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To the Graduate Council:

I am submitting herewith a thesis written by Eleanor Marguerite Pratt entitled "Tenderness of Beef as Affected by Variations in Time and Temperature of Application of a Meat Tenderizer." 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 Foods and Institutional Management.

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TENDERNESS OF BEEF AS AFFECTED BY VARIATIONS IN TIME AND
TEMPERATURE OF APPLICATION OF A MEAT TENDERIZER

A Thesis

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the Graduate Council of
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Master of Science

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E. M. P.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
II. REVIEW OF THE LITERATURE	4
Tenderization of Meat by Papain	4
Mode of Action	4
Optimum Temperature for Digestion of Meat by Papain . . .	5
Penetration of Papain into Meat	6
Time and Temperature of Precooking Holding-Period	6
Effect of Tenderizers Containing Papain on Other	
Sensory Qualities	8
Flavor	8
Juiciness	8
Effect of Tenderizer Containing Papain on Cooking Time . .	8
Effect of Tenderizers Containing Papain on Cooking Losses .	9
Proteolytic Activity of Papain in Comparison to	
Other Protein-Digesting Enzymes	10
III. PROCEDURE	11
Design of the Study	11
Cuts of Beef Used	13
Application of the Tenderizer	14
Cooking Methods	14
Sensory-Difference Tests	15
Shear Tests	16
Analysis of Data	16

CHAPTER	PAGE
IV. RESULTS	17
Comparison of Three Brands of Tenderizers	17
Sensory Tests	17
Flavor and juiciness	17
Tenderness	17
Shear Values	19
Effect of Variations in Length of Precooking	
Holding-Period on Steaks and Roasts	19
Sensory Tests	19
Flavor and juiciness	19
Tenderness	21
Shear Values	21
Effect of Variations in Temperature of Precooking	
Holding-Period on Steaks and Roasts	22
Sensory Tests	22
Flavor and juiciness	22
Tenderness	22
Shear Values	22
Cooking Losses	24
Discussion	24
V. SUMMARY	27
Principal Findings	27
Conclusion	28
BIBLIOGRAPHY	30

LIST OF TABLES

TABLE	PAGE
I. Flavor, Juiciness, and Tenderness of Round Steaks and Roasts Treated with Three Brands of Tenderizers	18
II. Effect of Variations in Length of Precooking Holding-Period on Flavor, Juiciness, and Tenderness of Round Steaks and Roasts Treated with a Tenderizer	20
III. Effect of Variations in Temperature of Precooking Holding- Period on Flavor, Juiciness, and Tenderness of Round Steaks and Roasts Treated with a Tenderizer	23
IV. Average Cooking Losses for Steaks and Roasts (in per cent)	25

CHAPTER I

INTRODUCTION

In recent years there has been considerable interest in the use of proteolytic enzymes for the tenderization of meat. Ziembra (13) reported that enzyme sales in 1957 amounted to \$10 million and that over two-thirds of this amount represented sales to homemakers. In spite of an increased use of tenderizers, there has been relatively little investigation of these preparations under home conditions. It seemed desirable, therefore, to compare the effectiveness of the various meat tenderizers containing a proteolytic enzyme which are available to the homemaker in the Knoxville retail market.

Studies (6, 8, 9, 10) have shown that proteolytic enzymes of plant, animal, and microbiological origin are effective in tenderizing meat. The most commonly used enzyme in meat-tenderization preparations, however, is papain which is of plant origin (2). A limited investigation of the Knoxville retail market revealed that there were 3 brands of unseasoned meat tenderizers available to the homemaker. Each of these 3 brands contained the proteolytic enzyme papain as the tenderizing agent.

Papain is obtained from the ripe fruit of the tropical pawpaw or melon tree, known as the Carica papaya, which is cultivated extensively in Ceylon and in British East Africa. Natives of the tropical countries have found many uses for the various parts of the papaya tree. The ripe fruit is used as a breakfast fruit, as a dessert, or in fruit cocktail. The juice of the ripe papaya is used as a drink or in jellies. The seeds

can be used as a condiment. The green fruits are baked, boiled, or stewed and served as a vegetable. The bark of the tree is used in the manufacture of rope. And it is from the latex of the ripe fruit that the enzyme papain is obtained. This enzyme resembles pepsin and trypsin in its digestive action on proteins (1).

Manufacturers of meat tenderizers containing papain usually recommend letting meat stand at room temperature after applying the tenderizer. The recommended time is 30 minutes for all cuts up to 1-inch thick or 1 hour for all cuts 1-inch or thicker. It would appear, therefore, that the precooking holding-period is related to the effectiveness of the meat tenderizers. A review of literature on studies concerned with this phase of enzyme tenderization shows that the effect of such a period after application of the tenderizer is controversial. More research, therefore, on the effectiveness of these meat tenderizers with respect to time and temperature of the precooking holding-periods seemed appropriate.

In the present study the effects of 3 meat tenderizers containing the proteolytic enzyme papain in powdered form, found in the Knoxville retail market, were compared. The effect of the tenderizers on flavor, juiciness, and tenderness of steaks and roasts cooked by dry-heat methods was investigated. One of the 3 meat tenderizers was then used to study the effect of increases in length of the precooking holding-period and of variations in temperature of the precooking holding-period on flavor, juiciness, and tenderness.

Tenderness was determined by sensory-difference tests, using a

panel of 6 judges, and by measuring shear values of representative samples of the meat. Flavor and juiciness were also scored by the panel.

The objective in using meat tenderizers is to increase the tenderness of lower grades of beef to the extent of making them more acceptable for public consumption (2). If less-tender cuts of meat, ordinarily cooked by moist-heat methods of cookery, could be cooked satisfactorily by dry-heat through the application of a tenderizer, variety would be added to the meals of low-income families who cannot afford the more expensive cuts of meat. This could even be a step in the direction of equalizing the price of all cuts of beef.

CHAPTER II

REVIEW OF THE LITERATURE

Centuries ago the natives of tropical and subtropical areas around the world discovered that tenderization could be accomplished by boiling meat with papaya fruit or by wrapping it with papaya leaves (2). These natives were familiar with the empirical application of papain to tenderize meat, but it was not until 1942 that the use of papain for tenderization purposes was studied quantitatively. At that time, Gottschall and Kies (3) did a study to estimate the importance of several factors which affect the proteolytic action of the enzyme. They pointed out that proteolytic activity depends upon such factors as optimum temperature; stability of papain at cooking temperatures in the presence of meat; extent of contact between the enzyme and the meat; ability of papain to penetrate the meat during digestion; and digestibility of the native compared with the heat-denatured proteins.

I. TENDERIZATION OF MEAT BY PAPAIN

Mode of Action

Papain induces tenderness in meat by means of protein breakdown. As explained by Weiner, Mangel, Maharg, and Kelly (11), the muscle fiber proteins, mainly actomyosin, are broken apart by the activity of the proteolytic enzyme. They stated that tenderization is also effected to some extent by hydrolysis of collagen and elastin, the connective tissues of meat.

In a comparison of the hydrolysis of actomyosin, actin, and collagen by papain, Tsen and Tappel (8) showed that hydrolysis of actomyosin proceeded faster than that of actin or collagen.

Optimum Temperature for Digestion of Meat by Papain

Gottschall and Kies (3) followed papain digestion of beef by measuring the blue color which the nonprotein digestion products give with Folin-Ciocalteu phenol reagent after precipitation of the proteins with tricholoacetic acid. The survival of papain when heated with meat under various conditions was also studied. They found that papain withstands a higher temperature than most enzymes without being inactivated. Results of their experiments showed that meat digestion by papain was very slow at room temperature but extensive and rapid at 55° and 75° C. At 100° C., however, papain was rapidly destroyed in the presence of meat so that there was very little digestion above 100° C.

These findings were confirmed in a later study on papain by Tappel, Miyada, Sterling, and Maier (7). They showed that the reaction transforming soluble proteins of beef biceps femoris muscle into amino acids was great at 60° and 80° C. compared with the lower temperature of 20° C. Also, hydrolysis of both elastin and collagen by papain was greatest at 60° C.

A study of the relative efficiency of 4 pure papains and 14 tenderizers containing papain by Weiner et al. (11), using both milk clotting and beef digestion methods, showed that as the temperature increased, the activity of the enzyme preparations increased over the

range studied. At 80° C. there was demonstrable activity even with those preparations which were completely inactive at 40° C.

Penetration of Papain into Meat

Two recent studies have shown that one of the problems in the use of proteolytic enzymes to tenderize meat is to obtain sufficient penetration of the tenderizer into the meat. These studies suggested that mere surface treatment with papain is ineffective and that precooking holding-periods are not advantageous.

Using histological techniques to study the penetration of papain into meat at room temperature, Tappel et al. (7) found no evidence of enzymatic activity after 3 hours of exposure to a thick layer of papain powder. Further evidence of the limitations of papain penetration was obtained from their dye tracer studies which showed that penetration into beef was limited to 2.0 mm. at temperatures ranging from 39° to 55° C.

Wang and Maynard (9), also using histological techniques, found limited penetration of the enzymes, papain and Rhozyme, when applied by either powdering or immersion methods to raw fresh semitendinosus muscle of beef. Penetration of the enzymes into the tissue was less than 1 mm. from the surface in 1 hour.

Time and Temperature of Precooking Holding-Period

Even though Tappel et al. (7) found no histological evidence of penetration of papain into beef after exposure for 3 hours at room temperature, there was a significant difference between the tenderness of papain-treated samples and that of untreated controls. There were no

significant differences, however, between samples held for 1 and 5 hours before cooking and the samples cooked immediately. They concluded that the effective tenderization must have occurred during the cooking period.

Hay, Harrison, and Vail (5) found that a powdered commercial tenderizer containing papain was effective in increasing the tenderness of all steaks and roasts treated at room temperature; however, untreated roasts were more tender than treated roasts held in the refrigerator for 18 hours. Since the enzyme was forked into the meat, forking may have introduced some tenderization in addition to that brought about by action of the tenderizer. The degree to which the forking was effective in increasing tenderness is not known because there was no sample which was forked and not treated with tenderizer.

Weir, Wang, Birkner, Parsons, and Ginger (12) used a liquid commercial meat tenderizer containing papain for treating steaks prior to freezing. They found that the extent of tenderization produced by the enzyme preparation was not influenced by freezing but was influenced markedly by temperature at which the steaks were thawed. Steaks thawed at room temperature of 70° F. for 2 hours were much more tender than those thawed for 18 hours in a 40° F. refrigerator. This was in agreement with the earlier work of Hay, Harrison, and Vail (4) on steaks. Studies by Gottschall and Kies (2), Tappel et al. (7), and Weiner et al. (11) showed, however, that the optimum temperature for papain activity is higher than room temperature.

II. EFFECT OF TENDERIZERS CONTAINING PAPAIN ON OTHER SENSORY QUALITIES

Flavor

Hay, Harrison, and Vail (5) reported very little difference in flavor scores for the treated and untreated meat used in their study. Analysis of variance of the flavor scores showed no significant difference due to treatment. The average flavor scores indicated preference for steaks treated with tenderizer and for untreated roasts.

Juiciness

The untreated cuts tested by Hay, Harrison, and Vail (5) received higher average juiciness scores than those treated with tenderizer except the braised steaks which were scored the same for both treatments. The authors pointed out that the treated meat may have seemed less juicy because it appeared to be more well-done than the untreated meat.

Griswold (4) reported that either a commercial papain preparation or a laboratory-prepared mixture containing papain, when forked thoroughly into the meat and allowed to stand 30 minutes, made the meat more tender but less juicy than meat braised by a standard method. This finding is in agreement with that of Hay, Harrison, and Vail (5).

III. EFFECT OF TENDERIZER CONTAINING PAPAIN ON COOKING TIME

Hay, Harrison, and Vail (5) found that the cooking time per pound of broiled and braised steaks and of roasts treated with a tenderizer

was less than for the untreated steaks or roasts. When cooked for the same length of time, the treated pan-fried steaks appeared to be more well-done than the untreated steaks. When cooked to the same internal temperature, treated broiled, braised, and roasted cuts appeared well-done, whereas untreated cuts appeared medium-done. The authors pointed out that the shorter cooking time of treated cuts may have resulted from a faster rate of heat penetration due to the breakdown of the muscle of meat that was forked when treated with the tenderizer.

IV. EFFECT OF TENDERIZERS CONTAINING PAPAIN ON COOKING LOSSES

Average percentage cooking losses as determined by Hay, Harrison, and Vail (5) were less for broiled and pan-fried round steaks treated with a tenderizer containing papain than for untreated cuts. The lower cooking losses for the treated broiled round steaks may have been due to the slightly shorter cooking time required for these steaks. Treated and untreated pan-fried steaks, however, were cooked the same length of time. In contrast, untreated braised round steaks, pan-fried sirloin tip steaks, and rump roasts lost less weight during cooking than treated cuts. When analyzed statistically, none of the differences in cooking losses between treated and untreated cuts were significant.

Weir et al. (12) found that use of a tenderizer solution containing papain did not affect the weight loss of ribeye steaks during cooking.

V. PROTEOLYTIC ACTIVITY OF PAPAIN IN COMPARISON TO OTHER PROTEIN-DIGESTING ENZYMES

The enzyme papain has been used extensively in meat tenderizers for both home and commercial use. Recent studies, however, have shown that many other enzymes also possess the proteolytic activity required for meat tenderization.

As an integral part of the investigations on papain and meat tenderization being conducted by Miyada and Tappel (6), the relative merits of a number of proteolytic enzymes have been studied. An overall evaluation of the results indicated that bromelin, ficin, trypsin, papain, and Rhozyme P-11 are all powerful proteolytic enzymes which merit further attention as potential meat tenderizers. The authors pointed out that a definite recommendation for the use of one of these 5 enzymes over the others could not be made on the basis of the research to date. Work done by Tsen and Tappel (8) showed that these same enzymes readily hydrolyzed actomyosin.

Wang and Maynard (9) found that papain and Rhozyme had very similar effects on muscle tissue components. Both attack muscle fiber protein but do not affect collagenous and elastic fibers at room temperature.

In a study by Wang, Weir, Birkner, and Ginger (10), enzyme preparations of 3 different origins were used. Only enzymes of plant origin (ficin, papain, and bromelin) disintegrated muscle fibers as well as collagen and elastin. "Microbial and fungal enzymes (Rhozyme P-11 and fungal amylase) affected principally" the muscle fibers.

CHAPTER III

PROCEDURE

The 3 brands of tenderizers used in this study were purchased in the Knoxville retail market. All 3 tenderizers were unseasoned and contained the proteolytic enzyme papain as the active ingredient.

The recommendation usually made by manufacturers of tenderizers containing papain is to let the treated meat stand at room temperature for 30 minutes for all cuts up to 1-inch thick or 1 hour for all cuts 1-inch or thicker. The principal objective in this study was to evaluate these directions in terms of length of time the tenderizer is on the meat and the temperature at which the meat is held after treatment. All tests were replicated 2 times.

I. DESIGN OF THE STUDY

In the first part of the study, 3 brands of meat tenderizers containing the proteolytic enzyme papain were used to study the comparative effects of these tenderizers when applied as generally directed by the manufacturers. The time of the precooking holding-period was 30 minutes for steaks and 1 hour for roasts. During this time, the meat was held at room temperature of 68° to 72° F. (20° to 22° C.).

In the second part of the study, Brand No. 1 tenderizer was used to determine if the length of the precooking holding-period affected the amount of tenderization. With the temperature of the meat remaining constant at approximately 68° to 72° F. (20° to 22° C.), the variations

in precooking holding time were as follows:

Steaks

1. Control, untreated, held 30 minutes
2. No holding-period, treated with tenderizer
3. 30-minute holding-period, treated with tenderizer
4. 1-hour holding-period, treated with tenderizer

Roasts

1. Control, untreated, held 1 hour
2. No holding-period, treated with tenderizer
3. 1-hour holding-period, treated with tenderizer
4. 2-hour holding-period, treated with tenderizer

In the third phase of the study, Brand No. 1 tenderizer was used to determine if the amount of tenderization could be increased by increasing the temperature of the precooking holding-period. With the time of the precooking holding-period remaining constant at 30 minutes for steaks and 1 hour for roasts, variations in temperature of the precooking holding-period for both steaks and roasts were as follows:

1. Control, untreated, held at room temperature
2. Room temperature, treated with tenderizer
3. Incubator temperature of 98° F. (36.5° C.), treated with tenderizer
4. Warming oven temperature of 163° F. (73° C.), treated with tenderizer

During the precooking holding-period, both the untreated controls and the treated steaks and roasts held at room temperature maintained an internal temperature of 68° to 72° F. (20° to 22° C.). The treated

steaks held in the 98° F. (36.5° C.) incubator for 30 minutes reached an internal temperature of 75° to 79° F. (24° to 26° C.) and the treated roasts held in the incubator reached an internal temperature of 79° F. (26° C.). With the thermostat set at 150° F. (66° C.), the warming oven temperature ranged from 147° to 187° F. (64° to 86° C.) and averaged 163° F. (73° C.). Under this condition, the internal temperature of the treated steaks at the end of 30 minutes was 93° to 100° F. (34° to 38° C.), and the internal temperature of the treated roasts at the end of 1 hour was 97° to 102° F. (36° to 39° C.).

II. CUTS OF BEEF USED

Steaks and roasts used in this study were taken from the left and right rounds of the same carcass which was purchased in the wholesale market. The beef was graded U. S. Good and had been aged for 7 days. The rounds were separated into component muscles to prepare steaks and roasts for this study. The steaks and roasts from the left and right sides of the carcass were cut as pairs. Two adjacent pairs from the same position on each side constituted the 4 samples for each replication. The steaks were cut three-fourths inch thick, and the roasts were cut 2 inches thick on a commercial meat slicer.

The same muscle was used for both replications of each test. The top round muscle was used for the steaks and roasts to compare the 3 brands of tenderizers. The bottom round muscle was used for steaks and roasts to test variations in length of the precooking holding-period. The tip muscle was used for the steaks whereas the eye muscle was used for the

roasts to test variations in temperature of the precooking holding-period.

Each cut of meat was wrapped in a waxed freezer paper, frozen in a blast freezer at -15° F. (-26° C.) and stored at 0° F. (-18° C.) until it was used. The meat was tested within a 3-month period.

III. APPLICATION OF THE TENDERIZER

In all cases a weighed amount of tenderizer equivalent to one-half teaspoon of tenderizer per pound of meat was applied. Since salt had been incorporated in the tenderizers, the untreated cut of meat in each test was given an application of salt. A weighed amount of salt equivalent to 50 per cent of the weight of the tenderizers was used. One-half of the weighed amount of the tenderizer or salt was sprinkled over each side of the steaks and roasts. After applying the tenderizer, the meat was forked; that is, it was pierced 50 times on each side with the tines of a fork. The untreated cuts were also forked after an application of salt so any tenderization caused by forking would be uniform on the 4 samples used in each test.

IV. COOKING METHODS

All steaks and roasts for the 3 phases were thawed and allowed to reach room temperature of 68° to 72° F. (20° to 22° C.) before applying the tenderizer or, in the case of the control cut, before applying the salt. In all 3 phases of the experiment, steaks were cooked by broiling and the roasts were oven roasted by dry heat.

Steaks. The steaks were placed on a wire rack in a shallow pan

after the tenderizer or salt had been applied. As soon as the holding-period was complete, the steaks were broiled in electric ovens of 30-inch household ranges. The ovens were preheated for 20 minutes at 425° F. (218° C.) with doors closed. Just prior to putting the steaks into the ovens, the controls were turned to the "Broil" position. The 4 steaks required for each replication were broiled simultaneously by placing 2 steaks in each of 2 ovens. Broiling was done with the oven doors left ajar in the position set for broiling. The steaks were cooked on one side to an internal temperature of 122° F. (50° C.), then turned and allowed to continue cooking to an internal temperature of 158° F. (70° C.), approximately medium-done stage. The steaks were weighed immediately upon removal from the oven to determine cooking losses.

Roasts. A revolving-hearth Despatch oven was used to cook the roasts. It was preheated for 30 minutes to reach a temperature of 300° F. (149° C.). During the entire cooking period, the temperature was held constant at 300° F. (149° C.). The roasts were placed on a wire rack in a shallow pan after application of either the tenderizer or the salt. Cooking was started upon completion of the precooking holding-period. The roasts were allowed to cook until an internal temperature of 154° F. (68° C.) was reached. They were then cooled at room temperature for 10 minutes to allow for any temperature rise before weighing to determine cooking losses.

V. SENSORY-DIFFERENCE TESTS

A panel of 6 judges experienced in scoring beef scored the meat for flavor, juiciness, and tenderness. The panel was composed of 3 men

and 3 women, and the same judges served throughout the study.

Scoring was done on a 9-point scale with the points defined as follows:

<u>For flavor and juiciness</u>	<u>For tenderness</u>
9 - Excellent	9 - Exceedingly tender
8 - Very good	8 - Very tender
7 - Good	7 - Tender
6 - Fair plus	6 - Slightly tender
5 - Fair	5 - Neither tender nor tough
4 - Fair minus	4 - Slightly tough
3 - Poor	3 - Tough
2 - Very poor	2 - Very tough
1 - Extremely poor	1 - Exceedingly tough

The order of presentation of samples was randomized for each replication.

The samples for each panel member were cut from the same locations of each steak or roast.

VI. SHEAR TESTS

Shear values for both steaks and roasts were measured by the Warner-Bratzler shearing apparatus, using cores of one-half inch diameter cut parallel to the muscle fibers. For each sample of meat, 8 shear values were averaged.

VII. ANALYSIS OF DATA

Simple averages were used for evaluating the data on flavor and juiciness. To evaluate the tenderness data, the standard error of difference between means was calculated for panel scores and shear values to have a basis for determining if the tenderness induced by the tenderizer treatments was significant.

CHAPTER IV

RESULTS

I. COMPARISON OF THREE BRANDS OF TENDERIZERS

Sensory Tests

Average panel scores for flavor, juiciness, and tenderness of round steaks and roasts treated with the 3 brands of tenderizers are shown in Table I. Shear measurements of tenderness are also shown in this table.

Flavor and juiciness. There was very little difference in the flavor and juiciness scores of treated and untreated steaks and roasts. No statistical analysis of the data was made. Inspection of the data does not seem to indicate that there was any consistent difference in flavor and juiciness of meat treated with the 3 brands of tenderizers or between tenderizer-treated cuts and untreated controls.

Tenderness. All treated steaks had higher average tenderness scores than untreated controls. When analyzed statistically, steaks treated with Brands No. 1 and No. 2 were significantly more tender than Brand No. 3 or the untreated control. The difference between tenderness scores of steaks treated with Brands No. 1 and No. 2 was not significant.

All treated roasts were scored as being more tender than the untreated controls. Tenderness scores of roasts treated with Brands No. 1 and No. 3 were significantly higher than the untreated controls. The difference between scores for Brand No. 2 and the control was not

TABLE I

FLAVOR, JUICINESS, AND TENDERNESS OF ROUND STEAKS AND ROASTS
TREATED WITH THREE BRANDS OF TENDERIZERS

Treatment	Flavor	Juiciness	Tenderness	
	Panel score	Panel score	Panel score	Shear in lbs.
<u>Steaks</u>				
Control, no tenderizer	7.4	6.9	5.3	4.2
Brand No. 1	7.2	6.9	7.5***	2.8*
Brand No. 2	7.0	6.6	8.1***	3.3
Brand No. 3	7.7	7.3	5.9	3.8
<u>Roasts</u>				
Control, no tenderizer	7.6	7.3	6.9	3.6
Brand No. 1	7.4	7.3	8.0*	3.1
Brand No. 2	6.8	6.4	7.5	2.9
Brand No. 3	7.8	7.2	8.0**	3.3

NOTE: The panel scores for flavor, juiciness, and tenderness are an average of 12 judgments; the shear values for tenderness are an average of 16 measurements.

- * Significantly different from control at P. 0.05
- ** Significantly different from control at P. 0.01
- *** Significantly different from control at P. 0.001

significant. Differences between brands were not significant even though roasts treated with 2 brands scored significantly higher than the controls.

Shear Values

All 3 treated samples of steaks and roasts had lower average shear values than the untreated controls which indicated that samples receiving a tenderizer treatment were somewhat more tender. However, only for steaks treated with Brand No. 1 was this difference significant. The shear values did not give as precise information about tenderness as panel scores. There was a wider range of values within the 16 shear measurements than within the 12 scores of the panel.

II. EFFECT OF VARIATIONS IN LENGTH OF PRECOOKING HOLDING-PERIOD ON STEAKS AND ROASTS

Sensory Tests

Average scores for flavor, juiciness, and tenderness of both steaks and roasts treated with Brand No. 1 tenderizer for various lengths of time are shown in Table II. Shear values for tenderness are also shown in this table.

Flavor and juiciness. Average flavor and juiciness scores for both treated and untreated steaks are very close. Data gave no indication that the flavor or juiciness of the steaks was affected by the length of time that the steaks were held at room temperature after application of the tenderizer. There was also very little difference in the flavor and

TABLE II

EFFECT OF VARIATIONS IN LENGTH OF PRECOOKING HOLDING-PERIOD
ON FLAVOR, JUICINESS, AND TENDERNESS OF ROUND STEAKS
AND ROASTS TREATED WITH A TENDERIZER

Holding-period	Flavor	Juiciness	Tenderness	
	Panel score	Panel score	Panel score	Shear in lbs.
<u>Steaks</u>				
Control, no tenderizer	7.4	7.2	5.4	7.0
None	7.2	6.8	7.1*	6.5
30 minutes	7.4	7.1	7.0*	5.4
1 hour	7.2	7.1	6.9*	6.1
<u>Roasts</u>				
Control, no tenderizer	7.7	7.4	6.8	4.5
None	7.5	6.8	7.4	3.9
1 hour	7.3	6.7	7.4	6.0*
2 hours	6.9	7.3	7.7	3.9

NOTE: The panel scores for flavor, juiciness, and tenderness are an average of 12 judgments; the shear values for tenderness are an average of 16 measurements.

* Significantly different from control at P. 0.05

juiciness scores of the treated and untreated roasts, but a tendency for the flavor scores of the roasts to decrease as the precooking holding-period increased was noted.

Tenderness. All treated steaks were scored as being significantly more tender than the untreated controls. All treated roasts were scored slightly more tender than untreated controls, but the differences were not significant. Differences in the tenderness scores between the 3 holding periods were not significant for either steaks or roasts; therefore, the sensory data do not indicate that increasing the length of the precooking holding-period had any significant effect upon tenderization of steaks or roasts by papain under the conditions of this study.

Shear Values

Differences in tenderness between treated and untreated meat as measured by shear values were not as large as differences in tenderness when measured by the taste panel. All treated steaks had lower average shear values than the control cuts which indicated that the tenderizer effected some tenderization, but in no case was the difference significant. Roasts treated immediately before cooking and 2 hours before cooking sheared more tender than the control, but again the difference was not significant. The roasts treated for 1 hour sheared less tender than the control. This was the only case where the tenderizer seemed to make no improvement in tenderness. No reason for this discrepancy is evident.

III. EFFECT OF VARIATIONS IN TEMPERATURE OF PRECOOKING HOLDING-PERIOD ON STEAKS AND ROASTS

Sensory Tests

Average scores for flavor, juiciness, and tenderness for both steaks and roasts treated with Brand No. 1 tenderizer and held at various temperatures before cooking are shown in Table III. Shear values for tenderness are also shown in this table.

Flavor and juiciness. There were very little differences between average flavor or juiciness scores of treated steaks and roasts held at various temperatures before cooking and the untreated controls. Data seem to indicate that an increase in temperature of the precooking holding-period from room temperature to 163° F. (73° C.) did not affect flavor or juiciness of steaks and roasts treated with a tenderizer.

Tenderness. Steaks and roasts held at any of the 3 temperature conditions before cooking were scored significantly more tender than the untreated controls, but there was no significant difference between the effects of 3 temperature treatments. No advantage, therefore, of using the higher temperatures was noted.

Shear Values

Treated steaks and roasts had slightly lower shear values than the untreated cuts. With the exception of the steaks held at 98° F. (36.5° C.) prior to cooking, none of the shears of treated meat were significantly lower than those of the untreated samples.

TABLE III

EFFECT OF VARIATIONS IN TEMPERATURE OF PRECOOKING HOLDING-PERIOD
ON FLAVOR, JUICINESS, AND TENDERNESS OF ROUND STEAKS
AND ROASTS TREATED WITH A TENDERIZER

Holding Temperature	Flavor	Juiciness	Tenderness	
	Panel score	Panel score	Panel score	Shear in lbs.
<u>Steaks</u>				
Control, no tenderizer, room temperature	7.4	7.5	6.3	4.3
Room temperature	7.3	7.3	7.9**	3.3
Incubator temperature of 98° F. (36.5° C.)	7.4	7.3	7.8*	2.9*
Warming oven temperature of 163° F. (73° C.)	7.4	7.3	8.2***	3.3
<u>Roasts</u>				
Control, no tenderizer, room temperature	7.5	7.8	6.9	3.8
Room temperature	7.2	7.2	8.3***	3.5
Incubator temperature of 98° F. (36.5° C.)	7.3	7.3	7.9*	3.4
Warming oven temperature of 163° F. (73° C.)	7.0	6.5	8.0*	3.3

NOTE: The panel scores for flavor, juiciness, and tenderness are an average of 12 judgments; the shear values for tenderness are an average of 16 measurements.

* Significantly different from control at P. 0.05

** Significantly different from control at P. 0.01

*** Significantly different from control at P. 0.001

IV. COOKING LOSSES

The average cooking losses for steaks and roasts used in all 3 phases of this study are shown in Table IV. The data are limited to 2 replications of each test. Since different muscles of the round were used in each phase of the study, no attempt was made to analyze these data. The table is included here as a matter of record. Others (5, 12) have reported that tenderizer applications had no significant effect on cooking losses.

V. DISCUSSION

Directions for the home use of tenderizers containing papain usually recommend holding the meat at room temperature for short intervals after applying the tenderizer. The primary purpose of this study was to determine if increases in either length or temperature of this precooking holding-period after application of the tenderizer would increase the amount of tenderization effected by the enzyme. This study should be considered exploratory in nature as the data are limited to tests of round muscles of one animal.

Considering the 2 criteria of tenderness, panel scores and shear values, data did not indicate that doubling the precooking holding-period at room temperature increased the amount of tenderization. As a matter of fact, meat treated with a tenderizer and cooked immediately was just as tender as when the usual precooking holding-period was doubled. This would seem to indicate that there was no advantage to a precooking holding-period at room temperature. Data seem to confirm the conclusion of

TABLE IV
AVERAGE COOKING LOSSES FOR STEAKS AND ROASTS
(in per cent)

Treatment	Steaks			Roasts		
	Volatile	Dripping	Total	Volatile	Dripping	Total
<u>Comparison of 3 Brands of Tenderizers</u>						
Control, no tenderizer	18.6	10.5	29.1	13.7	6.2	20.0
Brand No. 1	15.2	6.8	22.0	15.5	7.1	22.6
Brand No. 2	14.4	7.9	22.3	15.0	7.5	22.5
Brand No. 3	19.3	8.4	27.6	14.7	5.8	20.5
<u>Length of Precooking Holding-Period</u>						
Control, no tenderizer	16.4	8.1	24.5	14.3	5.0	19.4
None	15.6	8.5	24.1	16.8	5.0	21.7
30 minutes	16.0	7.9	23.9	-	-	-
1 hour	16.0	8.2	24.2	16.7	6.2	22.9
2 hours	-	-	-	14.4	4.9	19.3
<u>Temperature of Precooking Holding-Period</u>						
Control, no tenderizer, room temperature	20.8	6.6	27.5	14.0	4.4	18.4
Room temperature	19.9	6.1	26.0	15.8	4.6	20.5
98° F. (36.5° C.)	17.7	6.7	24.4	16.4	5.2	21.6
163° F. (73° C.)	14.4	5.5	19.9	16.7	4.8	21.5

Tappel et al. (7) that effective tenderization occurs during the cooking period.

The 2 criteria of tenderness also indicated that there was no advantage to increasing the temperature of the precooking holding-period as compared to applying the tenderizer at room temperature. Under the conditions of this study, using a 30-minute precooking holding-period for steaks and a 1-hour holding-period for roasts, the meat reached an internal temperature of about 77° F. (25° C.) in the incubator and 98° F. (36.5° C.) in the warming oven. Neither of these temperatures approached the optimum temperature for activity of papain as defined by Gottschall and Kies (3), Tappel et al. (7), and Weiner et al. (11). Additional work would be needed to determine if it would be practical under home conditions to elevate the temperature of meat closer to the optimum for papain activity before cooking. It seems likely that only during the cooking period does the meat attain a high enough temperature for much papain digestion.

CHAPTER V

SUMMARY

In this study 3 meat tenderizers, containing the proteolytic enzyme papain in powdered form, which were available in the Knoxville retail market were tested. The effect of these tenderizers on flavor, juiciness, and tenderness of steaks and roasts cooked by dry-heat methods was compared. One of the 3 meat tenderizers was then used to study the effect of increases in length of the precooking holding-period and of variations in temperature of the precooking holding-period on flavor, juiciness, and tenderness.

Sensory-difference tests were used to evaluate the flavor, juiciness, and tenderness of the steaks and roasts. The Warner-Bratzler shearing apparatus was also used to measure tenderness.

I. PRINCIPAL FINDINGS

Both sensory-difference tests and shear measurements indicated that all 3 brands of tenderizers improved the tenderness of steaks and roasts. Steaks treated with Brands No. 1 and No. 2 were judged significantly more tender than untreated controls, and roasts treated with Brands No. 1 and No. 3 were scored significantly more tender than untreated roasts. Two of the 3 brands were equally effective in improving tenderness scores of steaks, and all 3 brands were equally effective in improving tenderness scores of roasts.

When the length of the precooking holding-period at room temperature was varied, steaks and roasts treated with a tenderizer were more tender than untreated samples as determined by both sensory-difference tests and shear measurements. Treated steaks which had no precooking holding-period were just as tender as those which had been held for 30 minutes or 1 hour at room temperature after applying the tenderizer. Treated roasts which had no precooking holding-period were just as tender as those treated and held 1 or 2 hours after application of tenderizer.

As determined by sensory-difference tests, beef treated with a tenderizer and held at room temperature, incubator temperature of 98° F. (36.5° C.), or warming oven temperature of 163° F. (73° C.) was significantly more tender than untreated controls. Shear value data also indicated that meat treated at the 3 temperature conditions was more tender than the untreated control, but the differences were not significant. Elevating the precooking holding temperature to 98° F. (36.5° C.) or to 163° F. (73° C.) was no more effective than holding the meat at room temperature.

There were very little differences between average flavor and juiciness scores of steaks and roasts treated with unseasoned tenderizers and cuts which were not treated with a tenderizer.

II. CONCLUSION

Based on the data obtained from this study, it could be concluded that the use of a tenderizer containing the proteolytic enzyme papain

makes the meat more tender but does not affect the flavor or juiciness to any great extent. It could also be concluded that doubling the usual precooking holding-period at room temperature is not advantageous and that increasing the precooking holding temperature up to 163° F. (73° C.) does not increase the tenderness effected by the enzyme. More work would be necessary to determine if it would be advantageous under home conditions to change the procedure usually recommended for applying a tenderizer.

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