FLAVOR AND SELECTED CHEMICAL CHARACTERISTICS OF CONVENTIONALLY AND MICROWAVE REHEATED PORK

by

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TABLE OF CONTENTS

INTRODUCTION

The use of precooked meat products by institutions and homemakers has increased in the past several years as evidenced by the growing numbers of frozen, convenience-type items in the marketplace. Aside from convenience, an important factor in the acceptance of precooked meat products is the maintenance of meaty flavor during storage and the prevention of warmed-over or off-flavor development before and during reheating.

Certain chemical changes may occur during storage of cooked muscle. Lipid oxidation can cause rancid odors and flavors. Tissue lipid that contains a large amount of unsaturated fatty acids is susceptible to that kind of deterioration. Of the red meats, pork fat is the least saturated.

Reactions, such as the Maillard reaction, between amino acids and reducing sugars account for the formation of many flavor and aroma components. Browned surfaces and some meaty flavor and aroma components are results of the Maillard reaction. However, the importance of individual amino acids and reducing sugars as meat flavor precursors is not known.

The solubilities of various proteins in meat change with heat treatment. Low molecular weight flavor precursors are found in a water-soluble fraction of lean meat. Included in the non-protein nitrogen (NPN) fraction are amino acids. Changes occurring in those fractions as a result of heating may cause differences in flavor intensities.

The use of microwave ovens to heat meat saves time. Eating quality of microwave heated meats is not always desirable, but data on eating quality of microwave reheated red meats were not found in the literature.

The objectives of this study were to compare flavor and aroma of microwave and conventionally reheated pork with that of freshly cooked, and to study the relationships of flavor and aroma to various chemical characteristics of meat as a result of the heating treatments.

REVIEW OF LITERATURE

The following discussion reviews eating quality and chemical changes of precooked, reheated meat and effects of microwave heating on muscle.

Precooked and reheated muscle

The use of precooked and frozen meats can save time and labor. However, to be accepted for use by a large segment of the population, the reheated product must retain the palatability characteristics of the freshly cooked product.

Palatability of reheated meat. Flavor and odor are important factors in contributing to loss of palatability in precooked meats. Pork roasts that were precooked, frozen, held in frozen storage nine months and reheated were rated lower for aroma and flavor intensity and desirability than were roasts cooked after storage in the raw state (Watts, et al., 1948). Pork and lamb "roasteaks" (precooked to 44° C, frozen and grilled to 68° C) were rated as acceptable or above when scored for palatability on a hedonic scale (Korschgen and Baldwin, 1971). However, flavor and juiciness scores were significantly higher ($P < 0.05$) for the unstored control than for the precooked, stored and grilled "roasteaks." Similar results were found for "roasteaks" prepared from roast beef (Baldwin and Korschgen, 1968). Additional work on beef, pork and lamb (Korschgen and Baldwin, 1972) indicated that low temperature (82-85° C) precooking to an internal temperature of 71-74° C and slicing of meat prior to packaging for freezer storage enhanced flavor acceptability. Cash and Carlin (1968) reported flavor losses in precooked, frozen and reheated turkey. Flavor decreased as storage time increased (3, 7, 9 and 11 mo.). Bowers (1972) reported higher rancid and stale and lower meaty-brothy flavor and aroma scores for reheated turkey than for freshly cooked turkey. At the present, data pertaining to palatability characteristics of precooked and reheated muscle are limited. In addition, results are often difficult to compare because of lack of standardization of the term "precooked" and the application of this term to a wide variety of heating treatments.

Lipid oxidation and flavor of reheated meat. An important contribution to aroma and flavor of reheated meat comes from oxidation of tissue lipids. The resulting carbonyl compounds can give a rancid or stale flavor if present in high concentrations. In early work (Watts, et al., 1948), when peroxide values were the criterion for determining rancidity, the development of off-flavors in precooked and stored meat was not associated with rancidity. Peroxide value determinations are made on fat extracted with nonpolar solvents, and not all tissue lipids are extracted. Younathan and Watts (1960) later found that rancid or off-flavors perceived by sensory panels in reheated meat were attributable to oxidation of non-extractable phospho- and proteolipids. Deterioration products of those tissue lipids were measured by use of the 2-thiobarbituric (TBA) acid test. TBA values above 0.5 have been associated with off-aromas or flavors in pork (Tarladgis, et al., 1960; Tims and Watts, 1958). Recently, a substance responsible for the initiation of oxidative reactions in cooked beef has been associated with a water extracted fraction (Sato and Hegarty, 1971).

Attempts have been made to inhibit oxidative changes, and thus maintain palatability of cooked muscle for longer periods. Chang, et al., (1961) treated beef with phosphate antioxidants and successfully kept TBA values below 0.5 during refrigerated and frozen storage. The freshly cooked aroma also was maintained. No flavor data were reported. Irradiation of cooked meat also was studied as a means of inhibiting oxidative rancidity in cooked meats (Chang, et al., 1961; Greene and Watts, 1966).

Amino acids. The specific roles of individual free amino acids in cooked meat flavor are not fully known. However, research has shown that changes in amino acid concentrations occur during heating and that reactions between carbohydrates and amino acids are important for flavor and aroma of cooked meats. In comparing fresh with heated pork, beef, and lamb, Macy, et al., (1964) found large decreases in some free amino compounds and increases in others after cooking. The amount lost for each species was proportional to the total content in the raw tissue initially. An extracted amino acid fraction, when recombined with sugar fractions developed meatlike aroma on heating (Hornstein and Crowe, 1960). Usborne, et al., (1968) found significant partial correlation coefficients for flavor in cooked pork and free glutamic acid (-0.66**), tyrosine (-.51**), aspartic acid (-0.54*), serine (0.46*) and glycine (0.49*). McCain, et al., (1968) reported significant correlations for total ninhydrin positive material and several individual amino acids with aged flavor of ham.

Though amino acids can function in flavor precursor systems, they also can contribute directly to taste. Some amino acids contribute to the inherent tastes of foods themselves, some specific patterns of amino acid mixtures intensify the taste of foods and increase mouthfulness, and the buffering action of amino acids also can contribute to the taste of foods (Kirimura, et al., 1969). Data concerning free amino acids and flavor of precooked and reheated meats are lacking.

Heating with microwaves

The popularity of microwave ovens has increased rapidly, especially in food service systems in hospitals, restaurants and schools. As oven costs decrease and practical knowledge of oven use becomes known and readily available, microwave oven use in homes also will increase. A substantial number are already in use by homemakers throughout the country.

Nature of microwaves. Microwaves are high frequency energy waves, generated by a magnetron located in the oven. They are measured in frequencies in terms of megacycles or megahertz per second. Two frequencies have been assigned by the Federal Communications Commission: 915 and 2450 MHz/sec. Microwaves penetrate food to a depth of a few inches, depending on microwave frequency, loss factor (Van Zante, 1968), mass, shape, moisture content and other physical factors (Anon., 1969).

The heat produced by microwaves occurs within the food. Molecules in the food orient themselves to an alternating electric current, and this causes the movement of a small mass through a short distance, constituting work. This work is converted into heat energy and results in cooking of the food (Van Zante, 1968).

Cooking time. The primary advantage of microwave heating is decreased cooking time. Since the heat is produced within the food, there is no time lapse or lag during which heat must pass from an external source to the interior of the food. For heating rolled lamb roasts, Headley and Jacobson (1960) reported that microwaves were four times faster than conventional ovens. Heating time can be drastically reduced, especially if microwave ovens are used for meat or main dish items that normally require several hours to prepare.

Cooking losses. Microwave heating, though rapid, may cause increased cooking losses in meat. Increased drip and evaporation losses will result in drier, less palatable meat. Law, et al., (1967) found that total cooking losses were significantly greater ($P < 0.05$) for microwave than for conventionally roasted round steak (semimembranosus-SM-muscle), but that steaks (longissimus dorsi-LD-muscle) had significantly greater ($P < 0.05$) total cooking losses when broiled conventionally than when heated with microwaves. Other workers also have reported greater total cooking losses for microwave heating methods than for conventional methods of heating meats (Moore, et al., 1966; Bowers and Heier, 1970; Headley and Jacobson, 1960). Evaporation losses were higher for ground pork patties (Lim, et al., 1959), rolled lamb roasts (Headley and Jacobson, 1960) and turkey roasts (Bowers and Heier, 1970) heated with microwaves than with conventional methods, but in each case drip losses were less for the microwave heated meats than for the conventionally heated meats.

Flavor development. One disadvantage of microwave heating is that surface browning does not occur. Reactions between amino acids and carbohydrates do not continue to completion to produce a flavorful browned exterior. Reports of flavor evaluation of the lean portion of microwave heated meats have varied. Flavor of boneless steaks from SM or LD muscles of conventionally roasted or broiled steaks was preferred to that of microwave heated steaks (Law, et al., 1967). Flavor of rolled lamb roasts (Headley and Jacobson, 1960) and beef and pork roasts and loaves (Kylen, et al., 1964) was less desirable when meats were prepared in microwave ovens than when heated conventionally. Ground and frozen pork patties received higher aroma and flavor scores when heated with microwaves than when heated in either an electric oven or a skillet (Lim, et al., 1959). Gat'ko (1965) found that high frequency heating produced juicier meat with a more pronounced flavor than other cooking methods.

For pork patties, roasts and chops prepared with combinations of microwave and conventional heating methods, with and without browning units, no significant flavor or aroma differences were found (Apgar, et al., 1959). Davis, et al., (1971) also reported no significant difference in flavor preference of chicken prepared with microwaves, conventionally, or with a combination of the two methods.

The reheating of precooked meats with microwaves has not been investigated thoroughly. Causey and Fenton (1951) reported less desirable but acceptable palatability scores for several precooked and frozen meat dishes after reheating with microwaves. Cipra and Bowers (1971) reported more intense turkey flavor and less stale flavor for microwave reheated turkey than for conventionally reheated turkey. Additional study of reheated turkey muscle (Bowers, 1972) confirmed those results.

Effect on proteins. Heating, in general, causes changes in the solubility of the proteins in meat. Ginger, et al., (1954) reported a marked decrease (4-30 fold) in the soluble protein nitrogen of cooked steaks from raw steaks. Paul, et al., (1966) studied solubility of rabbit muscle (LD) proteins after various time- temperature treatments. Solubility of sarcoplasmic and myofibrillar proteins decreased only after 2 hr. at 40° C, after 30 min. at 45° C, or by the time the tissue reached 50° C. Beyond this, solubility decreased with longer time or higher temperature, and the amount of denatured protein increased. Hamm and Deatherage (1960) reported protein solubility of red meats changed most between a range of 40° C to 65° C. Acton (1972) found that the extractability of salt-soluble proteins of chicken muscle decreased as heating temperature increased from 4° C to 94° C.

The amount of protein change that occurs at a given temperature partly is dependent on the speed at which that temperature is reached. The more rapidly hams were heated, the more protein was insolubilized (Cohen, 1966). Because microwave heating is extremely rapid, proteins are probably insolubilized to a greater extent in microwave heated meats than in conventionally heated meats. No reports were found that studied the specific effects of microwaves on muscle protein solubility; however, analysis of raw and cooked meat and the juices (Gat'ko, 1965) indicated greater retention of extractable nitrogenous substances in meat heated with high frequency energy.

Several workers have reported toughening in microwave heated meats (Apgar, et al., 1959; Law, et al., 1967). Decareau (1968) also noted that extremely rapid heating of poultry parts at high power levels produced a tough product. Hegarty, et al., (1963) found a correlation between fibrillar protein solubility and tenderness ($r = -0.69$ for shear and $r = 0.59$ for taste panel).

Changes in proteins also may affect flavor. Usborne, et al., (1968) found a 33% decrease in a non-protein (NPN) nitrogen fraction from raw to cooked pork. They attributed the loss to volatilization of some of the NPN that might contribute to pork aroma. From another viewpoint, Solms (1969) proposed a total flavor picture in which proteins, along with amino acids and peptides, located at the base of an integrated flavor scheme, provide taste and tactile effects and contribute indirectly to over-all flavor sensation.

EXPERIMENTAL PROCEDURE

Treatments

Ten paired, frozen boneless loins (cut from the 10th thoracic vertebra to the 5th lumbar vertebra) from five 200-250 pound barrows were obtained from the Kansas State University Department of Animal Science and Industry. Each loin was thawed and divided into thirds. The treatments--1) freshly cooked; 2) conventionally precooked, frozen, conventionally-reheated; and 3) conventionally precooked, frozen, microwave-reheated--were assigned randomly to portions of each loin (Appendix, Table 5).

Two portions of each loin were wrapped in 3M Scotchpak Oven Service film, heated to 65° C in a rotary hearth gas oven at 325° F (163° C), cooled at room temperature for 15 minutes, packaged in polyethylene bags, and frozen and held at -17° C for five weeks. The other portion was wrapped in oven film, packaged in a polyethylene bag and frozen raw. At each evaluation period, the three loin portions (one for each treatment) were removed from the freezer and thawed at 4° C for 24 hours. The raw portion was cooked in the oven film at 325° F in a rotary hearth gas oven to an internal temperature of 77° C. The precooked portions were reheated in the oven film; one portion was reheated to 55° C in the gas oven and the other to 55° C in an Amana Radarange (model RR-2, MHz 2450) microwave oven. Spirit thermometers were used instead of mercury thermometers because they do not arc in microwave ovens. The microwave reheated portion was trimmed and sliced immediately to minimize post-oven temperature rise. Cooking times and total cooking losses were recorded. The cooked meat was trimmed of fat and browned surfaces. A center portion of the muscle was removed for sensory evaluation and the remainder was ground for chemical measurements.

Sensory evaluation

Slices one-fourth in. thick from the muscle were cut from the center of each cooked portion and placed in the upper part of 1 pt enamel double boilers over hot water. They were transferred to warm brandy snifters and covered with watch glasses just prior to evaluation. Juiciness and intensity of flavor and aroma components of the longissimus dorsi (LD) muscle were evaluated by an "experienced" laboratory panel of six members (Appendix, Form I). Descriptive word scores for juiciness evaluation were converted to a numerical scale of 1 to 7.

Objective measurements

Duplicate measurements were made on ground meat samples as follows:

Percentage total moisture. Percentage total moisture was determined in a 25 lb vacuum convection oven. Samples were dried 4 hr at 110° C.

TBA values. The 2-thiobarbituric acid values were determined by the method of Tarladgis, et al. (1960). Slurries were prepared from 7-g samples. Optical density readings (Beckman DU Spectrophotometer) were multiplied by a factor of 7.8 to convert to mg of malonaldehyde per 1,000 g tissue (Tarladgis, et al., 1960). Those values provided a measurement of lipid oxidation.

Total ninhydrin-reactive compounds. A deproteinized filtrate using 1% picric acid (Tallon, et al., 1954) was prepared from 2-g samples. The quantity of ninhydrin-positive material in the filtrate was determined by a colorimetric method based on the reaction with ninhydrin (Yemm and Cocking,

1955) and expressed as umoles per g of meat based on a standard curve prepared from glycine.

Protein fractionation. To determine changes in the various protein and non-protein nitrogen components of freshly cooked and reheated LD muscle, protein fractions were prepared from 5 g samples following procedures of Randall (1969). The fractions were: a low ionic strength fraction, a soluble fibrillar protein nitrogen fraction, a denatured fibrillar protein nitrogen fraction, a sarcoplasmic protein nitrogen fraction, and a non-protein nitrogen fraction.

Nitrogen analysis. Total nitrogen content and protein nitrogen in each fraction were determined with micro-Kjeldahl methods. Nitrogen in each fraction was expressed as a percent of the total.

Analysis of data

A randomized complete block design with ten replications of each treatment was used to collect the data and for the statistical analysis. The analysis (Appendix, Table 6) removed animal and loin (cooking period) variation from the desired comparisons and provided ample degrees of freedom for estimation of the error variance. The data were subjected to analysis of variance and LSD's were calculated when F-values were significant. Correlation coefficients between variables were determined.

RESULTS AND DISCUSSION

Freshly cooked, conventionally reheated and microwave reheated pork was evaluated by sensory scores and chemical measurements. Treatment means and significance of F-values for each measurement are given (Tables 1-4). Data for all replications are given in the Appendix Tables 7-14.

Sensory evaluation

Most aroma and flavor components of freshly cooked and reheated pork were similar (Table 1). No significant differences were found between freshly cooked and microwave reheated pork, but some differences were noted between conventionally reheated muscle and that of the other two treatments. Sweet aroma of freshly cooked and microwave reheated pork was similar and significantly higher ($P < 0.05$) than that of conventionally reheated pork. However, the difference was small and probably of no practical significance. Metallic flavor of freshly cooked and microwave reheated pork was similar and significantly lower ($P < 0.05$) than that of conventionally reheated pork. In similar work, comparing conventional and microwave precooked and reheated turkey, Cipra, et al., (1971) found more intense turkey and less stale flavor for microwave heating. Bowers (1972) reported that meaty-brothy flavor of freshly cooked and microwave reheated was similar and higher than that of conventionally reheated turkey, and that freshly cooked and microwave reheated turkey had similar and lower rancid aroma scores than did conventionally reheated turkey. Results of those studies and this study indicate that microwave reheated muscle is more like freshly cooked muscle than is conventionally

TABLE 1.--Means for sensory evaluation of freshly cooked (FC), conventionally reheated (CR) and microwave reheated (MR) pork.

Factor	FC	CR	MR	Sign. of F-value	LSD*
Aroma components[a]					
Meaty-brothy	1.6	1.5	1.7	ns	
Acid	0.3	0.3	0.3	ns	
Sweet	0.2	0.1	0.2	*	0.1
Bitter	0.1	0.1	0.1	ns	
Stale	0.7	0.9	0.6	ns	
Metallic	0.3	0.5	0.4	ns	
Animal-like	0.4	0.4	0.3	ns	
Flavor components[a]					
Meaty-brothy	1.8	1.7	1.9	ns	
Acid	0.4	0.6	0.4	ns	
Sweet	0.4	0.3	0.4	ns	
Bitter	0.0	0.1	0.1	ns	
Stale	0.4	0.5	0.4	ns	
Astringent	0.2	0.3	0.2	ns	
Metallic	0.2	0.4	0.2	*	0.2
Animal-like	0.4	0.3	0.4	ns	
Juiciness[b]	4.7	4.8	4.1	*	0.5

[a] Based on intensity of component, 3-(strong); 0-(absent)

[b] 7-(very juicy); 1-(very dry)

* $P < 0.05$

ns, not significant

reheated muscle.

Panelists noted sulfurous and fleeting rancid-oily flavor components in the conventionally reheated pork at several evaluation periods. The longer exposure to heat could have contributed to the development of those flavors, and also may be responsible for decreased sweet flavor and increased metallic flavor found by the taste panel. Correlation coefficients (Table 2) indicated that meaty-brothy flavor was related negatively to stale aroma (-0.40*) and flavor (-0.58**), and that meaty-brothy aroma was related positively to sweet aroma (0.45*) and negatively to astringent flavor (-.42*). Similar results for turkey were noted by Cipra (1969). An unexpected positive correlation was found for sweet flavor with bitter aroma (0.46*). No explanation for that relationship could be made. As metallic flavor increased, bitter flavor increased ($r = 0.61$**); and as metallic aroma increased, astringent flavor increased ($r = 0.53$**). Those are undesirable flavor and aroma components, and positive relationships would be expected.

Microwave reheated pork was significantly ($P < 0.05$) less juicy than either freshly cooked or conventionally reheated pork (Table 1). Others have reported lower juiciness scores for microwave heated lamb roasts (Headley and Jacobson, 1960) and pork roasts (Apgar, et al., 1959). Law, et al., (1967) also reported a significant negative correlation (-0.55**) between total cooking loss and juiciness score of steaks (LD) prepared in a microwave oven.

Objective measurements

Mean values for percentage total moisture, percentage total cooking losses, cooking time, TBA numbers, and ninhydrin-reactive compounds are found in Table 3. The moisture content of pork muscle differed significantly ($P < 0.001$) among the three treatments. Microwave reheated pork contained the

TABLE 2.--Simple, linear correlation coefficients for selected flavor and aroma scores for combined treatments of precooked and reheated pork.

Paired variates d.f. = 18	Combined treatments	
	Aroma	Flavor
Meaty-brothy flavor vs		
sweet	0.21	0.32
stale	-0.40*	-0.58**
Meaty-brothy aroma vs		
sweet	0.45*	0.10
stale	-0.43*	-0.35
astringent		-0.42*
Sweet flavor vs		
meaty-brothy	0.10	0.32
bitter	0.46*	0.27
Metallic flavor vs		
bitter	0.06	0.61**
Metallic aroma vs		
meaty-brothy	-0.30	-0.12
bitter	-0.03	0.31

* $P < 0.05$

** $P < 0.01$

TABLE 3.--Mean values of total moisture, total cooking losses, cooking time, TBA numbers and ninhydrin-reactive compounds of freshly cooked (FC), conventionally reheated (CR) and microwave reheated (MR) pork.

Factor	FC	CR	MR	Sign. of F-value	LSD*
Total moisture, %	63.59	60.67	57.79	***	1.61
Total cooking losses, %	28.47	30.85	35.54	***	2.46
Cooking time, min[a]	69	50	9	***	5
TBA number[b]	0.331	0.497	0.401	***	0.036
Ninhydrin-reactive compounds[c]	11.379	10.567	10.039	ns	

[a] Final cooking time immediately prior to evaluation

[b] mg malonaldehyde/1000g tissue

[c] umoles glycine/g tissue

* $P < 0.05$

*** $P < 0.001$

ns, not significant

least moisture, freshly cooked pork had the highest percentage moisture, and conventionally reheated pork had intermediate moisture content.

Percentage total cooking losses were significantly greater ($P < 0.001$) for microwave reheated pork than for freshly cooked or conventionally reheated pork, which had similar losses. A significant correlation (-0.60**) was found for percentage total moisture and percentage total cooking losses. Those results would account, in part, for differences in juiciness detected by the taste panel.

Differences among cooking times, at the time of final preparation, were all significant ($P < 0.001$) for all treatments. Total cooking times were not analyzed since users of precooked products would be concerned primarily with the final preparation time. Both reheating methods took significantly less preparation time than did cooking from the raw state, but the microwave reheating method was five times faster than the conventional reheating method.

TBA values, determined as a measure of fat oxidation, differed significantly ($P < 0.001$) among the three heating treatments. TBA values were highest for pork exposed to the longest heating treatment (precooked and conventionally reheated--106 min) and lowest for pork exposed to only one heating application (freshly cooked--69 min). The microwave reheated pork, though exposed to heat during precooking (55 min), was only subjected to reheating for a short time (9 min) before evaluation. Heat has the catalytic effect of increasing the rate of oxidative reactions, so those portions of pork exposed to the longest total heat treatment would be expected to have the largest TBA values. Significant correlations ($P < 0.05$) were found for TBA values with stale aroma (0.42*) and with astringent flavor (0.37*). Taste panel scores did not reflect differences in stale aroma or flavor components between the heating treatments, but Tims and Watts (1958) pointed out that TBA values exceed 0.5 before rancid or off-flavors caused by oxidation are detected by sensory panels. Jacobson and Koehler (1970) reported a significant correlation (-0.77) between flavor scores and TBA values of precooked and stored turkey; however, the TBA values were much higher than those found in this study, and more flavor differences also were detected. Their data also indicated the importance of storage temperature, as refrigerated cooked turkey had much higher TBA values than frozen cooked turkey.

Total ninhydrin-reactive compounds were not affected significantly by the heating treatments. Though amino acids are important flavor precursors, they may not be accurately accounted for by this method of evaluation. During heating, amino acids may combine with other compounds to yield flavor products or they may be carried out of the meat with other solubles and lost in the drip. Macy, et al., (1964) found increases in some amino acids and decreases in others after heating, indicating that while significant changes may have occurred, they could have cancelled each other out, and would not have been detected by this measurement. Further, the colorimetric reaction that occurs with ninhydrin also occurs with ammonia, primary amines and other compounds, so at best, the results can only serve to give a broad general measurement when perhaps a specific analysis is more desirable. And finally, taste panel results indicated little difference between flavor and aroma of pork subjected to the three treatments. Therefore, if the amount of ninhydrin-reactive compounds in meat is related to flavors and aromas as perceived by the taste panel, no other results from this measurement would be expected.

Results of the protein fractionation and nitrogen analysis are found in Table 4. No significant differences were found for protein fractions of pork

TABLE 4.--Protein nitrogen in extracted tissue fractions of freshly cooked (FC), conventionally reheated (CR) and microwave reheated (MR) pork.

Factor	FC	CR	MR	Sign. of F-value
Low ionic strength[a]	4.18	4.12	4.40	ns
Sarcoplasmic[a]	3.31	3.31	4.15	ns
Non-protein nitrogen[a]	0.86	0.81	0.85	ns
Soluble fibrillar[a]	0.56	0.54	0.51	ns
Denatured fibrillar[a]	34.21	34.49	34.44	ns
Total nitrogen[a]	53.9	51.4	53.1	ns
Low ionic strength[b]	7.84	8.10	8.42	ns
Sarcoplasmic[b]	6.22	6.50	6.80	ns
Non-protein nitrogen[b]	1.61	1.59	1.62	ns
Soluble fibrillar[b]	1.05	1.06	0.92	ns
Denatured fibrillar[b]	63.99	67.35	65.98	ns
Total nitrogen	5.39	5.15	5.31	ns

[a] mg nitrogen/g of muscle on a wet weight basis

[b] Calculated as a percent of the total nitrogen

ns, not significant

heated by the three methods. However, microwave reheated pork had slightly more protein nitrogen extractable at low ionic strength and slightly more sarcoplasmic protein nitrogen than did freshly cooked or conventionally reheated pork. For all treatments, the amount of total nitrogen and fibrillar protein nitrogen was nearly the same.

Changes in protein solubilities occur over various time-temperature ranges and the heating treatments used in this study probably were not different enough from each other to cause significant alterations in the protein fractions. Freshly cooked pork was heated to 77° C. Pork assigned to the other two treatments was precooked to 65° C and reheated to 55° C. Microwaves might have affected the proteins more if they had been used to precook the meat, as most protein changes would have occurred during the initial heating period. Hamm and Deatherage (1960) found that most changes in muscle protein occurred between 40° C and 65° C.

SUMMARY

Selected sensory evaluations and chemical measurements were made on freshly cooked, conventionally reheated and microwave reheated pork loin muscle (LD). A randomized complete block design with ten replications of each treatment was used for collection and analysis of the data. The taste panel evaluated the pork samples for meaty-brothy, acid, sweet, bitter, stale, metallic and animal-like aroma and flavor components, astringent flavor, and for juiciness. Freshly cooked and microwave reheated pork had sweeter ($P < 0.05$) aroma and less metallic ($P < 0.05$) flavor than conventionally reheated pork, and microwave reheated pork was less juicy ($P < 0.05$) than pork heated by the other treatments. Other sensory factors were not affected by the treatments. Significant correlations were found between some aroma and flavor components.

Percentage total moisture, percentage total cooking losses and cooking time at the final preparation were significantly ($P < 0.001$) affected by the heating treatments. Microwave reheated pork contained less moisture and had greater total cooking losses than did pork that was either freshly cooked or conventionally reheated. Microwave reheated pork also took significantly less time to prepare than pork heated by the other methods.

The heating treatments had a significant ($P < 0.001$) effect on TBA values. Freshly cooked pork had the lowest value, and conventionally reheated pork had the highest value. Heating treatments did not affect ninhydrin-reactive compounds or nitrogen content in the various extracted protein fractions.

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APPENDIX

FORM I

SCORE CARD FOR PORK

Name_____________________________Code___________________Date___________________________

Please rate intensity for each flavor and odor component according to the following scale:

0 = absent
1 = slight
2 = medium
3 = strong

Components	Aroma			Flavor		
	X	Y	Z	X	Y	Z
Meaty-Brothy						
Acid (sour)						
Sweet						
Bitter						
Stale						
Astringent	---	---	---			
Metallic						
Animal-like						
Other						

Additional comments:

Please score each sample for juiciness using the following scale (use abbreviations):

V.J. = very juicy
Ju. = juicy
Mod. J. = moderately juicy
Sl. J. = slightly juicy
Mod. D. = moderately dry
Dry = dry
V. Dry = very dry

Sample	Score
X	
Y	
Z	

TABLE 5.--Randomized assignment of treatments to anterior (ant), middle (mid) and posterior (post) portions of pork loin.

			Treatments		
Evaluation period	Animal number	Loin	Freshly cooked	Conventionally reheated	Microwave reheated
1	1	L	Ant	Mid	Post
2	1	R	Mid	Ant	Post
3	2	L	Ant	Post	Mid
4	2	R	Ant	Post	Mid
5	3	L	Post	Mid	Ant
6	3	R	Ant	Post	Mid
7	4	L	Ant	Mid	Post
8	4	R	Ant	Post	Mid
9	5	L	Mid	Ant	Post
10	5	R	Mid	Ant	Post

L, left
R, right

TABLE 6.--Analysis of variance.

Source of variation	df
Treatment	2
Animals	4
Loin: animals	5
Error	18
Total	29

TABLE 7.--Aroma[a] and juiciness[b] scores for freshly cooked (FC), conventionally reheated (CR), and microwave reheated (MR) pork.

	Evaluation Period										
Factor	1	2	3	4	5	6	7	8	9	10	Mean
Meaty-brothy											
FC	2.0	1.7	2.0	1.8	1.2	1.6	1.0	1.8	1.2	1.7	1.6
CR	1.4	1.5	0.8	1.2	1.6	1.5	1.7	1.5	1.7	1.6	1.5
MR	1.5	1.7	1.7	2.0	2.0	1.5	1.6	1.7	1.6	2.1	1.7
Acid											
FC	0.3	0.3	0.2	0.2	0.5	0.3	0.0	0.2	0.5	0.0	0.3
CR	0.0	0.2	0.6	0.5	0.5	0.3	0.3	0.5	0.0	0.3	0.3
MR	0.2	0.2	0.2	0.5	0.3	0.3	0.3	0.2	0.3	0.2	0.3
Sweet											
FC	0.0	0.2	0.2	0.2	0.2	0.3	0.0	0.3	0.0	0.3	0.2
CR	0.2	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.1
MR	0.1	0.3	0.2	0.4	0.3	0.2	0.2	0.2	0.0	0.3	0.2
Bitter											
FC	0.0	0.2	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1
CR	0.0	0.2	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.1
MR	0.0	0.2	0.0	0.3	0.0	0.2	0.0	0.3	0.0	0.0	0.1
Stale											
FC	0.3	1.4	0.6	0.6	1.0	1.0	0.7	0.4	0.2	0.6	0.7
CR	1.4	0.8	1.2	0.7	0.5	1.0	1.0	1.1	0.2	0.7	0.9
MR	1.3	0.7	0.6	0.5	0.3	0.6	0.2	0.7	0.8	0.0	0.6
Metallic											
FC	0.2	0.4	0.2	0.3	0.3	0.2	0.5	0.2	0.7	0.2	0.3
CR	0.3	0.6	0.5	0.3	0.3	0.8	0.2	0.7	0.6	0.2	0.5
MR	0.5	0.7	0.7	0.5	0.2	0.2	0.3	0.2	0.5	0.1	0.4

TABLE 7.--concl.

Factor	Evaluation Period										
	1	2	3	4	5	6	7	8	9	10	Mean
Animal-like											
FC	0.7	0.2	0.0	0.4	0.3	0.7	0.2	0.7	0.2	0.3	0.4
CR	0.3	0.4	0.5	0.7	0.5	0.3	0.2	0.5	0.2	0.3	0.4
MR	0.4	0.2	0.2	0.5	0.5	0.0	0.5	0.3	0.2	0.7	0.3
Juiciness											
FC	3.5	4.3	5.0	4.5	4.2	5.7	5.0	5.2	4.8	5.2	4.7
CR	3.5	4.2	5.0	4.5	4.3	4.0	5.3	6.0	5.0	6.0	4.8
MR	3.7	4.7	4.7	2.5	3.0	5.0	4.5	4.5	3.7	5.2	4.1

[a] 3-(strong); 0-(absent)

[b] 7-(very juicy); 1-(very dry)

TABLE 8.--Flavor[a] scores for freshly cooked (FC), conventionally reheated (CR), and microwave reheated (MR) pork.

Factor	Evaluation Period										
	1	2	3	4	5	6	7	8	9	10	Mean
Meaty-brothy											
FC	1.7	2.0	2.2	1.9	1.7	1.8	1.7	1.7	1.7	1.5	1.8
CR	1.1	1.6	1.5	1.7	1.9	1.4	2.2	1.8	2.1	1.7	1.7
MR	1.5	2.0	2.1	1.9	2.1	2.2	1.7	1.7	1.6	2.2	1.9
Acid											
FC	0.3	0.3	0.4	0.3	0.0	0.2	0.7	0.5	0.9	0.3	0.4
CR	0.7	0.2	0.7	0.6	1.1	0.6	0.5	0.7	0.2	0.6	0.6
MR	0.3	0.3	0.7	0.7	0.4	0.2	0.3	0.7	0.6	0.2	0.4
Sweet											
FC	0.2	0.3	0.7	0.3	0.5	0.5	0.3	0.3	0.3	0.4	0.4
CR	0.2	0.5	0.2	0.5	0.3	0.2	0.5	0.2	0.5	0.3	0.3
MR	0.1	0.3	0.3	0.3	0.3	0.3	0.9	0.5	0.0	0.2	0.3
Bitter											
FC	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0
CR	0.0	0.2	0.2	0.2	0.0	0.2	0.2	0.0	0.2	0.0	0.1
MR	0.0	0.2	0.2	0.0	0.2	0.0	0.2	0.0	0.1	0.0	0.1
Stale											
FC	0.5	0.7	0.3	0.2	0.8	0.7	0.2	0.2	0.2	0.2	0.4
CR	1.0	0.3	1.2	0.2	0.4	0.8	0.3	0.5	0.0	0.6	0.5
MR	0.8	0.3	0.2	0.7	0.1	0.3	0.2	0.7	0.3	0.0	0.4
Astringent											
FC	0.0	0.3	0.0	0.3	0.6	0.0	0.5	0.3	0.2	0.1	0.2
CR	0.3	0.3	0.3	0.5	0.3	0.2	0.2	0.6	0.2	0.2	0.3
MR	0.3	0.7	0.3	0.3	0.0	0.0	0.2	0.2	0.2	0.0	0.2

TABLE 8.--concl.

Factor	Evaluation Period										Mean
	1	2	3	4	5	6	7	8	9	10	
Metallic											
FC	0.2	0.2	0.2	0.5	0.5	0.2	0.3	0.2	0.2	0.0	0.2
CR	0.2	0.7	0.5	0.3	0.5	0.8	0.5	0.0	0.4	0.2	0.4
MR	0.0	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2
Animal-like											
FC	0.3	0.2	0.3	0.2	0.5	0.7	0.3	0.7	0.2	0.5	0.4
CR	0.2	0.3	0.2	0.3	0.3	0.3	0.0	0.5	0.2	0.5	0.3
MR	1.0	0.2	0.2	0.2	0.3	0.2	0.7	0.3	0.2	0.5	0.4

[a] 3-(strong); 0-(absent)

TABLE 9.--Analysis of variance for aroma and flavor components and juiciness.

Factor	F-values and probability levels		
	Animal	Loin	Treatment
Aroma			
Meaty-brothy	0.13021	0.5962	1.8948
Acid	1.4553	0.4323	0.4208
Sweet	0.7701	1.6822	4.6885*
Bitter	1.4823	1.8129	0.8531
Stale	2.0234	0.2841	1.6409
Metallic	0.3541	2.0530	1.1361
Animal-like	0.1806	2.1285	0.1582
Flavor			
Meaty-brothy	0.6539	0.7819	1.2243
Acid	0.8051	0.4479	1.2630
Sweet	1.0436	1.0966	0.3228
Bitter	1.0084	3.0133*	2.4288
Stale	1.6707	0.7806	0.9316
Astringent	1.5364	1.5496	0.9320
Metallic	0.9474	1.2017	4.8267*
Animal-like	0.7560	1.2786	0.6552
Juiciness	4.0803*	3.6723*	4.0839*

* $P < 0.05$

TABLE 10.--TBA numbers, ninhydrin-reactive compounds, total moisture, total cooking losses and cooking times for freshly cooked (FC), conventionally reheated (CR) and microwave reheated (MR) pork.

Factor	Evaluation Period										
	1	2	3	4	5	6	7	8	9	10	Mean
TBA number											
FC	0.444	0.477	0.358	0.393	0.377	0.263	0.254	0.300	0.223	0.225	0.331
CR	0.657	0.650	0.556	0.504	0.505	0.415	0.401	0.449	0.440	0.396	0.497
MR	0.432	0.530	0.535	0.394	0.406	0.373	0.281	0.428	0.312	0.316	0.401
Ninhydrin-reactive cmpds.											
FC	11.15	20.11	8.75	8.95	10.84	10.13	11.69	9.55	11.38	11.24	11.38
CR	9.22	13.50	8.55	9.62	9.25	11.87	13.03	9.53	9.37	11.36	10.57
MR	7.40	15.50	8.75	9.24	10.67	11.78	11.95	8.37	6.89	9.81	10.04
Total moisture, %											
FC	60.97	61.32	67.06	63.90	62.46	64.03	62.63		60.08	61.70	62.59
CR	59.55	60.64	60.05	60.29	62.80	61.79	60.40	60.34	60.74	60.11	60.67
MR	56.58	56.84	62.38	48.07	58.87	62.77	54.16	56.43	56.23	55.61	57.79
Cooking losses, %											
FC	31.12	29.80	28.06	26.95	27.47	25.59	28.33	26.75	32.07	28.61	28.47
CR	33.70	27.96	30.05	28.92	30.14	30.58	29.91	29.97	34.34	32.94	30.85
MR	31.80	33.26	28.75	39.40	37.96	30.46	38.68	34.92	42.29	37.86	35.54
Cooking times											
Total											
FC	78	72	61	75	58	78	54	55	84	76	69
CR	99	93	92	95	95	131	94	103	133	126	106
MR	53	51	47	57	61	78	57	63	95	79	64
Final											
FC	78	72	61	75	58	78	54	55	84	76	69
CR	51	51	49	54	47	61	41	44	51	54	50
MR	7	9	5	14	8	9	9	7	15	9	9

TABLE 11.--Analysis of variance for total moisture, total cooking losses, time TBA numbers, and ninhydrin-reactive compounds

Factor	F-values and probability levels		
	Animals	Loin	Treatment
Total moisture, %	5.180**	0.949	20.272***
Total cooking losses, %	2.7819	1.4392	18.8286***
Time[a]	4.7605**	2.4009	318.7119***
TBA numbers[b]	30.3939***	3.6404*	48.4533***
Ninhydrin-reactive compounds[c]	5.5201**	8.9675***	2.1427

[a] Final cooking time immediately prior to evaluation

[b] mg malonaldehyde/1000g tissue

[c] umoles glycine/g tissue

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

TABLE 12.--Nitrogen[a] in protein fractions of freshly cooked (FC), conventionally reheated (CR) and microwave reheated pork.

Factor	Evaluation Period 1	2	3	4	5	6	7	8	9	10	Mean
Low ionic strength											
FC	4.19	4.07	4.24	4.19	3.87	3.96	4.71	3.84	4.29	4.43	4.18
CR	2.43	4.22	4.50	4.88	4.66	3.18	4.61	4.39	4.03	4.30	4.12
MR	4.59	4.17	4.60	4.22	4.66	3.74	4.95	4.71	3.79	4.56	4.40
Sarcoplasmic											
FC	3.41	3.44	3.43	3.37	3.00	2.20	3.90	3.01	3.73	3.65	3.31
CR	1.71	3.60	3.63	4.06	3.76	2.19	3.80	3.63	3.17	3.53	3.31
MR	3.91	3.39	3.69	3.30	3.76	2.63	4.20	3.72	3.01	3.88	4.15
NPN											
FC	0.78	0.63	0.81	0.82	0.88	1.72	0.81	0.83	0.56	0.77	0.86
CR	0.72	0.62	0.87	0.81	0.90	0.99	0.81	0.76	0.86	0.76	0.81
MR	0.69	0.77	0.91	0.92	0.92	1.11	0.75	0.99	0.77	0.69	0.85
Soluble fibrillar											
FC	0.61	0.34	0.44	0.70	0.38	0.99	0.58	0.58	0.53	0.48	0.86
CR	0.72	0.28	0.40	0.59	0.52	0.78	0.66	0.46	0.63	0.39	0.54
MR	0.59	0.42	0.52	0.54	0.49	0.38	0.46	0.56	0.68	0.44	0.51
Denatured fibrillar											
FC	34.04	34.10	34.31	39.24	35.92	33.50	29.37	34.25	34.34	33.05	34.21
CR	34.95	41.24	35.29	36.23	37.49	29.36	33.87	29.11	32.17	35.20	34.49
MR	32.47	35.38	37.06	42.56	21.75	29.65	33.75	43.10	35.09	33.63	34.44
Total nitrogen											
FC	60.7	64.0	51.9	64.0	50.2	52.3	49.4	49.6	46.5	50.7	53.9
CR	58.4	49.6	63.9	50.2	52.4	47.4	49.2	46.3	47.4	49.9	51.4
MR	47.9	64.4	51.3	63.0	63.1	49.6	48.5	48.4	50.0	45.3	53.1

[a] mg nitrogen/g tissue

TABLE 13.--Nitrogen[a] in protein fractions of freshly cooked (FC), conventionally reheated (CR) and microwave reheated (MR) pork.

Factor	Evaluation Period 1	2	3	4	5	6	7	8	9	10	Mean
Low ionic strength[a]											
FC	6.90	6.35	8.16	6.54	7.70	7.57	9.53	7.74	9.22	8.73	7.84
CR	4.16	8.50	7.04	9.72	8.89	6.70	9.36	9.48	8.50	8.61	8.10
MR	9.58	6.47	8.96	6.69	7.41	6.54	10.20	9.73	7.58	10.06	8.42
Sarcoplasmic[a]											
FC	5.61	5.37	6.60	5.27	5.96	4.20	7.89	6.06	8.02	7.19	6.22
CR	2.92	7.25	5.68	8.09	7.18	4.62	7.71	7.83	6.68	7.07	6.50
MR	8.15	5.27	7.19	5.23	5.93	5.30	8.66	7.68	6.02	8.56	6.80
NPN[a]											
FC	1.28	0.99	1.56	1.27	1.74	3.28	1.63	1.67	1.21	1.52	1.61
CR	1.23	1.25	1.36	1.61	1.71	2.08	1.65	1.64	1.81	1.53	1.59
MR	1.43	1.20	1.76	1.45	1.46	2.24	1.54	2.04	1.55	1.51	1.62
Soluble fibrillar[a]											
FC	1.00	0.52	0.85	1.09	0.76	1.89	1.17	1.17	1.14	0.95	1.05
CR	1.24	0.56	0.62	1.16	0.98	1.63	1.33	0.99	1.33	0.77	1.06
MR	1.22	0.65	1.00	0.85	0.78	0.77	0.95	1.15	0.87	0.96	0.92
Denatured fibrillar[a]											
FC	56.07	53.27	66.11	61.31	71.55	64.06	59.46	69.05	73.84	65.18	63.99
CR	59.84	83.14	55.23	72.16	71.54	61.55	68.81	62.86	67.86	70.54	67.35
MR	67.78	54.94	72.24	67.56	34.46	59.77	69.59	89.04	70.17	74.22	65.98
Total nitrogen, %											
FC	6.07	6.40	5.19	6.40	5.02	5.23	4.94	4.96	4.65	5.07	5.39
CR	5.84	4.96	6.39	5.04	5.24	4.74	4.92	4.63	4.74	4.99	5.15
MR	4.79	6.44	5.13	6.30	6.31	4.96	4.85	4.84	5.00	4.53	5.31

[a] Expressed as a percentage of total nitrogen

TABLE 14.--Analysis of variance for protein fractions.

Factor	F-values and probability levels		
	Animal	Loin	Treatment
Low ionic strength[a]	1.8064	1.5416	1.0046
Sarcoplasmic[a]	0.7015	0.6464	1.2235
Non-protein nitrogen[a]	6.0736**	1.9684	0.3342
Soluble fibrillar[a]	0.4850	4.1786*	0.5118
Denatured fibrillar[a]	1.6380	0.5555	0.0119
Total nitrogen[a]	3.9214*	0.5397	0.5079
Low ionic strength[b]	3.0199*	0.3008	0.4824
Sarcoplasmic[b]	3.1947*	0.8074	0.5344
Non-protein nitrogen[b]	7.7877***	3.4415*	0.0383
Soluble fibrillar[b]	1.5646	4.2593**	1.1563
Denatured fibrillar[b]	0.9208	0.1935	0.2329
Total nitrogen	3.9214*	0.5397	0.5079

[a] mg nitrogen/g tissue on a wet weight basis

[b] Calculated as a percentage of the total nitrogen

* $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

FLAVOR AND SELECTED CHEMICAL CHARACTERISTICS OF CONVENTIONALLY AND MICROWAVE REHEATED PORK

by

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Flavor and aroma components and selected chemical characteristics of freshly cooked, conventionally reheated and microwave reheated pork were studied. A randomized complete block design with ten replications of each treatment was used. A laboratory panel evaluated flavor and aroma components and juiciness of the heated pork. Percentage total moisture, percentage total cooking losses, cooking time prior to evaluation, TBA values and ninhydrin-reactive compounds were determined. Nitrogen from various extracted protein fractions also was analyzed.

Flavor and aroma of pork was similar for the three treatments, but freshly cooked and microwave reheated muscle had sweeter ($P < 0.05$) aroma and less ($P < 0.05$) metallic flavor than conventionally reheated pork. Microwave reheated pork also was less ($P < 0.05$) juicy than pork heated by the other treatments. Other flavor and aroma components were the same. Significant correlations were found between some aroma and flavor components.

Percentage total moisture, percentage total cooking losses and cooking time at the final preparation were significantly ($P < 0.001$) affected by the heating treatments. Microwave reheated pork contained less moisture and had greater total cooking losses than did pork that was either freshly cooked or conventionally reheated. Microwave reheated pork also took significantly less time to prepare than pork heated by the other two methods.

The heating treatments had a significant ($P < 0.001$) effect on TBA values. Freshly cooked pork had the lowest value, and conventionally reheated pork had the highest value. Heating treatments did not affect ninhydrin-reactive compounds or nitrogen content in the various extracted protein fractions.