality of pork loin roasts. J. Home Econ. 57:442.
- Carpenter, Z. L. and G. T. King. 1965. Tenderness of lamb rib chops. Food Technol. 19:102.
- Carpenter, Z. L., H. C. Abraham and G. T. King. 1968. Relative effects of microwave cooking, deep fat frying and oven broiling on tenderness and cooking loss of beef and pork. J. Amer. Diet. Assoc. 53:353.
- Causey, K. and F. Fenton. 1951. Effect of reheating on palatability, nutritive value, and bacterial count of frozen cooked foods. 2. Meat dishes. J. Amer. Diet. Assoc. 27:491.
- Cross, H. R., H. R. Bernholdt, M. E. Dikeman, B. E. Greene, W. G. Moody, R. Staggs and R. L. West. 1978. Guidelines for cookery and sensory evaluation of meat. Am. Meat Sci. Assoc. and National Livestock and Meat Board.
- Deethardt, D., W. Costello and K. C. Schneider. 1973. Effect of electronic, convection and conventional oven roasting on the acceptability of pork loin roasts. J. Food Sci. 38:1076.
- Harvey, W. R. 1960. Least squares analysis of data with unequal subclass numbers. U.S.D.A., A.R.S. Bull. 20-8.
- Headley, M. E. and M. Jacobson. 1960. Electronic and conventional cookery of lamb roasts. Cooking losses and palatability. J. Amer. Diet. Assoc. 36:337.
- Holmes, Z. A., J. R. Bowers and G. E. Goertz. 1966. Effect of internal temperature on eating quality of pork chops. J. Amer.

Diet. Assoc. 48:121.

Jones, H. E., Jr. 1978. Low temperature cooking of frozen or thawed pork loin roasts. M.S. Thesis. Texas Tech University, Lubbock.

Kersh, R. C. 1978. Effect of cooking method and chop thickness on cooking losses and palatability of pork loin chops. M.S. Thesis. Texas Tech University, Lubbock.

Korschgen, B. M., R. E. Baldwin and S. Snider. 1976. Quality factors in beef, pork and lamb cooked by microwaves. J. Amer. Diet. Assoc. 69:635.

Kylen, A., B. H. McGrath, E. L. Hallmark and F. O. Van Duyne. 1964. Microwave and conventional cooking of meat. J. Amer. Diet. Assoc. 52:31.

Marshall, N. 1960. Electronic cookery of top round beef. J. Home Econ. 52:31.

Penner, K. K. and J. A. Bowers. 1973. Flavor and chemical characteristics of conventionally and microwave reheated pork. J. Food Sci. 38:553.

Schoman, C. M. 1960. The effect of oven air, temperature, circulation and pressure on the roasting of top rounds of beef and on the factors determining its acceptability. Ph.D. Thesis. Rutgers University, New Brunswick, NJ.

Sigler, D. H., C. B. Ramsey, H. E. Jones, Jr. and L. F. Tribble. 1978. Microwave and conventional reheating of chops from cooked hot and cold processed pork loin roasts. J. Anim. Sci. 46:971.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York.

University of Wisconsin. 1963. Pork quality standards. Wisc. Agr. Exp. Sta. Special Bull. No. 9.

Van Zante, H. J. 1973. The Microwave Oven. Houghton Mifflin Co., Boston.

Weir, C. E., C. Pohl, E. Auerback and G. P. Wilson. 1963. The effect of cooking conditions upon the yield and palatability of pork loin roasts. Food Technol. 17:1567.