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MEASUREMENT OF COHESIVENESS OF FABRICATED

Joseph S. Cohen, et al

Army Natick Laboratories
Natick, Massachusetts

April 1974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Studies of the cohesiveness of fabricated, irradiated meat rolls, (beef, ham, pork, corned beef, and breast and thigh chicken meat), using a Kramer Shear Press and a trained sensory panel, were conducted. The Kramer Shear Press and friability data correlated at the 99% significance level for ham, 98% level for beef, 95% level for thigh chicken meat and 88% level for pork. There was no significant correlation for breat chicken meat or corned beef. The correlation of greater than 99.9% significance was obtained by combining the data for all six meats. Irradiated meats were less cohesive than non-irradiated meats, and practically all Kramer Shear Press scores

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) were lower for the irradiated than for the non-irradiated products. The overall data indicate a tenerizing effect of irradiation, thus suggesting that a somewhat "tougher" initial raw product could be used for preparing radappertized final meat products. (26 references).

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TECHNICAL REPORT

74-45-FL

MEASUREMENT OF COHESIVENESS OF FABRICATED, IRRADIATED MEAT ROLLS

by

Joseph S. Cohen
Lucy J. Rice
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Project: 1G762713A033 FL-193

April 1974

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FOREWORD

These experiments were conducted to determine if an objective test of texture, a Kramer Shear Press measurement of force, could be made to correlate with and predict a subjective method, test panel friability, using irradiated meat rolls as an experimental material.

The results show that this correlation could be used with beef, ham, pork and thigh chicken meat, but not with corned beef or breast chicken meat.

Also, irradiated meat products showed increased friability and smaller Kramer Shear Press force values when compared with the same unirradiated meat products.

These studies were undertaken as a research project of the Irradiated Food Products Division, Food Laboratory, under Project 1G762713A033.

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INTRODUCTION

A number of investigators have studied the tenderness of meat products with various mechanical instruments and have correlated the results with subjective measurements by a sensory panel. Deatherage and Garnatz (1952) compared a Warner-Bratzler (W–B) Shear Press with sensory panel tenderness, using broiled steaks made from beef short loins. They did not obtain a good correlation. Miyada and Tappel (1956) compared data obtained with a Christel Texturementer, a Hamilton-Beach Food Grinder, and a W–B shear device. The texturemeter and food grinder data were more precise than that obtained with the shear device. The food grinder did not require a specific sample size. Bockian *et al.* (1958) showed good correlation between food grinder and sensory panel data that were obtained from cooked standing beef rib roast.

Sheering *et al.* (1959) used a modified Carver Juice Press for his measurements on raw and cooked beef. The press data from the cooked meat correlated well with sensory panel data. Press data for raw meat correlated well with W–B Shear Press data as well as with the panel tenderness of cooked meat. Emerson and Palmer (1960) studied the tenderness of beef with a food grinder and a W–B Shear Press. The W–B gave the greater correlation with sensory panel data. Burrill *et al.* (1962) compared sensory panel scores for the tenderness of beef with "panel chews", a W–B Shear Press for maximum force and a W–B Shear Press for total work. All methods showed a high correlation. Bratzler and Smith (1963) compared panel, press, and shear methods using lamb loins, beef ribs, short loins and rounds. The press and shear methods compared favorably with the panel data. Press data from the raw meat showed little relationship to data obtained from cooked meats, or with sensory panel data.

Carpenter *et al.* (1965) used a Wedge Tenderometer, a W–B Denture Tenderometer and a Grinder Tenderometer to predict the tenderness of park carcasses. All but the Wedge showed good potential. Sharrah *et al.* (1965) used a W–B Shear Press, a Lee-Kramer conventional Sheer Press (L–K) and an L–K with a W–B shear plate with beef. They showed a variation for sensitivity and reproducibility between instruments as well as variation within the same muscle. Panel judges also showed a considerable variation in sensitivity and reproducibility. Alsmeyer *et al.* (1966) used a modified W–B and a Slice Tenderness Evaluator to measure the tenderness of beef rib roasts and pork loin roasts. Standard and utility grades of beef correlated better with a taste panel than choice or good grades. Pork had a higher correlation with increase marbling. Szczesniak *et al.* (1970) used boiled, sliced beef to find that the rate of force increased with sample weight in a shear press. The rate was initially almost constant, and then began to decrease. The peak areas increased at a steadily increasing rate.

Hinnegardt and Tuomy (1970) modified a Kramer Shear Press to be used as a penetrometer to predict cooked meat tenderness of raw pork muscle. They found a significant correlation of the force required to penetrate the raw meat with the force required to penetrate the cooked meat as well as with sensory panel data. Carpenter *et al.* (1972) used the Armour Tenderometer to characterize beef carcasses as evaluated for tenderness of cooked steaks by a trained sensory panel and a W–B Shear Press. They determined that choice beef carcasses should be separated into tenderness desirability groups. Rhodes *et al.* (1972) examined roast beef with a sensory panel and with an Instron instrument. The data correlated more closely with "toughness-tenderness than with "juiciness' Smith and Carpenter (1973) compared the W–B Shear Press with a Nip Tenderometer on pork chops, lamb chops and beef steaks. The results were compared to sensory panel data for tenderness. The W–B showed better correlation than the Nip at 23°C. The Nip worked better at 75° than at 23°C.

Purchase (1973) described a hand operated "biting" instrument to be used on raw meat carcasses or cooked meats. Although it appears to measure the same characteristics as the W- B shear device, it may be more practical to use in some situations. It was not of much use in measuring the tenderness of raw meat.

There have also been a number of reports that have reviewed the entire field of texture measurement instrumentation. They include Schultz (1957), Pearson (1963), Finney (1969), Szczesniak (1972) and Voisey (1971).

Szczesniak (1963) described the mechanical characteristics of a food as: hardness, viscosity, elasticity, adhesiveness and cohesiveness. She defined cohesiveness as "the strength of the internal bonds making up the body of the product".

Earlier, unpublished work done in our laboratory indicated that a good correlation might be expected between Kramer Shear Press measurement of maximum force and cohesiveness measured by a sensory panel and defined as the ease (or difficulty) with which individual fibers of meat pulled apart from each other.

EXPERIMENTAL

Materials

This report describes an objective and subjective method for the analysis of meat texture using fabricated rolls of beef, pork ham, corned beef, and thigh and breast chicken meat that had been irradiated.

The objective method was the measurement of the peak force with an Allo-Kramer Shear Press. The subjective method was a sensory panel to evaluate the meat for friability as an index of cohesiveness.

We prepared the beef from whole rounds that consisted primarily of semi-membranosus, semi-tendinosus and biceps femoris muscles. We made the ham from these same muscles from pork rounds. We fabricated the pork from loins consisting primarily of longissimus dorsi muscles. We prepared the corned beef from briskets of deep pectoral muscles. We prepared the white chicken rolls from breast muscles and dark chicken rolls from thigh muscles.

We prepared each meat for the addition of salts and spices by deboning the muscles, where appropriate, removing as much visible fat as possible, and cutting the beef and pork into small pieces, approximately 50 – 75 mm on an edge. The chicken pieces were 20 – 40 mm. We then mixed the meat in a Hobart mixer for 10 minutes with 0.75% sodium chloride, 0.375% sodium tripolyphosphate and 3.0% ice. We stuffed this meat mixture into cellulose casings, placed the filled casings in a metal screen to yield a shape of 90 x 120 mm by 710 mm in length, chilled the meat at +4 ± 1°C overnight, and enzyme inactivated in a cookhouse.

We cured the ham by mixing the pork pieces with a solution of salts to give a calculated final analysis, prior to enzyme inactivation, of 600 ppm sodium nitrate, 150 ppm sodium nitrite, 200 ppm sodium iso-ascorbate, 200 ppm sodium ascorbate, 1.5% sodium chloride and 0.375% sodium tripolyphosphate. We cured the corned beef in the same manner as the ham, but with the addition of pickling spices and a total of 1.2% sodium chloride. The proximate analysis and the sodium chloride and phosphorous content of the meats, done on duplicate samples, using standard A.O.A.C. (1970) methods are listed in Table 1.

The enzyme inactivation conditions for all but the ham were: 57.2°C (135°F) for 3 hours; 71.1°C (160°F) for 4 hours; 90.6°C (195°F) for two hours, or until a final internal temperature of 68.3°C (155°F) was achieved.

The enzyme inactivation conditions for the ham were: 65.6°C (150°F) and 90% relative humidity for 1 hour with no smoke; 65.6°C and 90% relative humidity with smoke generated from hardwood sawdust for 2 hours; 76.6°C (170°F) and 92% relative humidity for 5 hours; 82.2°C (180°F) and 94% relative humidity with smoke for 2 hours, 76.7°C and no humidity but with smoke for 2 hours or until a yield of 95% of the initial weight, before salt addition, was achieved.

After enzyme inactivation we again chilled the meat rolls overnight at +4 ± 1°C. We then sliced the meat to a thickness of 13 mm and sealed one slice of meat approximately 100 g weight into a laminated pouch with the contactant layer of medium density polyethylene. We sealed the pouches under a pressure of 20 mm Hg. and then froze the meat in the sealed pouches to the desired temperature in preparation for irradiation.

Irradiation was done with a linear accelerator, utilizing 10 Mev electrons and a dose rate of 10^8 rads per second. The irradiation doses received and the irradiation temperatures are listed in Table 2. The dose received is in MR (megarads). One MR is equivalent to 10^4 joules absorbed per kg. We held the irradiated meat packages at $-40 \pm 2^\circ C$ until they were used for analysis, as was a frozen unirradiated sample of each meat.

Methods

We defrosted these frozen samples at $+4 \pm 1^\circ C$ overnight just prior to analysis. The analyses consisted of an objective method using a Kramer Shear Press, and a subjective method utilizing a sensory panel to measure friability. A description by Schults (1957) of the Kramer Shear Press is quoted in Appendix I. This modified Shear-Press was used for the measurements. It is illustrated in Figures 1 and 2.

We used the 5,000 lbs. (2,270 kg) ring and a scale of 10%. Pieces of meat, 25 x 25 mm, were cut from the 13 mm thick slice. Three pieces were placed in the metal box for each analysis. The 10 blade shear compression cell was used with the blades traveling through a depth of meat of 13 mm. The pieces were randomly placed in the bottom of the shear cell.

Since the meat fibers were randomly oriented, it was not necessary to align the meat precisely with the ten blade shear cell. The maximum force was the data recorded and used.

We made sixteen replicate readings on each meat sample, with each reading being done with three pieces of meat. The average weight of an individual meat piece was 7.9 g with a standard deviation of ± 0.8 g.

The meat rolls were sliced so that, from the same roll, alternate slices were used for Kramer Shear Press and friability measurements. Pieces from these reserved slices were taken at random.

A nineteen member sensory panel measured the cohesiveness (friability) of the meat samples. We defined friability as the ease (or difficulty) with which individual fibers of meat pulled apart from each other. A nine point sensory scale was used with the following definitions: 1 – not friable; 2 – trace; 3 – slight; 4 – below moderate; 5 – moderate; 6 – above moderate; 7 – strong; 8 – very strong; 9 – extreme friability. The panelists were given all ten samples of a meat at one sitting and were encouraged to compare them against each other. The panelists were instructed to determine friability by pulling the individual fibers from each other with a knife and fork.

We tabulated the Kramer Shear Press scores and the friability scores and calculated a correlation coefficient by combining the scores for all six meats.

We ran an analysis of variance test for each method with each meat to determine if the texture was a function of dose and/or temperature of irradiation. The statistical methods are as given by Snedecor (1956).

RESULTS AND DISCUSSION

Tables 3 – 8 show the Kramer Shear Press scores in Newtons force and the friability scores for ham, corned beef, chicken breast, chicken thigh, beef and pork, with the standard deviation for each score.

Table 9 is a summary of the correlation coefficients between the Kramer Shear Press and friability scores for each meat, as well as a value derived by combing all the data. There is a highly significant correlation (99%, r = –0.87) for the two methods, with ham. Thigh meat chicken and beef showed a correlation of greater significance than 95% (r = –0.71, –0.78). Pork was significant at a level of 88% (r = –0.50). Corned beef and breast meat chicken were not significant. A significance level of 99.9% was obtained by combining all the data. The correlation coefficient for each meat is based on 10 data pairs. The combined data uses 60 data pairs.

Table 10 is a listing of the least squares regression lines for friability as a function of the Kramer Shear Press score, where the correlation coefficient is significant.

Table 11 shows the Kramer Shear Press and friability scores as a function of irradiation dose and temperature as determined by analysis of variance, using a significance level of 95%.

With four of the six fabricated, irradiated meat products studied, the Kramer Shear Press objective measurement of texture was a good predictor of the sensory panel subjective method of friability. This instrument is a useful tool for texture measurement with meats.

The Kramer Shear Press data for beef was a function of irradiation dose and temperature, for pork a function of irradiation dose only. We further found friability data for beef to be a function of irradiation temperature; for thigh meat chicken a function of dose; for ham a function of irradiation temperature.

Practically all Kramer Shear Press scores were lower for irradiated than for non-irradiated meat. Almost all of the friability scores were greater for irradiated than non-irradiated meat. This indicates that irradiation tends to decrease the cohesiveness of meat. This also confirms a temderizing effect found previously on irradiated beefsteaks (Kauffman and Harlan, 1969). Because of this tenderizing effect, a somewhat "tougher" initial raw product could be used for irradiation processing.

Because of the inherent variability of meat, great care must be taken with either method to insure that the evaluated samples are homogenous. Also, a large number of replicate measurements should be made.

APPENDIX I

DESCRIPTION OF KRAMER SHEAR PRESS (SCHULTZ, 1951)

"In 1951, Kramer, Aamlid, Guyer, and Rodgers described a new instrument for measuring tenderness of fruits and vegetables. This instrument, the rugged construction of which distinguishes it from most other instruments, uses hydraulic pressure to force a series of metal plungers (plates) downward through product held in a metal box. Originally the pressure required to plunge through the material in the box was determined by measuring the pressure of the hydraulic fluid. More recently a Dillon mechanical pressure gage has replaced the hydraulic pressure gage to give a wider range of pressure recordings. In either arrangement, the Shear Press measures the maximum pressure required to force the plunger through the material.

"In a recent refinement of this Shear-Press, called the Lee-Kramer Shear-Press, a sensitive dial mechanical pressure indicator which registers through a proving ring is placed between the hydraulically operated piston and the plunger plates, thus providing a more direct measure of force against the product being tested.

"A still later modification by Decker utilizes a transducer in conjunction with the Dillon mechanical pressure gage, which, when connected through an amplifier to a recording device, results in a continuous chart recording of pressure as the plunger plates travels through the product. The recorder provides a pressure-time curve which can then be utilized to measure the total work required to penetrate the product."

BIBLIOGRAPHY

Alsmeyer, R. H., Thornto, J. W., Hiner, R. L. and Bollinger, N. C. 1966. Beef and pork tenderness measured by the press, Warner-Bratzler and S.T.E. methods. Food Tech. 20: 683

Association of Official Analytical Chemists, Methods of analysis. 1970, 11th Ed. A.O.A.C., Washington, D.C.

Bockian, A. H., Anglemier. A. F. and Sather, L. A. 1959. A comparison of an objective and subjective measurement of beef tenderness. Food Tech. 13: 155

Bratzler, L. J. and Smith, H. D. 19[illegible]. A comparison of the press method with taste panel and shear measurements of tenderness in beef and lamb muscles. J. Food Science. 28: 99

Burrill, L. M., Deethardt, D. and Saffle, R. L. 1962. Two mechanical devices compared with taste panel evaluation for measuring tenderness. Food Tech. 16, 145

Carpenter, Z. L., Kauffman, R. G., Bray, R. W. and Weckel, K. G. 1965. Objective and subjective measures of pork quality. Food Tech. 19: 1424

Carpenter, Z. L., Smith G. C., and Butler, O. D. 1972. Assessment of beef tenderness with the Armour Tenderometer. J. Food Science. 37: 126

Deatherage, F. E. and Garnatz, G. 1942. A comparative study of tenderness determination by sensory panel and by shear strength measurements. Food Tech. 6: 260

Emerson, J. A. and Palmer, A. Z. 1960. A food grinder-recording ammeter method for measuring texture. Food Tech. 14: 214

Finney, E. E. 1969. Objective measurement for texture in foods. J. Texture Studies. 1: 19

Hinnergardt, L. C. and Tuomy, J. M. 1970. A penetrometer test to measure meat tenderness. J. Food Science. 35: 312

Kauffman, F. L. and Harlan, J. W. 1969. Effect of low temperature irradiation on chemical and sensory characteristics of beef steaks. Tech. Rpt. #69–64–FL, U.S. Army Natick Labs, Natick, Mass. 01760

Kramer, A., Aamlid, K., Guyer, R. N. and Rodgers, H. P., Jr., 1951. New shear press predicts quality of canned lima beans. Food Eng. 23: 112

BIBLIOGRAPHY (cont'd)

Miyada, D. S. and Tappel, A. L., 1956. Meat tenderization I, two mechanical devices for measuring texture. Food Tech. 10: 142

Pearson, A. M. 1963. Objective and subjective measurements for meat tenderness. Proceedings, Meat Tenderness Symposium, Campbell Soup Co.: 135

Purchase, R. W. 1973. Some aspects of meat tenderness. J. Food Science. 38: 556

Rhodes, D. N., Jones, R. C. D., Chrystal, B. B. and Harries, J. M. 1972. Meat texture II, the relationship between subjective assessments and a compressive test on roast beef. J. Texture Studies. 3: 298

Schultz, H. W. 1957. Mechanical methods of measuring tenderness of meat. Proceedings of Tenth Annual Reciprocal Meat Conference. 17

Sharrah, N., Kunze, M. S. and Pangborn, R. M. 1965. Beef tenderness comparison of sensory methods with the Warner-Bratzler and Lee-Kramer Shear Press. Food Tech. 19: 238

Smith, G. C., Carpenter, Z. L. 1973. Mechanical measurements of meat tenderness using the Nip Tenderometer. J. Texture Studies. 4: 196

Snedecor, G. W., 1956. Statistical methods. The Iowa State College Press, Ames, Iowa

Sperring, D. D., Platt, W. T. and Hiner, R. L. 1959. Tenderness in beef muscle as measured by pressure. Food Tech. 13: 155

Szczesniak, A. S., 1963. Classification of textural characteristics. J. Food Sci. 28: 385

Szczesniak, A. S., Humbaugh, P. R. and Block, H. W. 1970. Behavior of different foods in the standard shear compression cell of the shear press and the effect of sample weight on peak area and maximum force. J. Texture Studies. 1: 356

Szczesniak, A. S. 1972. Instrumental methods of texture measurement. Food Tech. 26 (1): 50

Voisey, O. W., 1971. Modernization of texture instrumentation. J. Texture Studies. 2: 129

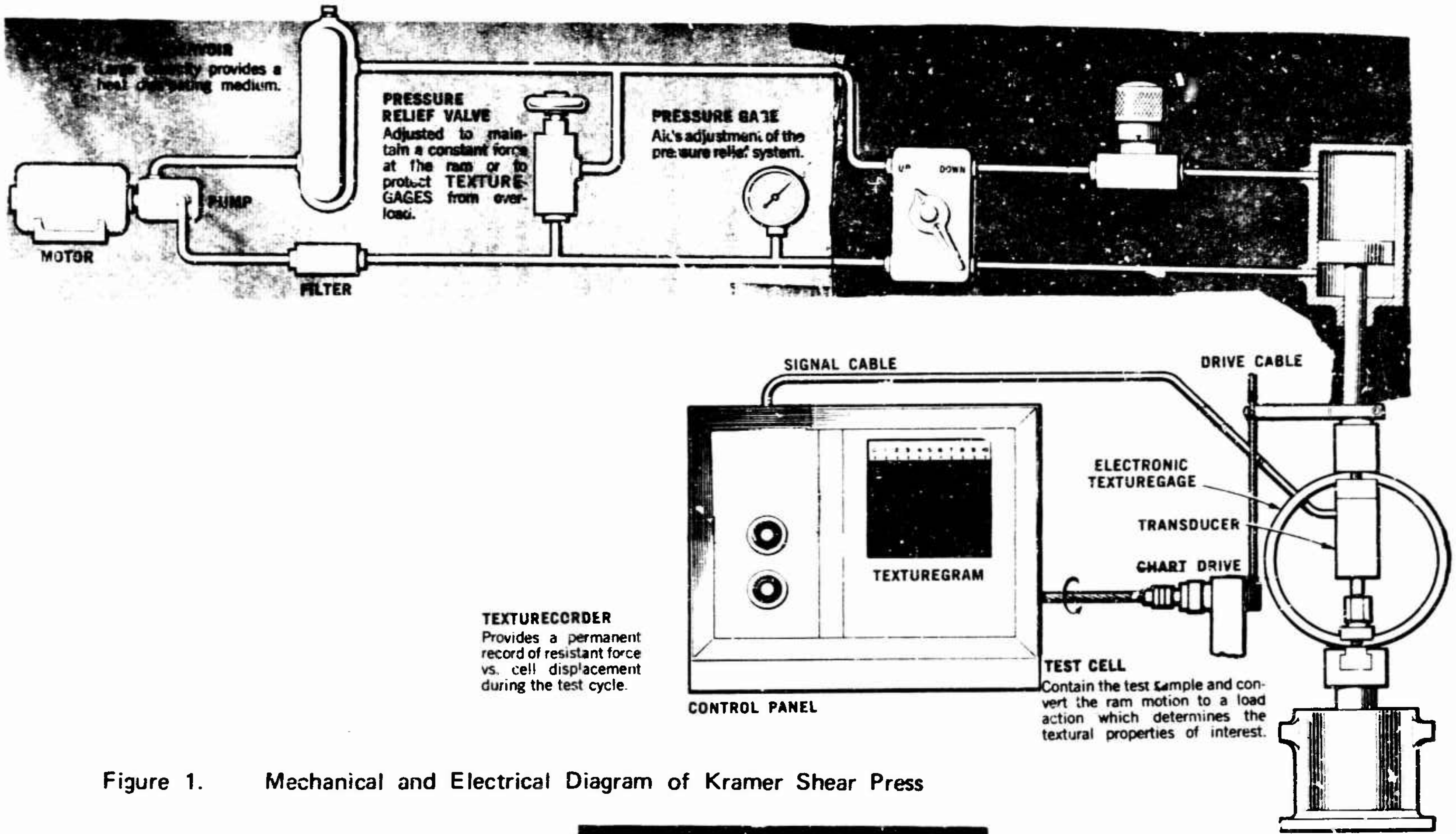

Figure 1. Mechanical and Electrical Diagram of Kramer Shear Press

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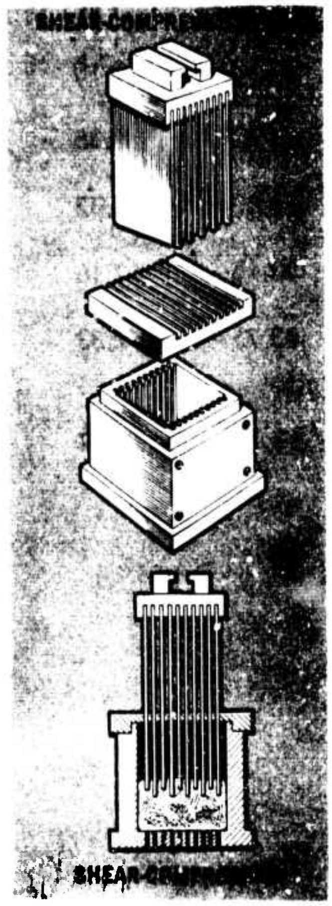

Figure 2. Design of Shear-Compression Cell

TABLE 1

PROXIMATE ANALYSIS AND SALT AND PHOSPHOROUS CONTENT OF MEATS*

Meat	% Water	% Protein	% Fat	% Ash	% NaCl	% P
Beef	65.53	22.53	9.10	2.10	0.88	0.31
Pork	66.54	21.32	9.35	1.99	0.87	0.29
Corned Beef	63.60	26.60	6.92	2.09	1.20	0.24
Ham	66.27	23.15	7.16	2.79	1.57	0.30
Breast Meat Chicken	70.68	23.71	2.33	2.16	0.88	0.30
Thigh Meat Chicken	70.04	18.73	8.97	1.94	0.85	0.24

*Prior to enzyme inactivation

TABLE 2

IRRADIATION TEMPERATURE AS A FUNCTION OF IRRADIATION DOSE

Minimum Dose, MR*	Maximum Dose, MR*	Initial Temp. °C	Final Temp. °C
2.3	3.0	−10.0	− 7.1
2.3	3.0	−42.9	−29.7
2.3	3.0	−72.3	−51.7
4.6	6.0	−12.8	− 5.3
4.6	6.0	−43.3	−14.6
4.6	6.0	−73.0	−45.5
6.9	9.0	− 9.0	− 2.4
6.9	9.0	−42.6	− 7.8
6.9	9.0	−73.1	−38.3

*Within a single piece of meat

1 MR (Megarad) = 10^{-2} joules absorbed per kg

TABLE 3

A – KRAMER SHEAR PRESS SCORES, MAXIMUM NEWTON FORCE FOR HAM (WITH STANDARD DEVIATION)

Irrad. Temp. °C	Dose, Mrad, (Minimum) 2.3	4.6	6.9
–10	708 ± 142	610 ± 156	596 ± 107
–40	142 ± 89	654 ± 121	699 ± 156
–70	810 ± 151	677 ± 138	721 ± 200
Control ––	792 ± 112		

B – FRIABILITY SCORES FOR HAM (WITH STANDARD DEVIATION)*

Irrad. Temp. °C	Dose, Mrad, (Minimum) 2.3	4.6	6.9
–10	4.0 ± 1.9	4.3 ± 2.4	5.2 ± 2.1
–40	2.8 ± 1.6	4.0 ± 2.0	4.5 ± 2.1
–70	3.1 ± 1.8	3.9 ± 2.1	4.3 ± 2.3
Control ––	2.8 ± 1.6		

*See Page 4 for explanation of friability scores

TABLE 4

A – KRAMER SHEAR PRESS SCORES, MAXIMUM NEWTON FORCE FOR CORNED BEEF (WITH STANDARD DEVIATION)

Irrad. Temp. °C	Dose, Mrad, (Minimum)		
	2.3	4.6	6.9
–10	1322 ± 178	957 ± 289	1144 ± 245
–40	1460 ± 263	1425 ± 191	1162 ± 280
–70	1362 ± 160	1345 ± 280	1122 ± 209
Control ––	1269 ± 147		

B – FRIABILITY SCORES FOR CORNED BEEF (WITH STANDARD DEVIATION)*

Irrad. Temp. °C	Dose, Mrad, (Minimum)		
	2.3	4.6	6.9
–10	3.4 ± 1.6	4.5 ± 1.8	4.6 ± 1.6
–40	3.3 ± 1.5	5.1 ± 1.6	4.3 ± 2.0
–70	4.0 ± 1.6	4.6 ± 2.1	3.8 ± 1.3
Control	4.0 ± 1.8		

*See Page 4 for explanation of friability scores

TABLE 5

A – KRAMER SHEAR PRESS SCORES, MAXIMUM NEWTON FORCE FOR BREAST MEAT CHICKEN (WITH STANDARD DEVIATION)

Irrad. Temp. °C	Dose, Mrad, (Minimum)		
	2.3	4.6	6.9
–10	454 ± 72	498 53	463 31
–40	481 ± 67	481 72	485 53
–70	498 ± 63	450 ± 76	480 ± 53
Control ––	502 ± 76		

B – FRIABILITY SCORES FOR BREAST MEAT CHICKEN (WITH STANDARD DEVIATION)*

Irrad. Temp. °C	Dose, Mrad, (Minimum)		
	2.3	4.6	6.9
–10	5.8 ± 2.0	5.3 ± 1.9	6.1 ± 1.8
–40	5.2 ± 2.1	4.8 ± 1.9	6.0 ± 2.1
–70	5.2 ± 1.4	5.0 ± 2.3	5.0 ± 2.2
Control ––	4.7 ± 2.2		

*See Page 4 for explanation of friability scores

TABLE 6

A – KRAMER SHEAR PRESS SCORES, MAXIMUM NEWTON FORCE FOR THIGH MEAT CHICKEN (WITH STANDARD DEVIATION)

Irrad. Temp. °C	Dose, Mrad, (Minimum)		
	2.3	4.6	6.9
–10	387 ± 58	468 ± 804	396 ± 58
–40	432 ± 129	387 ± 67	396 ± 63
–70	440 ± 84	401 ± 76	379 ± 58
Control ––	445 ± 72		

B – FRIABILITY SCORES FOR THIGH MEAT CHICKEN (WITH STANDARD DEVIATION)*

Irrad Temp. °C	Dose, Mrad, (Minimum)		
	2.3	4.6	6.9
–10	5.8 ± 2.0	5.9 ± 1.5	6.8 ± 1.[illegible]
–40	5.5 ± 2.0	6.6 ± 1.7	6.6 ± 1.6
–70	6.1 ± 2.1	6.1 ± 1.5	6.8 ± 58
Control ––	5.3 ± 1.7		

*See Page 4 for explanation of friability scores

TABLE 7

A – KRAMER SHEAR PRESS SCORES, MAXIMUM NEWTON FORCE FOR BEEF (WITH STANDARD DEVIATION)

Irrad. Temp. °C	Dose, Mrad, (Minimum) 2.3	4.6	6.9
–10	797 ± 138	690 ± 112	517 ± 84
–40	948 ± 156	708 ± 112	610 ± 98
–70	913 ± 200	838 ± 125	686 ± 102
Control ––	850 ± 138		

B – FRIABILITY SCORES FOR BEEF (WITH STANDARD DEVIATION)*

Irrad. Temp. °C	Dose, Mrad, (Minimum) 2.3	4.6	6.9
–10	4.4 ± 2.2	4.8 ± 2.4	6.0 ± 2.1
–40	4.0 ± 2.2	4.4 ± 2.2	4.6 ± 2.3
–70	3.7 ± 2.2	4.0 ± 1.8	4.0 ± 2.0
Control ––	3.0 ± 1.8		

*See Page 4 for explanation of friability scores

TABLE 8

A – KRAMER SHEAR PRESS SCORES, MAXIMUM NEWTON FORCE FOR PORK (WITH STANDARD DEVIATION)

Irrad. Temp. °C	Dose, Mrad, (Minimum) 2.3	4.6	6.9
–10	801 ± 170	512 ± 191	601 ± 200
–40	775 ± 263	547 ± 112	432 ± 118
–70	780 ± 263	735 ± 125	517 ± 156
Control ––	953 ± 209		

B – FRIABILITY SCORES FOR PORK (WITH STANDARD DEVIATION)*

Irrad. Temp. ° C	Dose, Mrad, (Minimum) 2.3	4.6	6.9
–10	4.4 ± 2.2	4.4 ± 1.8	5.4 ± 1.8
–40	3.8 ± 1.9	4.6 ± 1.9	4.3 ± 1.8
–70	3.7 ± 1.8	4.1 ± 1.8	4.2 ± 2.1
Control ––	3.8 ± 2.2		

*See Page 4 for explanation of friability scores

Table 9

CORRELATION COEFFICIENTS FOR KRAMER SHEAR PRESS AND FRIABILITY SCORES

Product	r	Significance Level	
Ham	–0.87	99.1%	
Corned Beef	–0.18	42%	(NSD)
Chicken, Breast Meat	–0.33	67%	(NSD)
Chicken, Thigh Meat	–0.71	96.7%	
Beef	–0.78	98.1%	
Pork	–0.50	88%	
Combined Data	–0.61	99.9%	

N = 10 (individual meats)

N - 60 (combined data)

TABLE 10

FRIABILITY AS A FUNCTION OF KRAMER SHEAR PRESS VALUE (LEAST SQUARES LINE)

Product	Equation
Ham	$F = 10.24 - 0.44\ K$
Corned Beef	Not significant
Chicken, Breast Meat	Not significant
Chicken, Thigh Meat	$F = 11.06 - 0.59\ K$
Beef	$F = 7.68 - 0.22\ K$
Pork	$F = 5.30 - 0.03\ K$
Combined Data	$F = 6.13 - 0.02\ K$

F = Friability Score

K = Kramer Shear Press Value

TABLE 11

FRIABILITY AND KRAMER SHEAR PRESS VALUES AS A SIGNIFICANT FUNCTION OF IRRADIATION DOSE AND TEMPERATURE STUDIED

Product	Kramer Shear Press		Friability	
	Dose	Temperature	Dose	Temperature
Ham	–	–	–	+
Corned Beef	–	–	–	–
Chicken, Breat Meat	–	–	–	–
Chicken, Thigh Meat	–	–	+	–
Beef	+	+	–	+
Pork	+	–	–	–

+ --- Significant (95% of greater)

– --- Not Significant