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To the Graduate Council:

I am submitting herewith a thesis written by Robert Milton Reeves, Jr., entitled "The Effects of Differing Batter Levels upon Enzymatically and Mechanically Tenderized Pork and Beef Steaks." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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THE EFFECTS OF DIFFERING BATTER LEVELS UPON ENZYMATICALLY AND MECHANICALLY TENDERIZED PORK AND BEEF STEAKS

A Thesis

Presented to

The Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

By

Robert Milton Reeves, Jr.

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ABSTRACT

Beef round and pork loin steaks were machanically and enzymatically tenderized and treated with either 0, 5, 10, 15, or 20 percent batter levels. Steaks were cooked by open grill and deep fat frying methods. Chemical composition was determined by proximate analysis and organoleptic characteristics evaluated by taste panelists.

Both beef and pork steaks tended to have higher cooking losses as battering levels were increased; however, steaks of both species with no coating had the greatest cooking losses.

Little variation of either fat or ash content was observed in uncooked and cooked steaks of both species.

Moisture content generally increased with increases in battering level in both cooked and uncooked steaks of both species. Water absorption by vegetable gums in the batter apparently contributed to water retention in the cooked steaks of both species.

Protein content was highest in the unbattered steaks of both species when compared to all levels of battering. The addition of high carbohydrate-low protein batters to steaks apparently was responsible for lower protein percentages in battered steaks.

Trends of flavor and tenderness scores were similar to those of overall preference scores for both species. The appearance scores of cooked and uncooked steaks of both species showed no specific trends.

Overall preference scores of both grilled and deep fat fried beef steaks were significantly higher ($P < .05$) for battered steaks than for non-battered steaks. No differences were observed among steaks receiving different levels of batter.

Grilled pork loin steaks with the 15 percent level of battering received a significantly higher overall preference score than other batter coated steaks. All batter levels of deep fat fried loin steaks were significantly higher ($P < .05$) in preference score than unbattered steaks.

Under the conditions of this study, battering of mechanically and enzymatically tenderized beef and pork steaks from cow and sow carcasses appears to offer an acceptable method of improving consumer acceptability of these lower grade meats.

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CHAPTER I

INTRODUCTION

The growing competition in the meats industry has resulted in the development of many new meat products. Most innovations in development tend to affect the main consumer acceptance attributes of tenderness, flavor and appearance.

One method of tenderizing meat which has become increasingly popular has been through the use of plant enzymes. The application of tenderizing enzymes to most commercial meat products had been by antemortem injections or by administration of powdered enzymes during cooking. Other products have been tenderized by the addition of enzymes subsequent to deboning of the chilled carcass. These enzymes are activated at higher temperatures during cooking resulting in tenderization of the meat product.

Another area of development has involved the application of batters to meat products. Battering and breading have long been used on seafoods and certain poultry products. One of the newest products to emerge in the meats industry has been a battered meat product which has been enzymatically and mechanically tenderized.

Meat products of this type have caused problems in the industry however, because no standards are available by which the product can be Federally governed. Standards have been established specifically for enzyme-treated products and batter coated products, but none have been established for meat products using a combination of the two treatments. Federal regulations regarding such products are temporary pending further investigation in this area.

The purpose of this study was to evaluate the effects of battering levels upon consumer acceptance of enzymatically and mechanically tenderized meat products. Comparative research in this area is needed to assist in establishing standards for such products.

CHAPTER II

LITERATURE REVIEW

Papain as a Meat Tenderizer

Much work has been conducted involving the use of proteolytic enzymes in tenderizing meat. The most widely used enzyme for this purpose has been papain. Few studies using papain as a tenderizing agent on pork are recorded in the literature; however, many such studies have been conducted with beef.

Tsen and Tappel (1958) compared the crystalline enzymes papain, bromelin, trypsin, and chymotrypsin and found papain to be the most active in digesting beef. Miyada and Tappel (1956) made similar comparisons using the enzymes bromelin, ficin, trypsin, papain, and Rhozyme P-11. All enzymes were found to be powerful meat tenderizers, but no single enzyme was found to exceed the others in tenderizing properties.

Weiner *et al.* (1958) tested the tenderizing action of pure crystalline papain, finely powdered papain, and papain in a liquid media by milk clotting and beef digestion methods. Powdered papain was found to have higher digestive activity than liquid tenderizers by both testing methods. The activity of all forms of papain was increased as temperature increased.

Huffman *et al.* (1967b) administered ante-mortem injections of crude papain, crystalline papain, denatured crude papain, ashed crude papain, and sodium chloride and compared their effects on beef liver and kidney. Consistent though non-significant improvement in tenderness was indicated when animals were injected with crude papain ash or denatured crude papain. Crude papain injections resulted in over-tenderized livers and kidneys.

The applications of papain to less tender cuts of meat has gained wide acceptance. Mier et al. (1962) compared beef round steaks which had been treated with papain solutions, papain solutions plus physical piercing, and piercing with no papain treatment. The piercing plus papain treatment resulted in the greatest increase in tenderness as determined by shear values and taste panel rating.

Hay et al. (1943) applied powdered papain to round steaks, sirloin tip steaks, and rump roasts of commercial beef carcasses. The meat was "forked" before and after applications of the papain. No significant differences were found due to papain in cooking loss, aroma, or flavor of any cut of meat. Papain was effective in increasing tenderness of all steaks. Juiciness scores were higher for untreated than for treated meat.

Huffman et al. (1967a) injected weaning calves of different breeds with various levels of papain solution ante-mortem. Loin steaks, rib roasts, kidney, and livers from papain injected calves were significantly more tender than those from non-injected control cattle. A significant breed times papain level interaction ($P < .05$) was found indicating a differential response by breeds to papain injection.

McHugh et al. (1959) prepared "grill" steaks from top rounds and mechanically cubed "minute" steaks taken from bottom rounds by immersing them in papain solution before cooking. Both choice and utility rounds were used in each treatment. Grill type round steaks from utility rounds were more acceptable when enzymatically tenderized. Flavor, tenderness, and juiciness were all improved by the use of the papain tenderizer. Minute steaks from both choice and utility rounds, however, were unfavorably affected by the tenderizer in regard to juiciness, flavor, and overall acceptability.

Huffman et al. (1967b) and Weir et al. (1958) reported improved steak tenderness with added levels of sodium chloride in combination with papain tenderizers.

Several workers have studied the effects of time of papain application and temperature on the protein hydrolysis of meat. Early work by Gottschall and Kies (1942) indicated maximum digestion of beef by papain at 55°-75°C with very little digestion taking place below 27°C or above 100°C. Tsen and Tappel (1958) reported maximum hydrolysis of beef at 60°C or higher. The greatest hydrolysis of beef tissue occurred at temperatures of 60°C and 80°C according to Wang and Maynard (1955) and Tappel et al. (1956).

Little penetration of papain in meat prior to cooking has been reported. Tappel et al. (1956) indicated a 2mm maximum penetration of papain in beef skeletal muscle at room temperature. Gottschall and Kies (1942) reported a maximum papain penetration of 2.5mm in beef at room temperature. Wang and Maynard (1955) reported penetration depths in beef of 2mm at temperatures from 39°-55°C. Such evidence suggests pre-cooking holding periods have no significant tenderizing effects on beef treated with papain.

The mode of action of papain on meat has been investigated by many. Weir et al. (1958) reported sarcolemma and muscle fiber envelopes were disintegrated and extensive granulation of the endomysial collagen resulted from papain treatment. Tappel et al. (1956) suggested the most important tenderization mechanism is the hydrolysis of muscle fiber protein, which is three-fourths of the edible portion of beef. He reported the hydrolysis of the sarcolemma and muscle cell nuclei occured before any apparent digestion of muscle fibers themselves.

Wang and Maynard (1955) found papain capable of readily hydrolyzing actomyosin, elastin, and collagen. Tsen and Tappel (1958) indicated that three muscle components, actomyosin, actin, and collagen, were apparently broken down by papain and of the three, actomyosin was most readily hydrolyzed. Compared to actomyosin, actin was hydrolyzed to a limited extent, suggesting that myosin may be the component readily attacked by papain. McIntosh et al. (1963) indicated that mucoproteins and collagen were more affected by papain than other muscle proteins. Collagen was apparently converted to thick gels by the action of papain.

Wang et al. (1958) studied the action of enzymes from three different sources on steaks from utility grade steers. Collagen and elastin fibers were best broken down by plant source enzymes including papain. Microbial source fungal enzymes worked best on collagens.

McIntosh (1967) suggested the action of papain on beef muscle was very similar to that of post-mortem aging. Apparent breakdown of the mucoproteins into fragments of lower molecular weight was observed in both treatments.

The action of papain may be inactivated by oxidizing agents such as hydrogen perioxide according to Gottschall (1944). Reactivation may be accomplished by addition of sulfhydryl compounds or cyanide.

Limited research is found in the literature concerning the use of enzymatic tenderizers in species of meat other than beef. Rogers et al. (1965) injected sixty-four skinned hams with a 0.012% solution of papain at a rate of 4% fresh weight. All hams showed increased tenderness after 16 week aging periods as determined by Warner-Bratzler shear tests. Taste panel results showed a general mushiness and unacceptance.

Ante-mortem injections of papain solutions have been used in chickens to determine tenderizing effects (Fry et al., 1966; Huffman et al., 1961; and Anon, 1970). All workers reported significant tenderizing action of papain on chicken muscle. Sosebee et al. (1964) dipped chicken breasts in papain solutions and reported extensive degradation of collagen and granulated muscle fibers when boiled for 10 minutes.

Strandine and Koonz (1963) injected papain solutions into the wings of turkeys immediately post-mortem. Panel evaluation of the roasted turkeys indicated satisfactorily increased tenderness especially in older birds.

Sen et al. (1962) reported using papain as a tenderizing agent in fish. They found meat proteins to be partially hydrolyzed and degraded by the action of papain.

Virtually no research has been conducted on meat products having been enzymatically and mechanically tenderized and coated with batter. There has also been very limited research conducted on batter coated meat products not enzymatically tenderized.

Miller (1969) reported a product consisting of cuboidal pieces of meat coated with batter which produced a spheroidal form upon cooking. Belshaw (1969) described a recently developed "finger steak" coated with batter and breading. Such treatment prevented moisture removal by fat during cooking, retarded fat pickup, and enhanced the flavor.

Water Holding Capacity of Meat

The ability of muscle to retain water is an important characteristic of meat since it is closely related to taste, tenderness, color, and other features of meat quality according to Hamm (1960). He defined this water holding capacity as the ability of meat to hold fast its own or added water when subjected to applied forces such as pressing, heating, grinding, or chewing. Water liberated by some method is usually termed "loose water," and the water retained by the tissue is termed "bound water."

Several consumer quality attributes of meat seem to be closely related to water binding capacity. Wierbicki et al. (1956) and Deatherage (1955) indicated that tenderness, shrinkage on cooking, drip on freezing and thawing, and changes in tenderness with post-mortem aging were closely related to the water holding capacity of meat.

It is generally accepted that muscle proteins are responsible for the binding of water in meat. Hamm (1960) indicates that tightly bound water, representing approximately 5% of total moisture, is held by the proteins by monomolecular and multimolecular adsorption between the peptide chains. The physical properties of this bound water are different from those of free water. Bound water has a lower freezing point, a lower vapor pressure, and a lower dissolving power than normal water.

Loose water is held by a "net charge effect" according to Hamm (1959) which appears to hold water by electrostatic attraction of opposite charges within the protein structure. However, most loose water is apparently influenced by the spatial network of the muscle tissue. Tightening of the protein network decreases the availability of the polar groups on the peptide chains resulting in decreased immobilized water and increased expressible water.

Wierbicki et al. (1959) showed water absorption by meat to fall to a minimum at the isoelectric point of the meat proteins (pH 5.0-5.5) and rose at both higher and lower pH values. This is in agreement with work of Weber (1925), Hollwede and Weber (1938), and Grau (1953) as reviewed by Hamm (1960).

Water holding capacity of muscle generally decreases as temperature increases. Satorius and Child (1938), using heating temperatures of 58°C, 67°, and 75°C found beef muscle to decrease in press fluid and total water content with respective increases in temperature. Sherman (1961) heated pork at 25°-100°C and found similar results. Wierbicki and Deatherage (1956) indicated that loss of moisture on cooking increased with temperature above 65°C with maximum protein hydration occurring at 55°-65°C. Wierbicki et al. (1957) showed heat denaturation of protein beginning at 40°C and essentially finished at 70°C. Thus, it was suggested that 70°C was sufficient for the determination of water holding capacity of heat denatured proteins, and 30°-40°C could be used to study moisture losses in fresh or frozen and thawed meats.

Swift and Berman (1959) compared composition and properties of eight different bovine muscles and noted water retention was directly related to moisture--protein ratio. Although protein complexes are primarily responsible for water binding, water retention was inversely related to protein content.

CHAPTER III

EXPERIMENTAL PROCEDURE

Meat Source and Cooking Methods

Mechanically and enzymatically tenderized pork loin steaks from U.S. Medium Grade sow carcasses and round steaks from Utility Grade beef carcasses were provided by a commercial packing plant. All steaks were prepared in 100 pound batches, and random samples used for chemical and organoleptic analysis were shipped immediately after processing by the packing plant.

Processing at the plant consisted of several steps. Beef and pork steaks were first mechanically tenderized by being passed once through a Hobart tenderizer. Steaks were then placed in a Leland blender and mixed thoroughly with three points of a papain and water solution (0.5 percent papain by weight) per 100 pounds of meat. Steaks were then treated with either 0, 5, 10, 15, or 20 percent batter levels and packaged for shipment to the University of Tennessee meat laboratory (see Table I).

All steaks were stored in a refrigerator (34^{o}-40^{o}F) until weighing and cooking (approximately 24 hours after processing). All steaks were weighed to the nearest 0.1 gram immediately prior to cooking. Samples were taken from each of the uncooked steaks at each battering level and frozen for proximate analysis.

Both beef and pork steaks were cooked by open grill and deep fat frying methods. Grilled steaks were cooked on 14" x 20" portable grills for 4-1/2 minutes per side at 350^{o}F. Grills were lightly coated with

TABLE I

FORMULATION OF BATTER LEVELS APPLIED TO TENDERIZED BEEF AND PORK STEAKS

Battering[a] Level (%)	Ingredients in Pounds /Cwt. of Steaks					
	Water	Binder[b]	Salt	Gum	Msg[c]	Total
0	--	--	--	--	--	--
5	3	2-1/2	1	1/8	1/4	5.88
10	6	2-1/2	1-1/4	1/4	1/4	10.25
15	12	2-1/2	1-1/4	1/2	1/4	16.50
20	18	2-1/2	1-1/4	3/4	1/4	22.75

[a]U.S.D.A. Meat Inspector certified ingredients and batter levels.

[b]Commerical binder composed of cereal grain flours.

[c]Monosodium Glutamate.

vegetable oil prior to heating to prevent sticking during cooking.

Deep fat fried steaks were immersed in pre-heated cottonseed oil and cooked at approximately 325°F for four minutes. Steaks from each battering level were cooked in separate pans to prevent flavor interaction between two or more battering levels during cooking.

All steaks were allowed to cool for five minutes and reweighed to the nearest 0.1 gram. This weight was subtracted from the uncooked to derive the total cooking loss of the steaks. When necessary, steaks were wrapped in aluminum foil and placed in a warming oven in an attempt to serve warm samples to taste panel members.

Samples were taken from each cooked steak to be used for proximate analysis. The remainder of each steak was cut into four samples for sensory testing. The order of sample presentation was randomized.

Twelve inexperienced panel members consisting of secretaries, teachers, students, and other employees of the Food Technology and Animal Husbandry Departments were chosen to represent the tastes and preferences of the average consumer. Panel members scored each sample for tenderness, flavor, cooked appearance and uncooked appearance on a seven point scale ranging from -3 to +3, with +3 being most desirable (see Appendix). The ten percent level of battered steaks was used as the reference in all sensory evaluations. Samples were also ranked according to overall acceptability. Beef and pork samples were replicated three times within each cooking method and battering level as shown in Table II.

Means and standard deviations of sensory attribute scores are found in Tables XVI, XVII, XVIII, and XIX. Taste panel results were analyzed by analysis of variance (Steele and Torie, 1960) and significant differences

TABLE II

EXPERIMENTAL DESIGN

Species	Method	Battering Level (%) 0	5	10	15	20
Beef	Grill	3[a]	3	3	3	3
	Deep Fat	3	3	3	3	3
Pork	Grill	3	3	3	3	3
	Deep Fat	3	3	3	3	3

[a]Replications.

among means determined by the use of Duncan's New Multiple Range Test (Steele and Torie, 1960). Overall preference ranking was converted to score values (Fisher and Yates, 1948) before being subjected to analysis of variance procedures.

Methods of Chemical Analysis

Both cooked and uncooked steak samples were ground twice while in a semi-frozen state through a 3/16 inch plate with a small Hobart grinder. Samples were thoroughly mixed and placed in small glass sample bottles and refrigerated until chemical analyses were performed a short time later.

Moisture, ether extract, protein, and ash analyses were conducted according to procedures outlined by the Association of Official Agricultural Chemists (1965). Duplicate analyses were conducted for each sample. The average of the two determinations was used for calculations. Means and standard deviations of proximate analysis components are presented in Tables XX, XXI, XXII, XXIII, XXIV, and XXV.

The data were analyzed by conventional analysis of variance procedures (Steele and Torie, 1960). Simple correlations among all variables were calculated and significant differences of variation among means were determined by Duncan's New Multiple Range Test (Steele and Torie, 1960).

CHAPTER IV

RESULTS AND DISCUSSION

I. EFFECTS OF BATTERING LEVELS AND COOKING METHOD ON TENDERIZED BEEF ROUND STEAKS

Cooking Loss of Beef Steaks

Total cooking losses of deep fat fried tenderized beef steaks were greater and more uniform among battering levels than of those which were grilled (Table III). Lower cooking losses of steaks at all levels of battering from both cooking methods than of unbattered steaks may be attributed to water being bound by vegetable gums present in the batter coatings. There was a general tendency for total cooking losses to increase with increases in batter level, especially from grilled steaks. Water absorbed by the vegetable gum in the batter might be driven out by heating and contribute to higher cooking losses for higher levels of battering.

Proximate Analysis of Uncooked Beef Steaks

The 20 percent battered steaks had significantly ($P < .05$) greater moisture content than either the 5 or 10 percent batter levels but were not different from the 0 or 15 percent battered steaks (Table IV). These data indicate that with the batter formula used in this study, up to 20 percent batter may be added to tenderized beef steaks without significantly increasing total moisture content above that of unbattered steaks.

TABLE III

TOTAL COOKING LOSSES OF BATTERED AND TENDERIZED STEAKS

Species	Method	Battering Level (%)				
		0[a]	5	10	15	20
Beef	Grill	33.7[b]	22.2[d]	23.5[d]	28.2[c]	32.2[b]
	Deep Fat	42.1[b]	36.4[c]	35.2[c]	35.9[c]	37.2[c]
Pork	Grill	37.1[b]	24.0[d]	27.2[c,d]	32.0[b,c]	35.8[b]
	Deep Fat	41.3[b]	35.1[c]	36.8[c]	37.2[c]	37.9[b,c]

[a]Sample was mechanically and enzymatically tenderized as were steaks of all other battering levels but no batter was applied.

[b,c,d]Means in the same row not bearing the same superscript are significantly ($P < .05$) different.

TABLE IV

PROXIMATE ANALYSIS OF UNCOOKED BATTERED AND TENDERIZED BEEF STEAKS

Component*	Battering Level (%)				
	0	5	10	15	20
Moisture	75.78[a,b]	73.85[b]	73.99[b]	75.77[a,b]	76.76[a]
Fat	1.94[a]	2.16[a]	1.84[a]	1.67[a]	1.77[a]
Protein	19.90[a]	19.46[a]	18.91[a]	16.92[b]	16.77[b]
Ash	9.96[a]	1.11[a]	0.97[a]	0.93[a]	0.84[a]

*Proximate analysis was conducted according to A.O.A.C. procedures (1965).

a,bMeans in the same row not bearing the same superscript are significantly ($P < .05$) different.

Protein in the 15 and 20 percent batter levels was found to be significantly lower ($P < .05$) than that in the 0, 5, or 10 percent levels. According to present regulations any additive is regarded as an adulterant if it lowers the nutritive value of any meat product. In this study up to 10 percent batter was added before the protein level was reduced.

Neither fat nor ash contents showed significant differences ($P < .05$) among batter levels.

Proximate Analysis of Grilled Beef Steaks

The zero percent battering level of grilled beef steaks was significantly ($P < .05$) lower in moisture than the 5, 10, 15, and 20 percent levels (Table V).

Protein was significantly higher ($P < .05$) in steaks having no batter coating than in any of the steaks with batter coatings since batter ingredients were low in protein. Batter and meat juices adhered to the grill during cooking. Unbattered steaks did not adhere to the grill nor leave residue.

As in the uncooked steaks, fat and ash did not differ significantly ($P < .05$) among battering levels.

Proximate Analysis of Deep Fat Fried Beef Steaks

There were no significant differences ($P < .05$) observed in moisture content of deep fat fried beef steaks among steaks having batter coatings; however, the 20 percent battered steaks were significantly higher in moisture than those with no batter coating (Table VI). The percent moisture of deep fat fried beef steaks was lower at all battering levels.

TABLE V

PROXIMATE ANALYSIS OF GRILLED BATTERED AND TENDERIZED BEEF STEAKS

Component*	Battering Level (%)				
	0	5	10	15	20
Moisture	63.82[b]	65.91[a]	67.03[a]	65.58[a]	65.15[b]
Fat	3.09[a]	3.03[a]	2.34[a]	2.69[a]	3.48[a]
Protein	30.17[a]	25.40[b]	25.59[b]	26.91[b]	24.73[b]
Ash	1.17[a]	1.39[a]	1.23[a]	1.23[a]	1.24[a]

*Proximate analysis was conducted according to A.O.A.C. procedures (1965).

[a,b]Means in the same row not bearing the same superscript are significantly ($P < .05$) different.

TABLE VI

PROXIMATE ANALYSIS OF DEEP FAT FRIED BATTERED AND TENDERIZED BEEF STEAKS

	Battering Level (%)				
Component*	0	5	10	15	20
Moisture	59.36^{b}	$59.86^{a,b}$	$60.69^{a,b}$	$61.17^{a,b}$	62.49^{a}
Fat	5.97^{a}	$5.47^{a,b}$	4.33^{b}	5.76^{a}	6.77^{a}
Protein	31.91^{a}	$29.56^{a,b}$	28.68^{b}	27.47^{b}	27.43^{b}
Ash	1.12^{b}	1.42^{a}	$1.39^{a,b}$	$1.23^{a,b}$	$1.26^{a,b}$

*Proximate analysis was conducted according to A.O.A.C. procedures (1965).

a,bMeans in the same row not bearing the same superscript are significantly ($P < .05$) different.

Percent fat was higher in deep fat fried beef steaks than in grilled beef steaks. This higher fat content may partially explain the lower moisture level of these steaks compared to grilled steaks. Moisture of steaks driven out by deep fat frying is often replaced by fat. Among battering levels only the 10 percent level contained significantly ($P < .05$) lower fat than the uncooked steaks.

Protein content tended to decrease as batter levels increased with the zero percent level being higher than the higher levels of battering (10, 15, and 20 percent). These results agree with those of grilled beef steaks.

Ash content did not vary appreciably; however, there was a tendency for battered steaks to have more ash than unbattered steaks.

Sensory Attributes of Grilled Beef Steaks

Flavor scores of non-battered grilled beef steaks were significantly lower ($P < .05$) than the reference steaks (10 percent batter level). The 5, 15, and 20 percent battering levels were significantly higher than the 10 percent level (Table VII). Such results indicate that batter added to tenderized beef steaks in this study tended to increase flavor.

Similar trends were observed when tenderness was compared within battering levels. The 5, 15, and 20 percent levels were significantly higher ($P < .05$) and the zero level was significantly lower than the reference steaks. Although all steaks were mechanically tenderized and subjected to papain treatment, those having batter coatings tended to have increased tenderness.

The appearance of the uncooked steaks with 5 percent batter was significantly lower in score than the 10 percent level. All other battering

TABLE VII

SENSORY ATTRIBUTES OF GRILLED BATTERED AND TENDERIZED BEEF STEAKS

Attribute	Battering Level (%) 0	5	10[a]	15	20
Flavor	-0.86*	0.81*	--	0.50*	0.72*
Tenderness	-0.61*	1.11*	--	1.09*	0.94*
Uncooked Appearance	-0.25	-1.06*	--	0.22	0.11
Cooked Appearance	0.28	0.50	--	0.33	0.44
Preference	-0.66[d]	0.33[d]	-0.20[c]	0.27[c]	0.20[c]

*Mean is significantly different from 10 percent batter level ($P < .05$).

[a]The 10 percent battering level was used as the reference sample in all sensory evaluation and scored "0" on a modified hedonic scale ranging from -3 to +3, with +3 being most desirable.

[b]Preference values were converted to scores for ranked data (Fisher and Yates, 1948).

[c,d]Means in the same row not bearing the same superscript are significantly ($P < .05$) different.

levels were not significantly different from the reference level. Appearance after cooking showed no significant differences among battering levels.

Overall preference scores indicated a significantly ($P < .05$) greater preference of battered steaks. There were no significant differences among levels of the batter coated beef steaks. A close relationship between tenderness and flavor and overall preference was indicated by respective trends of panel scores being very similar.

Sensory Attributes of Deep Fat Fried Beef Steaks

Trends of all sensory attributes of deep fat fried beef steaks were similar to those of grilled beef steaks. Flavor scores were higher for battered steaks than for non-battered steaks but were not significantly different ($P < .05$) from the 10 percent batter level (Table VIII).

Steaks without batter coating had significantly lower tenderness scores than the reference steaks. Of the battered steaks, only the 15 percent level had significantly higher ($P < .05$) tenderness scores than the reference.

Uncooked steaks show no significant differences in appearance scores. However, when steaks were cooked, the 20 percent battered steaks showed a significantly higher score than the 10 percent battered steaks. The zero level of batter was scored significantly lower than the reference steaks.

Overall preference rating showed the battered steaks had significantly higher ($P < .05$) scores than unbattered steaks. No significant differences existed among levels of batter coating. Such results indicate that the addition of batters used in this study tends to increase

TABLE VIII

SENSORY ATTRIBUTES OF DEEP FAT FRIED BATTERED AND TENDERIZED BEEF STEAKS

	Battering Level (%)				
Attribute	0	5	10[a]	15	20
Flavor	-1.89	0.22	--	0.44	-0.14
Tenderness	-1.64*	0.64	--	0.89*	0.64
Uncooked Appearance	-0.06	0.36	--	0.17	0.28
Cooked Appearance	-0.75*	-0.47	--	-0.44	0.56*
Preference[b]	-1.00[d]	-0.20[c]	0.20[c]	0.36[c]	0.26[c]

*Mean is significantly different from 10 percent batter level ($P < .05$).

[a]The 10 percent battering level was used as the reference sample in all sensory evaluations and scored "0" on a modified hedonic scale ranging from -3 to + 3, with +3 being most desirable.

[b]Preference values were converted to scores for ranked data (Fisher and Yates, 1948).

[c,d]Means in the same row not bearing the same superscript are significantly ($P < .05$) different.

overall consumer acceptability of both grilled and deep fat fried beef steaks.

II. EFFECTS OF BATTERING LEVEL AND COOKING METHOD ON TENDERIZED PORK LOIN STEAKS

Cooking Loss of Pork Loin Steaks

Deep fat fried loin steaks had increased total cooking losses with increases in battering levels, especially from the grilling method; however, highest losses occurred in steaks having no batter coating (Table III, page 16). These results are similar to those found in beef steaks for both methods of cooking.

Proximate Analysis of Uncooked Pork Loin Steaks

Moisture content of the uncooked pork loin steaks increased as batter level was increased from 5 to 20 percent (Table IX). Pork steaks containing 20 percent batter were significantly ($P < .05$) higher in moisture than those containing 5 or 10 percent batter. These data are in agreement with those for uncooked beef steaks (Table 4, page 17) and indicate that up to 20 percent batter of the formula used in this study may be added to tenderized pork loin steaks without significantly increasing the moisture level above that normally found in non-battered products.

Fat and ash content did not vary significantly ($P < .05$) among battering levels.

The addition of carbohydrate rich batter to pork loin steaks decreased the percent protein but the decrease was not significant ($P < .05$) until the 15 percent level was reached. Thus, it is indicated that pork

TABLE IX

PROXIMATE ANALYSIS OF UNCOOKED BATTERED AND TENDERIZED PORK LOIN STEAKS

Component*	Battering Level (%)				
	0	5	10	15	20
Moisture	$68.32^{a,b,c}$	65.53^{c}	$66.98^{b,c}$	$69.44^{a,b}$	70.49^{a}
Fat	8.65^{a}	8.57^{a}	8.29^{a}	7.34^{a}	7.61^{a}
Protein	21.73^{a}	$19.46^{a,b}$	$20.06^{a,b}$	18.31^{b}	17.34^{b}
Ash	1.02^{a}	0.93^{a}	0.83^{a}	0.82^{a}	0.79^{a}

*Proximate analysis was conducted according to A.O.A.C. procedures (1965).

a,b,cMeans in the same row not bearing the same superscript are significantly ($P < .05$) different.

as well as beef tenderized steaks may be combined with up to 10 percent batter without significantly decreasing protein of the uncooked product (Table IX, page 26).

Proximate Analysis of Grilled Pork Loin Steaks

Moisture content of pork loin steaks tended to increase with increases in battering levels with the 10, 15, and 20 percent levels being significantly ($P < .05$) higher than the zero percent level (Table X). Among battering levels, however, there were no significant differences in moisture.

The application of batter to pork loin steaks did not significantly change the percentage of either fat or ash.

Grilled pork loin steaks receiving batter were not different in protein at any batter level but all levels were significantly ($P < .05$) lower in percent protein than the unbattered steaks.

Proximate Analysis of Deep Fat Fried Pork Loin Steaks

Similar trends in moisture content existed in deep fat fried pork loin steaks when compared to those which were grilled. The 15 and 20 percent batter coated steaks were significantly higher in moisture than the 0, 5, and 10 percent level steaks with the general trend being an increase in moisture accompanying an increase in battering levels (Table XI).

Fat and ash content showed no variation among all battering levels ($P < .05$).

Protein content again tended to decrease as batter levels increased; however, the 5, 10, 15, and 20 percent levels did not vary significantly. These levels were significantly lower ($P < .05$) in protein than the steaks having no batter coating.

TABLE X

PROXIMATE ANALYSIS OF GRILLED BATTERED AND TENDERIZED PORK LOIN STEAKS

Component*	Battering Level (%) 0	5	10	15	20
Moisture	52.94^{b}	$54.97^{a,b}$	57.27^{a}	56.96^{a}	57.34^{a}
Fat	11.22^{a}	10.00^{a}	9.19^{a}	9.84^{a}	11.15^{a}
Protein	33.45^{a}	27.09^{b}	28.58^{b}	26.06^{b}	25.69^{b}
Ash	1.45^{a}	1.41^{a}	1.35^{a}	1.28^{a}	1.22^{a}

*Proximate analysis was conducted according to A.O.A.C. procedures (1965).

a,b Means in the same row not bearing the same superscript are significantly ($P < .05$) different.

TABLE XI

PROXIMATE ANALYSIS OF DEEP FAT FRIED BATTERED AND TENDERIZED PORK LOIN STEAKS

Component*	Battering Level (%)				
	0	5	10	15	20
Moisture	51.75^{b}	51.76^{b}	51.75^{b}	55.24^{a}	56.66^{a}
Fat	11.92^{a}	11.51^{a}	10.95^{a}	12.19^{a}	10.47^{a}
Protein	34.31^{a}	29.71^{b}	30.19^{b}	26.45^{b}	27.34^{b}
Ash	0.68^{a}	0.75^{a}	0.98^{a}	0.80^{a}	0.75^{a}

*Proximate analysis was conducted according to A.O.A.C. procedures (1965).

[a,b]Means in the same row not bearing the same superscript are significantly ($P < .05$) different.

Sensory Attributes of Grilled Pork Loin Steaks

When flavor was evaluated, loin steaks without batter had scores significantly ($P < .05$) lower than reference steaks (10 percent batter level). Steaks containing 15 percent batter had higher flavor scores than the reference level (Table XII).

Non-battered loin steaks were significantly ($P < .05$) lower in tenderness scores than were reference steaks, while the 15, 15, and 20 percent battered steaks were significantly higher in tenderness scores than the reference steaks. According to these data, tenderness of battered steaks tended to be greater than that of unbattered steaks.

The uncooked appearance of the non-battered loin steaks, however, received significantly higher ($P < .05$) scores than the reference steaks while the 5 percent battered steaks showed significantly lower scores than the reference.

When overall preference of the loin steaks was evaluated, the 15 percent battered steaks showed significantly higher ($P < .05$) scores than the 5, 10, or 20 percent battered steaks. The unbattered loin steaks were significantly lower in preference score than the battered steaks.

Sensory Attributes of Deep Fat Fried Pork Loin Steaks

Flavor scores were significantly lower ($P < .05$) for the unbattered pork steaks; however, no significant variation was evident among the 5, 15, and 20 percent batter levels when compared to the 10 percent level (Table XIII).

Tenderness scores followed a trend similar to that of grilled pork loin steaks. The zero percent battering level was consistent in

TABLE XII

SENSORY ATTRIBUTES OF GRILLED BATTERED AND TENDERIZED PORK LOIN STEAKS

	Battering Level (%)				
Attribute	0	5	10[a]	15	20
Flavor	-0.86*	0.44	--	0.78*	0.30
Tenderness	-1.25*	0.58*	--	0.64*	0.72*
Uncooked Appearance	0.50*	-0.50*	--	0.33	0.03
Cooked Appearance	-0.06	0.22	--	0.58*	0.64
Preference[b]	-0.74[e]	0.11[d]	0.17[d]	0.55[c]	0.16[d]

*Mean is significantly different from 10 percent batter level ($P < .05$).

[a]The 10 percent battering level was used as the reference sample in all sensory evaluations and scored "0" on a modified hedonic scale ranging from -3 to +3, with +3 being most desirable.

[b]Preference values were converted to scores for ranked data (Fisher and Yates, 1948).

[c,d,e]Means in the same row not bearing the same superscript are significantly ($P < .05$) different.

TABLE XIII

SENSORY ATTRIBUTES OF DEEP FAT FRIED BATTERED AND TENDERIZED PORK LOIN STEAKS

	Battering Level (%)				
Attributes	0	5	10[a]	15	20
Flavor	-1.50*	-0.11	--	-0.03	-0.03
Tenderness	-0.86*	0.22	--	0.78*	1.00*
Uncooked Appearance	0.14	-0.19	--	0.36	0.36
Cooked Appearance	-0.14	-0.03	--	0.14	0.53*
Preference[b]	-0.84[d]	0.14[c]	0.35[c]	0.27[c]	0.38[c]

*Mean is significantly different from 10 percent batter level ($P < .05$).

[a]The 10 percent battering level was used as the reference sample in all sensory evaluations and scored "0" on a modified hedonic scale ranging from -3 to +3, with +3 being most desirable.

[b]Preference values were converted to scores for ranked data (Fisher and Yates, 1948).

[c,d]Means in the same row not bearing the same superscript are significantly ($P < .05$) different.

being significantly lower ($P < .05$) in tenderness score than the reference while the higher battering levels of 15 and 20 percent showed significantly greater tenderness scores than the reference steaks.

No significant ($P < .05$) differences in uncooked appearance scores were found; however, when the loin steaks were deep fat fried, the 20 percent battered steaks had significantly higher ($P < .05$) appearance scores than the reference steaks. In overall preference rating, battered loin steaks were scored significantly higher ($P < .05$) than unbattered steaks with no differences existing among the batter levels. Thus the acceptability of both grilled and deep fat fried pork loin steaks were increased when steaks were combined with the batter used in this study.

III. RELATIONSHIPS BETWEEN CHEMICAL AND SENSORY CHARACTERISTICS OF COOKED BATTERED AND TENDERIZED PORK AND BEEF STEAKS

Correlations Between Chemical and Sensory Characteristics of Cooked Battered Beef Steaks

Correlations between sensory attributes and proximate analysis of cooked battered beef steaks are presented in Table XIV. Both percent fat and protein were significantly ($P < .01$) correlated with percent moisture (-.80 and -.77 respectively) when proximate analysis components were compared. This is in agreement with Goll et al. (1965) who found a significant correlation (-.72, $P < .01$) between percent fat and percent moisture. Romans et al. (1965) found a significant correlation (-.81, $P < .01$) between percent fat and percent moisture; however, no significant correlation was found between percent protein and percent moisture. Percent protein was significantly correlated with percent fat (0.45, $P < .01$)

TABLE XIV

SIMPLE CORRELATION COEFFICIENTS BETWEEN COMPOSITION AND SENSORY ATTRIBUTES OF COOKED BATTERED BEEF STEAKS

	Moisture	Fat	Protein	Ash	Flavor	Tenderness	Uncooked Appearance	Cooked Appearance	Preference
Moisture	1.00								
Fat	-0.80**	1.00							
Protein	-0.77**	0.45**	1.00						
Ash	-0.06	0.01	-0.16	1.00					
Flavor	0.37*	-0.26	-0.67**	0.31	1.00				
Tenderness	0.45**	-0.22	-0.73**	0.25	0.87**	1.00			
Uncooked Appearance	-0.33	0.28	0.22	-0.16	0.04	0.03	1.00		
Cooked Appearance	0.32	-0.15	-0.31	0.10	0.30	0.31	-0.24	1.00	
Preference	0.18	-0.01	-0.55**	0.44**	0.86**	0.86**	0.01	0.21	1.00

*P < .05.

**P < .01.

which is substantiated by Romans <u>et al</u>. (1965).

When proximate analysis components were correlated with sensory attributes, flavor had a significant relationship with percent moisture ($r = 0.37$, $P < .05$) and percent protein ($r = -.67$, $P < .01$). This is in contrast to work by Goll <u>et al</u>. (1965) who observed a low negative relationship between moisture content and flavor. Tenderness was significantly ($P < .01$) correlated to percent moisture (0.45) and percent protein (-.73). Goll <u>et al</u>. (1965), however, found a negative and non-significant correlation between tenderness and percent moisture (4 = -.02). Husaini <u>et al</u>. (1950) reported a low correlation between tenderness and moisture content. A non-significant correlation was found between tenderness and percent fat. Conflicting results are reported in the literature concerning the relationship between tenderness and percent fat. Lowe <u>et al</u>. (1961), Cover <u>et al</u>. (1956), Kropf and Graf (1958), and Husaini <u>et al</u>. (1950) reported positive significant correlations between tenderness and and percent fat; however, Goll <u>et al</u>. (1965), Ritchey (1965), and Wellington and Stouffer (1959) found non-significant correlations between the two factors. Overall preference scores were significantly correlated with percent protein ($r = -.55$, $P < .01$).

Comparison within sensory attributes showed tenderness and flavor to be significantly correlated ($r = -.87$, $P < .01$) which is in agreement with Dryden <u>et al</u>. (1969) and Romans <u>et al</u>. (1965) but in contrast to results reported by Kropf and Graf (1958) who found a positive but non-significant correlation. Overall preference was significantly ($P < .01$) correlated to both flavor (0.86) and tenderness (0.86) indicating that these attributes contribute most to general acceptability of the attributes studied. These data are substantiated by work of Kropf and Graf (1958), Dryden et al. (1969), and Means and King (1959).

Correlations Between Chemical and Sensory Characteristics of Cooked Battered Pork Loin Steaks

Simple correlations between sensory attributes and the composition components of cooked pork loin steaks are reported in Table XV. When composition components were compared, percent moisture were significantly correlated ($P < .01$) to both fat ($r = -.75$) and protein ($r = -.55$) content. Karmas et al. (1963) reported similar relationships; however, Judge et al. (1960) showed a significant positive correlation between percent moisture and percent fat.

When sensory attributes were compared to composition components, moisture percent was significantly correlated ($P < .01$) with flavor (0.46) and tenderness (0.48). Lewis et al. (1963) showed a significant correlation of 0.69 between tenderness and percent moisture; however, flavor was negatively related to percent moisture. Judge et al. (1960) found moisture to be positively correlated to both flavor and tenderness. Overall preference scores were significantly ($P < .01$) correlated to percent protein ($r = -.65$) indicating a preference of steaks with lower protein content.

When sensory attributes were compared, flavor was found to be significantly correlated ($P < .01$) to tenderness ($r = 0.67$). Work by Judge et al. (1960) gave a similar correlation of 0.60 between tenderness and flavor scores. Overall preference scores were significantly correlated

TABLE XV

SIMPLE CORRELATION COEFFICIENTS BETWEEN COMPOSITION AND SENSORY ATTRIBUTES OF COOKED BATTERED PORK LOIN STEAKS

	Moisture	Fat	Protein	Ash	Flavor	Tenderness	Uncooked Appearance	Cooked Appearance	Preference
Moisture	1.00								
Fat	-0.57**	1.00							
Protein	-0.55**	0.18	1.00						
Ash	0.33	-0.30	0.06	1.00					
Flavor	-0.46**	-0.24	-0.67**	0.25	1.00				
Tenderness	0.48**	0.00	-0.73**	-0.11	0.67**	1.00			
Uncooked Appearance	0.03	0.18	0.26	0.04	-0.06	-0.20	1.00		
Cooked Appearance	0.31	0.05	-0.38*	0.11	0.45**	0.52**	0.36*	1.00	
Preference	0.33	-0.10	-0.65**	-0.02	0.89**	0.76**	-0.05	0.46**	1.00

*P < .05.

**P < .01.

($P < .01$) with flavor (0.89), tenderness (0.76), and cooked appearance (0.46). Flavor and tenderness apparently contributed most to consumer acceptability of cooked battered pork loin steaks.

CHAPTER V

CONCLUSION

Both beef round and pork loin steaks which were both mechanically and enzymatically tenderized tended to have higher cooking losses as battering levels were increased; however, steaks of both species with no batter coating had the greatest cooking losses. Higher total cooking losses of battered steaks could be attributed to the unbound water of the higher battering levels being driven out by heat during cooking. Some cooking loss in grilled steaks of both species could be partially explained by batter adhering to the grill during cooking.

Little variation of either fat or ash content was observed in uncooked and cooked steaks of both species.

Moisture content generally increased with increases in battering level in both cooked and uncooked steaks of both species. Water absorption by the vegetable gums in the batter apparently contributed to water retention in the cooked steaks of both species.

Protein was highest in the unbattered steaks of both species when compared to all levels of battering. The addition of high carbohydrate-low protein batters to steaks apparently was responsible for lower protein percentages in battered steaks.

Trends of flavor and tenderness scores were similar to those of overall preference scores for both species. The appearance scores of cooked and uncooked steaks of both species showed no specific trends.

Overall preference scores of both grilled and deep fat fried beef steaks were significantly higher ($P < .05$) for battered steaks than for non-battered steaks. No differences were observed among steaks receiving different levels of batter.

Grilled pork loin steaks with the 15 percent level of battering received a significantly higher overall preference score than other batter coated steaks. All batter levels of deep fat fried loin steaks were significantly higher ($P < .05$) in preference score than unbattered steaks.

Flavor and tenderness scores were highly correlated ($P < .01$) with overall preference scores in both pork and beef steaks cooked by both methods.

Under the conditions of this study, battering of mechanically and enzymatically tenderized beef and pork steaks from cow and sow carcasses appears to offer an acceptable method of improving consumer acceptability of these lower grade meats.

BIBLIOGRAPHY

BIBLIOGRAPHY

Anon. 1970. Some observations on the effects of crude papain on tenderization of poultry meat. J. Food Sci. and Tech. 7:40.

Association of Official Agricultural Chemists. 1965. Official Methods of Analysis, Washington, D. C. 10th ed.

Belshaw, Frances. 1969. Specially breaded steak cooks in 4½ minutes. Food Proc. 12:33.

Cover, Sylvia, O. D. Butler and T. C. Cartwright. 1956. The relationship of fatness in yearling steers to juiciness and tenderness of broiled and braised steaks. J. Animal Sci. 15:464.

Deatherage, F. E. 1955. Investigations of the nature of certain qualities in meat. Proc, Seventh Annual Res. Conf. A.M.I. 52-61.

Dryden, F. D., J. A. Marchello and D. E. Ray. 1969. Relationship of certain chemical constituents of beef muscle to its eating quality. J. Food Sci. 34:37.

Fisher, R. A. and Frank Yates. 1948. Statistical Tables for Biological Agricultural and Medical Research (3rd ed.). Hafner Publishing Company, Inc., New York.

Fry, J. L., P. W. Waldroup, E. M. Ahmed and H. Lydick. 1966. Enzymatic tenderization of poultry meat. Food Tech. 20:952.

Goll, D. E., A. F. Carlin, L. P. Anderson, E. A. Kline and M. J. Walter. 1965. Effect of marbling and maturity of beef muscle characteristics II. Physical, chemical and sensory evaluation of steaks. Food Tech. 19:845.

Gottschall, G. Y. 1944. Activation of papain during digestion of meat. Food Res. 9:6.

Gottschall, G. Y. and M. W. Kies. 1942. The digestion of beef by papain. Food Res. 7:373.

Grav, R., R. Hamm and A. Baumann. 1953. Uber das Wasserbindungsvermogen des Saugetiermuskels. I. Mitt. Der Einfluss des pH-wertes auf die Wasserbindung von Zerkleinertem Rindermuskel. Biochem. Z. 325:1. (as cited by Hamm, 1960).

Hamm, R. 1959. Biochemistry of meat hydration. Proc. Eleventh Annual Res. Conf. A.M.I. 50:17.

Hamm, R. 1960. Biochemistry of meat hydration. Adv. in Food Res. 10: 355.

Hay, P. P., D. L. Harrison and G. E. Vail. 1943. Effects of meat tenderizer on less tender cuts of beef cooked by four methods. Food Tech. 7:217.

Hollwede, W. and H. H. Weber. 1938. Alkalibindung and Isoelestrischer Punkt des Myosins. Biochem. Z. 295:205. (as cited by Hamm, 1960.)

Huffman, D. L., A. Z. Palmer, J. W. Carpenter, D. D. Hargrove and M. Koger. 1967a. Effect of breeding, level of feeding and ante-mortem injection of papain on the tenderness of weanling calves. J. Animal Sci. 26:290.

Huffman, D. L., A. Z. Palmer, J. W. Carpenter, J. F. Hentges, Jr., and R. L. Shirley. 1967b. Effect of ante-mortem injection of sodium chloride, papain and papain derivatives on the tenderness of beef. J. Animal Sci. 26:285.

Huffman, D. L., A. Z. Palmer, J. W. Carpenter and R. L. Shirley. 1961. The effect of ante-mortem injection of papain on tenderness of chickens. Poultry Sci. 40:1627.

Husaini, S. A., F. E. Deatherage, L. E. Kunkle and H. N. Draudt. 1950. Studies on meat I. The biochemistry of beef as related to tenderness. Food Tech. 4:313.

Judge, M. D., V. R. Cahill, L. E. Kunkel and F. E. Deatherage. 1960. Pork quality II. Physical, chemical, and organoleptic relationships in fresh port. J. Animal Sci. 19:145.

Karmas, Endel, J. E. Thompson and L. G. Eisen. 1963. Preliminary studies on protein and moisture relationship in fresh and processed hams. Food Tech. 17(5):153.

Kropf, D. H. and R. L. Graf. 1958. Interrelationships of subjective, chemical and sensory evaluation of beef quality. Food Tech. 13:492.

Lewis, P. K., M. C. Heck and C. J. Brown. 1963. Relationship of certain chemical and physical measurements to certain organoleptic characteristics of pork. Ark. Agr. Exp. Sta. Bul. 667.

Lowe, Belle and J. Kastelic. 1961. Organoleptic, chemical, physical and microscopic characteristics of muscles in eight been carcases, differing in age of animal, carcass grade, and extent of cooking. Iowa State Exp. Sta. Bul. 495.

McHugh, H., H. D. Naumann and V. J. Rhodes. 1959. Consumer acceptance of round steaks tenderized by cubing and papain. Mo. Agr. Exp. Res. Bul. 713.

McIntosh, E. N. 1967. Effect of post-mortem aging and enzyme tenderizers on mucoprotein of bovine skeletal muscle. J. Food Sci. 32:310.

McIntosh, E. N. and A. F. Carlin. 1963. The effect of papain preparations on beef skeletal muscle proteins. J. Food Sci. 28:283.

Means, R. H. and C. T. King. 1959. The effect of sire on tenderness of beef loin steaks as measured by a panel of families and the Warner-Bratzler shear machine. J. Animal Sci. 18:1475.

Mier, G., V. J. Rhodes, L. G. Maharg, N. S. Webb, C. Rogers, M. Mangel and R. Baldwin. 1962. Beef tenderization by proteolytic enzymes: The effects of two methods of application. Food Tech. 16:111.

Miller, A. E. 1969. A batter coated meat product. Unilever, Ltd. Canadian Patent 823 139.

Miyada, D. S. and A. L. Tappel. 1956. The hydrolysis of beef protein by various proteolytic enzymes. Food Res. 21:217.

Ritchey, S. J. 1965. The relationship of total, bound and free water and fat content to subjective scores for eating quality in two beef muscles. J. Food Sci. 30:375.

Rogers, R. W., J. D. Kemp and W. Y. Varney. 1965. Effects of enzyme addition on palatability, tenderness, and rancidity development in quick-aged country-style hams. Food Tech. 19:1950.

Romans, J. R., H. J. Tuma and W. L. Tucker. 1965. Influence of carcass maturity and marbling on the physical and chemical characteristics of beef. I. Palatability, fiber diameter and proximate analysis. J. Animal Sci. 24:681.

Satorius, M. J. and A. M. Child. 1938. Effect of coagulation on press fluid, shear force, muscle cell diameter, and composition of beef muscle. Food Res. 3:619.

Sen, D. P., N. V. Sripathy, N. L. Lahiry, A. Sreenivasan and V. Subranmanyan. 1962. Fish hydrolysates. I. Rates of hydrolysis of fish flesh with papain. Food Tech. 16:138.(as cited by Hamm, 1960).

Sherman, P. 1961. The water binding capacity of fresh pork. 3. The influence of cooking temperature on the water binding capacity of lean pork. Food Tech. 15:90.

Sosebee, M. E., K. N. May and S. C. Schmittle. 1964. The histological effects of proteolytic enzyme addition on freshly-dehydrated chicken meat. Poultry Sci. 43:553.

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

Strandine, E. J. and C. H. Koonz. 1963. Effect of ante-mortem enzyme application on the tenderness of turkeys. Poultry Sci. 42:1310.

Swift, C. E. and M. D. Berman. 1959. Factors affecting the water retention of beef. 1. Variations in composition and properties among eight muscles. Food Tech. 13:365.

Tappel, A. L., D. S. Miyada, C. Sterling and V. P. Maier. 1956. Meat tenderization. II. Factors affecting the tenderization of beef by papain. Food Res. 21:375.

Tsen, C. C. and A. L. Tappel. 1958. Meat tenderization. III. Hydrolysis of actomyosin, actin, and collagen by papain. Food Res. 24:362.

Wang, H., C. E. Weir, M. Birkner and B. Ginger. 1958. Studies on enzymatic tenderization of meat. III. histological and panel analysis of enzyme preparations from three distinct sources. Food Res. 23:423.

Wang, H. and N. Maynard. 1955. Studies on enzymatic tenderization of meat. I. Basic technique and histological observations of enzymatic action. Food Res. 20:587.

Weber, H. H. 1925. Das Kolloidale Verhalten der Muskeleiweisskorper. I. Mitt. Isoelektrischer Punkt und Stabilitatsbedingungen des Myogens. Biochem. Z. 158:443.

Wellington, G. H. and J. R. Stouffer. 1959. Beef marbling, its estimation and influence on tenderness and juiciness. Cornell Univ. N. Y. Agr. Exp. Sta. Bul. 941.

Weiner, S., M. Mangel, L. Maharg and G. G. Kelly. 1958. Effectiveness of of commerical papain in meat tenderation. Food Tech. 12:248.

Weir, C. E., H. Wang, M. L. Birkner, J. Parsons and B. Ginger. 1958. Studies on enzymatic tenderization of meat. II. Panel and histological analysis of meat treated with liquid tenderizers containing papain. Food Res. 23:411.

Wierbicki, E. and F. E. Deatherage. 1956. The effect of temperature of heating and post-mortem age on the water holding capacity and shrinkage of meat. (Abs.) Food Tech. 10:27.

Wierbicki, E., L. E. Kunkle and F. E. Deatherage. 1957. Changes in water holding capacity and cationic shifts during the heating and freezing and thawing of meat as revealed by a simple centrifugal method for measuring shrinkage. Food Tech. 11:69.

Wierbicki, E., M. G. Tiede and R. C. Burrell. 1959. Effects of pH on the water holding capacity of meat as determined by three different methods for water holding determination. Proc. Nineteenth Annual Meeting, Inst. Food. Tech.

APPENDIX

APPENDIX

SCORE SHEET FOR BEEF ROUND STEAKS AND PORK LOIN STEAKS

Name ______________________ Date ______________________

Scoring System: Reference = 0. Give "0" score to any sample equivalent to reference.

+ 3 Very much better than reference
+ 2 Better than reference
+ 1 Slightly better than reference
0 Reference
- 1 Slightly inferior to reference
- 2 Inferior to reference
- 3 Very inferior to reference

Sample Number	Ref.				
Flavor					
Tenderness					
Appearance Uncooked Sample					
Appearance Cooked Sample					

Rank according to preference, including the reference sample. More than one sample may have the same rank.

First choice ______________________

Second choice ______________________

Third choice ______________________

Fourth choice ______________________

Fifth choice ______________________

Which attribute influenced your choice?

TABLE XVI

MEANS AND STANDARD DEVIATIONS OF THE SENSORY CHARACTERISTICS OF GRILLED BATTERED BEEF STEAKS

Sensory Attribute	Batter Level (%)	Mean[a]	Standard Deviation ±
Flavor	0	-0.86	1.74
	5	0.81	1.30
	10[b]	--	--
	15	0.50	1.13
	20	0.72	1.45
Tenderness	0	0.61	1.56
	5	1.11	1.34
	10[b]	--	--
	15	1.09	1.31
	20	0.94	1.57
Uncooked Appearance	0	-0.25	1.87
	5	-1.06	1.43
	10[b]	--	--
	15	0.22	1.27
	20	0.11	1.86
Cooked Appearance	0	0.28	0.96
	5	0.50	0.94
	10[b]	--	--
	15	0.33	1.12
	20	0.44	1.13
Overall Preference[c]	0	-0.66	0.74
	5	0.33	1.11
	10	-0.20	0.64
	15	0.27	0.63
	20	0.21	0.79

[a]Mean of 36 observations, each scored on a numerical scale of -3 to +3 with +3 being most desirable.

[b]The 10 percent battering level was used as the reference and scored 0 in all sensory evaluations.

[c]Preference values were converted to scores for ranked data (Fisher and Yates, 1948).

TABLE XVII

MEANS AND STANDARD DEVIATIONS OF THE SENSORY CHARACTERISTICS OF DEEP FAT FRIED BATTERED BEEF STEAKS

Sensory Attribute	Batter Level (%)	Mean[a]	Standard Deviation ±
Flavor	0	-1.89	0.85
	5	0.22	1.22
	10[b]	--	--
	15	0.44	1.18
	20	-0.14	1.50
Tenderness	0	-1.64	1.48
	5	0.64	1.51
	10[b]	--	--
	15	0.89	1.09
	20	0.64	1.42
Uncooked Appearance	0	-0.06	1.17
	5	0.36	1.64
	10[b]	--	--
	15	0.17	1.16
	20	0.28	0.97
Cooked Appearance	0	-0.75	1.30
	5	-0.47	0.84
	10[b]	--	--
	15	-0.44	0.84
	20	0.56	1.58
Overall Preference[c]	0	-1.00	0.34
	5	0.20	0.69
	10	0.20	0.72
	15	0.36	0.66
	20	0.26	0.62

[a]Mean of 36 observations, each scored on a numerical scale of -3 to +3 with +3 being most desirable.

[b]The 10 percent battering level was used as the reference and scored 0 in all sensory evaluations.

[c]Preference values were converted to scores for ranked data (Fisher and Yates, 1948.

TABLE XVIII

MEANS AND STANDARD DEVIATIONS OF THE SENSORY CHARACTERISTICS OF GRILLED BATTERED PORK LOIN STEAKS

Sensory Attribute	Batter Level (%)	Mean[a]	Standard Deviation ±
Flavor	0	-0.86	0.96
	5	0.44	1.48
	10[b]	--	--
	15	0.78	1.31
	20	0.31	1.14
Tenderness	0	-1.25	1.13
	5	0.58	1.13
	10[b]	--	--
	15	0.64	1.15
	20	0.72	1.09
Uncooked Appearance	0	0.50	1.21
	5	-0.50	1.38
	10[b]	--	--
	15	0.33	1.01
	20	0.28	1.01
Cooked Appearance	0	-0.06	1.53
	5	0.22	1.27
	10[b]	--	--
	15	0.58	1.02
	20	0.64	0.95
Overall Preference[c]	0	-0.74	0.53
	5	0.11	0.83
	10	0.17	0.50
	15	0.55	0.66
	20	0.16	0.64

[a]Mean of 36 observations, each scored on a numerical scals of -3 to +3 with +3 being most desirable.

[b]The 10 percent battering level was used as the reference and scored 0 in all sensory evaluations.

[c]Preference values were converted to scores for ranked data (Fisher and Yates, 1948).

TABLE XIX

MEANS AND STANDARD DEVIATIONS OF THE SENSORY CHARACTERISTICS OF DEEP FAT FRIED BATTERED PORK LOIN STEAKS

Sensory Attribute	Batter Level (%)	Mean[a]	Standard Deviation ±
Flavor	0	-1.50	1.23
	5	-0.11	1.45
	10[b]	--	--
	15	-0.03	1.40
	20	-0.03	1.16
Tenderness	0	-0.86	1.18
	5	0.22	1.17
	10[b]	--	--
	15	0.78	1.12
	20	1.00	1.10
Uncooked Appearance	0	0.14	1.24
	5	-0.19	1.17
	10[b]	--	--
	15	0.36	1.35
	20	0.36	0.93
Cooked Appearance	0	-0.14	1.40
	5	-0.03	1.08
	10[b]	--	--
	15	0.14	1.35
	20	0.53	1.08
Overall Preference[c]	0	-0.84	0.43
	5	0.14	0.81
	10	0.35	0.60
	15	0.27	0.57
	20	0.38	0.93

[a]Mean of 36 observations, each scored on a numerical scale of -3 to +3 with +3 being most desirable.

[b]The 10 percent battering level was used as the reference and scored 0 in all sensory evaluations.

[c]Preference values were converted to scores for ranked data (Fisher and Yates, 1948).

TABLE XX

MEANS AND STANDARD DEVIATIONS OF THE PROXIMATE ANALYSIS COMPONENTS OF GRILLED BATTERED BEEF STEAKS

Component[a]	Batter Level (%)	Mean	Standard Deviation ±
Moisture	0	63.83	1.38
	5	65.91	0.05
	10	67.03	1.30
	15	65.58	1.51
	20	65.16	0.58
Fat	0	3.09	0.24
	5	3.03	0.10
	10	2.34	0.27
	15	2.69	0.17
	20	3.48	0.56
Protein	0	30.17	1.66
	5	25.40	0.93
	10	25.59	1.81
	15	26.91	2.56
	20	24.73	0.61
Ash	0	1.17	0.21
	5	1.39	0.21
	10	1.23	0.16
	15	1.23	0.21
	20	1.24	0.20

[a]Proximate analysis was conducted according to A.O.A.C. procedures, 1965.

TABLE XXI

MEANS AND STANDARD DEVIATIONS OF THE PROXIMATE ANALYSIS COMPONENTS OF DEEP FAT FRIED BATTERED BEEF STEAKS

Component[a]	Batter Level (%)	Mean	Standard Deviation ±
Moisture	0	59.39	0.42
	5	59.86	3.30
	10	60.69	3.10
	15	61.17	2.13
	20	62.49	1.72
Fat	0	5.96	0.32
	5	5.47	1.24
	10	4.33	1.75
	15	5.76	0.32
	20	6.77	1.12
Protein	0	31.91	0.17
	5	29.56	2.96
	10	28.68	2.42
	15	27.47	0.71
	20	27.43	0.69
Ash	0	1.11	0.16
	5	1.42	0.05
	10	1.39	0.05
	15	1.23	0.10
	20	1.26	0.06

[a]Proximate analysis was conducted according to A.O.A.C. procedures, 1965.

TABLE XXII

MEANS AND STANDARD DEVIATIONS OF THE PROXIMATE ANALYSIS COMPONENTS OF UNCOOKED BATTERED BEEF STEAKS

Component[a]	Batter Level (%)	Mean	Standard Deviation ±
Moisture	0	75.78	0.62
	5	73.85	1.58
	10	73.98	1.30
	15	75.77	0.79
	20	76.76	1.07
Fat	0	1.94	0.12
	5	2.16	0.74
	10	1.84	0.76
	15	1.67	0.73
	20	1.77	0.43
Protein	0	19.90	0.69
	5	19.46	2.06
	10	18.91	0.45
	15	16.92	0.70
	20	16.77	0.64
Ash	0	0.96	0.17
	5	1.11	0.17
	10	0.97	0.19
	15	0.93	0.20
	20	0.84	0.12

[a]Proximate analysis was conducted according to A.O.A.C. procedures, 1965.

TABLE XXIII

MEANS AND STANDARD DEVIATIONS OF THE PROXIMATE ANALYSIS COMPONENTS OF GRILLED BATTERED PORK LOIN STEAKS

Component[a]	Batter Level (%)	Mean	Standard Deviation ±
Moisture	0	52.94	1.68
	5	54.97	2.29
	10	57.27	2.67
	15	56.96	2.21
	20	57.34	1.26
Fat	0	11.22	1.27
	5	10.00	0.51
	10	9.19	2.63
	15	9.84	1.74
	20	11.15	1.10
Protein	0	33.45	0.82
	5	27.09	1.98
	10	28.58	1.71
	15	26.06	0.53
	20	25.69	1.56
Ash	0	1.45	0.10
	5	1.41	0.21
	10	1.35	0.35
	15	1.28	0.10
	20	1.22	0.32

[a]Proximate analysis was conducted according to A.O.A.C. procedures, 1965.

TABLE XXIV

MEANS AND STANDARD DEVIATIONS OF THE PROXIMATE ANALYSIS COMPONENTS OF DEEP FAT FRIED BATTERED PORK LOIN STEAKS

Component[a]	Batter Level (%)	Mean	Standard Deviation ±
Moisture	0	51.75	1.00
	5	51.76	1.72
	10	51.74	1.02
	15	55.24	1.00
	20	56.66	0.82
Fat	0	11.92	0.95
	5	11.51	2.36
	10	10.95	2.40
	15	12.19	0.69
	20	10.47	0.89
Protein	0	34.31	1.33
	5	29.71	0.81
	10	30.19	2.14
	15	26.45	0.56
	20	27.34	1.10
Ash	0	0.68	0.21
	5	0.75	0.10
	10	0.10	0.10
	15	0.80	0.10
	20	0.75	0.12

[a]Proximate analysis was conducted according to A.O.A.C. procedures, 1965.

TABLE XXV

MEANS AND STANDARD DEVIATIONS OF THE PROXIMATE ANALYSIS COMPONENTS OF UNCOOKED BATTERED PORK LOIN STEAKS

Component[a]	Batter Level (%)	Mean	Standard Deviation ±
Moisture	0	68.32	0.94
	5	65.53	0.81
	10	66.98	1.84
	15	69.44	0.35
	20	70.49	2.55
Fat	0	8.65	1.30
	5	8.57	1.22
	10	8.29	2.55
	15	7.34	0.88
	20	7.61	1.29
Protein	0	21.73	0.35
	5	19.46	1.19
	10	20.06	1.69
	15	18.31	1.15
	20	17.34	1.79
Ash	0	1.02	0.26
	5	0.93	0.24
	10	0.83	0.14
	15	0.82	0.24
	20	0.79	0.24

[a]Proximate analysis was conducted according to A.O.A.C. procedures, 1965

VITA

Robert Milton Reeves, Jr. was born in Memphis, Tennessee, on November 10, 1945, where he lived for one year before moving to Brownsville, Tennessee. He attended elementary school in that city and was graduated from Haywood County High School in 1963. The following September he entered the University of Tennessee, and in August, 1967, he received a Bachelor of Science degree in Agriculture.

He entered the Graduate School at the University of Tennessee in September, 1968, and studied for one year before entering the U. S. Naval Reserve for two years. Upon returning from Military Service, he married the former Susan Read of Brownsville, Tennessee, in June, 1970. He re-entered the Graduate School that summer and received the Master of Science degree in August, 1971.