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TECHNICAL REPORT
FD-8

MEASUREMENT OF TEXTURE IN FRANKFURTERS AND LUNCHEON MEAT

by

S. Simon

J. Field D. Dieball W. Kramlich

VISKING COMPANY,
DIVISION OF UNION CARBIDE CORPORATION
Chicago, Illinois

Contract No. DA 19-129-QM-2015

April 1965

U. S. Army Materiel Command
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts

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Foreword

This study was undertaken in response to numerous and persistent complaints from all branches of the Armed Forces regarding the toughness and rubberiness of frankfurters supplied through military procurement. Particularly emphatic were the complaints from abroad where frankfurters are supplied in the frozen state to avoid the possibility of microbial activity during the protracted period required for shipment and distribution. Technologists experienced in the preparation of frankfurters recognize several raw materials and a number of processing conditions as conducive to toughness and rubberiness in finished frankfurters. It is impractical, however, to avoid all probable sources of toughness and rubberiness through control of raw material and processing operations in frankfurter specifications. A feasible means for eliminating frankfurters of excessive toughness and rubberiness from military procurement is seen in the development of objective measurements which reveal these defects in the finished product at the time of inspection.

The primary objective of this contract is to develop and establish the validity of objective physical measurements which can be used to define acceptable and unacceptable limits for toughness and rubberiness in frankfurters. In order to achieve full advantage of such measurements, it is essential that they be suitable for incorporation into specifications for frankfurters.

This report represents approximately one year of work by the Visking Division of the Union Carbide Corporation under contract DA19-129-QM-2015. The program was conducted under the general supervision of Mr. F. Warren Tauber, Manager of Food & Packaging Development. Dr. S. Simon served as Official Investigator; J. Field, W. Kramlich and D. Dieball were collaborators.

The Project Officer for the U. S. Army Natick Laboratories was Dr. M. C. Brockmann. Alternate Project Officer was Mr. G. J. Legris. Both are members of the Animal Products Branch, Food Division.

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Contents

List of Tables

SUMMARY

A compression stress-strain test was devised to measure the toughness and rubberiness of frankfurters and/or a combination of the two properties. This was utilized in evaluating the influence of frankfurter formulation, method of emulsion preparation, and processing conditions on frankfurter texture.

Moduli calculated from stress-strain measurements on frankfurters indicate that toughness increased as the ratio of muscle protein to fat increased. Moduli values decreased as processing humidity increased but were similar for the basic emulsification methods employed.

Data showed that the degree of firmness, as reflected by the puncture modulus, was also a function of the degree of vacuum at which the product was prepared.

Apparent density, measured by the weight/volume relationship, was essentially independent of product composition for frankfurters containing 25 to 35 per cent fat. For the formulations and processing methods evaluated the results suggest that the apparent density was chiefly related to the degree of air exclusion during product preparation.

MEASUREMENT OF TEXTURE IN FRANKFURTERS AND LUNCHEON MEAT

INTRODUCTION

The primary objectives of this investigation were the development of test procedures for the evaluation of certain physical properties of frankfurters and bologna. The properties under consideration were: (a) tenderness or toughness, (b) rubberiness, (c) density, and (d) air pockets. This report summarizes the advances made in these areas during this project.

SAMPLE PREPARATION

Emulsions containing 60% beef and 40% pork (A), 40% beef and 60% pork (B), and 50% lean beef, 25% fat beef and 25% pork (C), were prepared at (1) 0, 14, and 28 inches of mercury with a Cut Mix sausage converter (Schnellkutter), (2) with a Kramer Grebe Cut Mix (K.G.), (3) with the Cut Mix (K.G.) and Griffith Mincemaster, and (4) with a Buffalo Mixer and Griffith Mincemaster.

Table I

Frankfurter Formulations

Ingredients	Formulation A	B	C
Beef plate	-	-	7.5 lb
Beef chucks	18 lb	12 lb	15 lb
Regular pork trimmings	12 lb	18 lb	7.5 lb
Ice	9 lb	9 lb	9 lb
Salt	1 lb	1 lb	1 lb
Sodium nitrate	4 g	4 g	4 g
Sodium nitrite	2 g	2 g	2 g
Sodium isoascorbate	7.5 g	7.5 g	7.5 g
Seasonings	4 oz	4 oz	4 oz

The frankfurters were stuffed, linked, and then processed to 150°F in the smokehouse at (a) less than 14 per cent (dry house), (b) 25% ± 3, and (c) 50% ± 5, relative humidity. Subsequently, the products were hot and cold showered. The frankfurters were stored at 40°F. Physical properties of the frankfurters were measured the following day. Three replications were made of each set. Proximate analyses of the products are presented in Tables II and III.

Table II

Proximate Analysis of Schnellkutter Emulsified Frankfurters Processed at less than 14 (L), 25 (M), and 50 (H) % R.H.[a]

Frank-furter	Test No.[b]	% Moisture			% Fat			% Protein			% Ash		
		L	M	H	L	M	H	L	M	H	L	M	H
A	1	55.6	56.2	61.9	24.7	26.7	20.7	13.7	11.8	12.9	3.3	3.2	2.8
	2	56.0	55.4	61.4	25.4	27.6	21.8	13.5	12.2	12.1	3.1	3.3	2.5
	3	57.4	56.4	60.7	24.4	25.4	19.8	13.6	12.7	13.5	3.3	3.3	2.9
	Avg.	56.3	56.0	61.3	24.8	26.6	20.8	13.6	12.2	12.8	3.2	3.3	2.7
B	1	51.7	49.5	49.8	31.5	36.7	36.4	11.7	9.6	10.0	3.2	2.9	2.8
	2	52.1	51.4	56.0	29.2	33.3	30.0	13.1	10.7	10.1	3.7	3.0	2.4
	3	54.3	-	57.4	27.9	-	27.8	12.2	-	10.7	3.2	-	2.6
	Avg.	52.7	50.5	54.4	29.5	35.0	31.4	12.7	10.2	10.3	3.4	3.0	2.6
C	1	55.0	53.9	52.8	27.3	29.3	28.3	12.2	11.8	11.7	3.3	3.2	2.6
	2	55.5	55.2	55.7	27.4	25.0	29.0	12.4	12.4	10.9	3.4	3.3	2.8
	3	57.9	54.2	53.1	24.4	27.3	32.1	12.8	12.0	11.2	3.1	3.3	2.7
	Avg.	56.1	54.6	53.9	26.4	27.2	29.8	12.5	12.0	11.3	3.3	3.3	2.7

[a] L, M, and H were prepared from separate meat blocks.

[b] 1, 2, and 3 refer to product prepared on successive days.

Table III

Proximate Analysis of Non-Vacuum Chopped Frankfurters[a]

Frank-furter	Test No.[b]	% Moisture	% Fat	% Protein	% Ash
A	1	53.0	31.5	10.9	3.1
	2	56.2	26.8	11.8	3.0
	3	56.7	25.5	12.7	3.0
	Avg.	55.3	27.9	11.8	3.0
B	1	52.6	32.5	10.3	2.9
	2	48.7	37.5	9.5	2.8
	3	54.3	30.0	11.1	3.0
	Avg.	51.9	33.3	10.3	2.9
C	1	54.4	28.1	12.3	3.0
	2	53.1	30.7	11.4	2.8
	3	57.5	25.0	12.1	2.8
	Avg.	55.0	27.9	11.9	2.9

[a]The frankfurters were processed at 25% R.H.

[b]1, 2, and 3 refer to product prepared on successive days. Each individual value represents the average analysis for the (2) Cut Mix (K.G.), (3) Cut Mix (K.G.) and Mincemaster, and (4) mixer and Mincemaster product from which the average of three replicates is given.

TENDERNESS AND RUBBERINESS

Methods. A penetrometer test was conducted on frankfurters to determine relative tenderness and rubberiness. For this purpose, an Instron Tensile Tester operating at 1 in/min and in later work, the Visking apparatus operating at 5 in/min were used to develop force-compression (stress-strain) data at the puncture of the frankfurter surface. Three frankfurters were used for each test, the tests being conducted at room temperature. Each frankfurter was probed three times in the transverse direction; i.e., the incisor surface long axis perpendicular to that of the frank longitudinal axis.

Taste panels were conducted on each of the sets and evaluated by a nine point hedonic scale. The skin, core, and whole frank were individually evaluated by this scale.

Results. The puncture modulus is defined as the ratio of force to compression. Modulus values have been determined as a function of emulsion composition, preparation, and processing humidity. The data are summarized in Tables IV, V, and VI.

Table IV

Instron Moduli and Force at Puncture as a Function of Vacuum Chopped Frankfurters Processed at ≤14% R.H.

Frankfurter	Test No.[a]	Frankfurter Emulsion Chopped At[b] 0 in. Mercury Modulus (lb/in)	0 in. Mercury Force (lb)	14 in. Mercury Modulus (lb/in)	14 in. Mercury Force (lb)	28 in. Mercury Modulus (lb/in)	28 in. Mercury Force (lb)
A	1	4.3	2.0	4.9	2.3	4.5	1.9
	2	4.2	1.7	4.5	1.9	5.7	2.3
	3	4.6	1.9	5.2	2.3	5.6	2.4
	Avg.	4.4	1.9	4.9	2.2	5.3	2.2
B	1	3.5	1.5	4.2	1.6	4.3	1.6
	2	3.0	1.2	3.4	1.4	3.9	1.7
	3	4.0	1.7	4.4	1.7	4.7	1.9
	Avg.	3.5	1.5	4.0	1.6	4.3	1.7
C	1	3.6	1.5	3.8	1.6	3.8	1.6
	2	4.1	1.6	4.0	1.7	4.3	1.7
	3	3.5	1.5	3.7	1.6	4.2	1.8
	Avg.	3.7	1.5	3.8	1.6	4.1	1.7

[a] 1, 2, and 3 refer to product prepared on separate days.

[b] Nine individual punctures (three per frank) are represented in each individual moduli and force value.

Table V

Instron Moduli and Force at Puncture as a Function of Vacuum Chopped Frankfurters Processed at 25% R.H.

Frankfurter	Test No.[a]	Frankfurter Emulsion Chopped At[b] 0 in. Mercury		14 in. Mercury		28 in. Mercury	
		Modulus (lb/in)	Force (lb)	Modulus (lb/in)	Force (lb)	Modulus (lb/in)	Force (lb)
A	1	3.0	1.2		1.6	3.3	1.4
	2	3.5	1.5	.5	1.4	3.9	1.6
	3	3.6	1.5	3.6	1.5	4.6	2.0
	Avg.	3.4	1.4	3.5	1.5	3.9	1.7
B	1	2.2	0.9	2.5	1.0	2.6	1.0
	2	2.8	1.1	2.8	1.2	3.1	1.2
	3	2.2	0.9	2.3	0.9	2.6	1.0
	Avg.	2.4	1.0	2.5	1.0	2.8	1.1
C	1	3.0	1.3	3.0	1.3	3.7	1.6
	2	3.9	1.7	4.1	1.8	4.3	1.7
	3	3.7	1.6	3.9	1.7	4.1	1.7
	Avg.	3.5	1.5	3.7	1.6	4.0	1.7

[a] 1, 2, and 3 refer to product prepared on separate days.
[b] Nine individual punctures (three per frank) are represented in each individual moduli and force value.

Table VI

Instron Moduli and Force at Puncture as a Function of Vacuum Chopped Frankfurters Processed at 50% R.H.

Frankfurter	Test No.[a]	Frankfurter Emulsion Chopped At[b] 0 in. Mercury Modulus (lb/in)	0 in. Mercury Force (lb)	14 in. Mercury Modulus (lb/in)	14 in. Mercury Force (lb)	28 in. Mercury Modulus (lb/in)	28 in. Mercury Force (lb)
A	1	2.4	0.9	2.9	1.1	3.0	1.0
	2	2.6	0.9	3.2	1.1	2.9	1.0
	3	3.2	1.4	3.3	1.2	3.5	1.2
	Avg.	2.7	1.1	3.1	1.1	3.1	1.1
B	1	1.7	0.6	2.2	0.8	1.9	0.7
	2	1.9	0.7	2.1	0.7	2.0	0.6
	3	2.4	0.9	2.5	0.9	2.6	0.8
	Avg.	2.0	0.7	2.3	0.8	2.2	0.7
C	1	3.2	1.3	2.8	1.1	3.0	1.1
	2	3.2	1.3	3.5	1.3	3.2	1.2
	3	2.9	1.1	2.8	1.0	3.0	1.0
	Avg.	3.1	1.2	3.0	1.1	3.1	1.1

[a] 1, 2, and 3 refer to product prepared on separate days.

[b] Nine individual punctures (three per frank) are represented in each individual moduli and force value.

Tables VII and VIII summarize moduli data determined with the Instron and Visking apparatus as a function of emulsion composition and preparation. Franks from the same run were tested on both instruments; i.e., test number 1 (Cut Mix) Table VII, same product as number 1 (Cut Mix) Table VIII.

Table VII

Instron Moduli and Force at Puncture as a Function of Frankfurter Emulsification Methods[a]

Frankfurter	Test No.[b]	Emulsification Method[c]					
		Cut Mix		Cut Mix and Mincemaster		Mixer and Mincemaster	
		Modulus (lb/in)	Force (lb)	Modulus (lb/in)	Force (lb)	Modulus (lb/in)	Force (lb)
A	1	3.3	1.3	3.0	1.2	3.3	1.4
	2	3.9	1.5	3.9	1.5	3.5	1.4
	3	3.8	1.5	3.9	1.4	3.8	1.3
	Avg.	3.7	1.4	3.6	1.4	3.5	1.4
B	1	2.2	0.8	2.4	0.9	2.1	0.8
	2	1.8	0.7	2.4	0.9	2.1	0.8
	3	3.4	1.4	3.6	1.5	3.1	1.3
	Avg.	2.5	1.0	2.8	1.1	2.4	1.0
C	1	3.4	1.4	4.0	1.6	3.5	1.5
	2	2.8	1.1	3.1	1.1	3.3	1.2
	3	4.1	1.6	4.1	1.7	3.1	1.2
	Avg.	3.4	1.4	3.7	1.5	3.3	1.3

[a]The frankfurters were processed at 25% R.H.

[b]1, 2, and 3 refer to product prepared on separate days.

[c]Nine individual punctures (three per frank) are represented in each individual moduli and force value.

Table VIII

Visking Penetrometer Moduli and Force at Puncture as a Function of Frankfurter Emulsification Methods[a]

Frankfurter	Test No.[b]	Emulsification Method[c]					
		Cut Mix		Cut Mix and Mincemaster		Mixer and Mincemaster	
		Modulus (lb/in)	Force (lb)	Modulus (lb/in)	Force (lb)	Modulus (lb/in)	Force (lb)
A	1	2.4	1.1	2.2	1.0	2.5	1.1
	2	3.1	1.4	2.8	1.2	2.6	1.2
	3	3.4	1.4	3.1	1.2	2.6	1.1
	Avg.	3.0	1.3	2.7	1.1	2.6	1.1
B	1	2.0	0.8	2.0	0.8	1.6	0.6
	2	1.4	0.5	1.9	0.8	1.6	0.6
	3	2.4	1.0	2.6	1.2	2.4	1.0
	Avg.	1.9	0.8	2.2	0.9	1.9	0.7
C	1	2.6	1.1	3.3	1.5	3.0	1.2
	2	2.2	0.8	2.7	1.0	2.5	1.0
	3	3.3	1.4	2.8	1.3	2.4	1.0
	Avg.	2.7	1.1	2.9	1.3	2.6	1.1

[a]The frankfurters were processed at 25% R.H.

[b]1, 2, and 3 refer to product prepared on separate days.

[c]Nine individual punctures (three per frank) are represented in each individual moduli and force value.

Taste panel scores for skin, core and whole frankfurters are summarized in Tables IX and X.

Table IX

Taste Panel Evaluation of Vacuum Chopped Frankfurters Processed at less than 14 (L), 25 (M), and 50 (H) % R.H.[a]

Frank-furter	Vacuum (in. Mercury)	Area Judged[b] Skin L	Skin M	Skin H	Core L	Core M	Core H	Whole Frank L	Whole Frank M	Whole Frank H
A	0	3.4	5.2	6.3	5.5	7.3	6.7	3.8	5.5	6.1
	14	3.2	5.2	6.1	5.4	7.1	6.3	3.2	5.3	5.8
	28	3.1	5.1	5.9	6.0	6.7	5.7	3.7	5.3	5.3
	Avg.	3.2	5.2	6.1	5.8	7.0	6.3	3.6	5.4	5.7
B	0	4.9	6.9	6.9	6.8	7.5	7.4	5.2	6.7	6.7
	14	5.1	6.5	6.9	6.9	7.1	7.3	5.4	6.5	7.1
	28	4.9	6.5	7.4	7.3	7.1	7.4	5.0	6.8	7.1
	Avg.	5.0	6.6	6.7	7.0	7.2	7.4	5.2	6.7	7.0
C	0	4.7	5.1	5.9	6.6	7.1	7.7	4.9	5.7	6.3
	14	5.0	5.3	7.1	6.7	6.9	7.9	5.2	5.8	7.2
	28	4.9	5.5	6.8	6.5	6.7	7.5	5.0	5.7	6.9
	Avg.	4.9	5.3	6.6	6.6	6.9	7.7	5.0	5.7	6.8

[a] L, M, and H were prepared from separate meat blocks.

[b] The specimens were rated from 1 (exceptionally tough) to 9 (exceptionally tender) by a five member taste panel and the average calculation of three replicates were combined to calculate each individual value shown from which the final average is given.

Table X

Taste Panel Evaluation of Non-Vacuum Chopped Frankfurters[a]

Frank-furter	Emulsification Method	Area Judged[b]		
		Skin	Core	Whole Frank
A	Cut Mix	4.6	7.0	5.2
	Cut Mix-Mincemaster	5.4	7.1	5.7
	Mixer-Mincemaster	6.0	7.3	6.3
	Average	5.3	7.1	5.7
B	Cut Mix	6.3	7.3	6.1
	Cut Mix-Mincemaster	6.0	7.1	6.1
	Mixer-Mincemaster	6.9	7.7	6.7
	Average	6.4	7.4	6.3
C	Cut Mix	6.1	7.0	5.9
	Cut Mix-Mincemaster	5.2	6.9	5.3
	Mixer-Mincemaster	6.4	7.5	6.5
	Average	5.9	7.1	5.9

[a]The frankfurters were processed at 25% R.H.

[b]The specimens were rated from 1 (exceptionally tough) to 9 (exceptionally tender) by a five member taste panel and the average calculation of three replicates were combined to calculate each individual value shown from which the final average is given.

The data listed in Tables IV thru VIII indicate that emulsions containing a greater percentage of muscle protein vs. fat processed under otherwise similar processing conditions will be tough relative to lower muscle protein emulsions. Tenderness or toughness are related to quality of skin formation due to variables such as muscle protein content, smoke, relative humidities, air flows, and processing times and temperatures. The data indicate that the degree of firmness as characterized by degree of vacuum at which the product was prepared will be reflected in the puncture modulus. It was further indicated that the most spongy or rubbery product, all other variables being similar, will be the product produced without vacuum. An increase in processing humidity resulted in a corresponding increase in product tenderness. The data (Tables V and VII) indicate that, disregarding evacuated products, the emulsification method was not reflected in the puncture moduli.

The taste panel scores indicate that the high fat content frankfurters possess a more tender skin as well as core. The fact that the whole-frank panel scores are almost identical to those for the skin alone would imply that the tenderness of a frankfurter is judged primarily as a function of the tenderness of its skin. Processing humidity variations were not readily differentiated by the panel.

The data (Tables VII and VIII) indicate that the Visking apparatus gave proportional moduli to that of the Instron. The Instron to Visking moduli ratio becomes a factor of $1.3 \pm .1$ standard deviation. The correlation coefficients of instrument moduli to taste scores and instrument to instrument were calculated and are summarized in Table XI.*

The correlation coefficient (r) between the Instron and Visking apparatus puncture test moduli was .947 for the average of three replications. An (r) value of 1.0 or -1.0 is perfect correlation.

*Ezekial, M., and Fox, K. A., (1959) "Methods of Correlation and Regression Analysis," 3rd ed., John Wiley and Sons, Inc., New York.

Table XI

Correlation Coefficients (r) of Puncture Moduli and Taste Panel Score Evaluations

	Taste Scores[a]		Puncture Moduli (Visking) Table VIII
	Whole Frank	Frank Skin	
Puncture Moduli (Instron) Table VII[b]	-.727	-.758	.947
Puncture Moduli (Visking) Table VIII[c]	-.795	-.837	
Puncture Moduli (Instron) Tables IV-VI[d]	-.873	-.917	

[a]Taste scores of the whole frankfurter and skin correlated with respect to moduli for given product.

[b]Puncture moduli of non evacuated product tested on the Instron.

[c]Puncture moduli of non evacuated product tested on the Visking apparatus.

[d]Puncture moduli of Schnellkutter product processed at three humidity levels tested on the Instron.

The (r) data (Table XI) indicate good correlation also existed between the Instron Puncture values and taste panel scores for rubberiness and tenderness of frankfurters. The correlation coefficient between Instron puncture moduli (Tables IV, V, and VI) and whole frankfurter taste panel scores (Table IX) was -.873 and -.917 for the moduli versus frankfurter skin panel scores. The (r) between Instron puncture moduli (Table VII) and whole frankfurter taste panel scores (Table X) was -.727 and -.758 for the moduli verses frankfurter skin panel scores. The (r) between Visking apparatus puncture moduli (Table VIII) and whole frankfurter taste panel scores (Table X) was -.795 and -.837 for the moduli versus frankfurter skin panel scores.

Equipment. The photograph (Figure 1) represents an instrument (Visking) built to perform the frankfurter puncture test featuring:

(a) a constant (5.0 inches/minute) driving mechanism;

(b) an accurate force transducer (balance counter weight system);

(c) an accurate (gear train) compression transducer; and

(d) an incisor type probe, commercially available from The Hunter Spring Company, Lansdale, Pennsylvania.

The equipment, upon being subjected to comparative evaluation with the Instron, was found to perform the operations with precision and accuracy.

APPARENT DENSITY

Method. The method selected for measuring frankfurter density is based on a measurement of the volume of water displaced in a graduated vessel by a sample of known mass. The apparent density is calculated by dividing the sample weight by the volume of water displaced by the sample. The method is accurate to within $\pm$ 1%.

Results. Apparent densities have been measured as a function of emulsion composition, preparation, and processing humidity. Ten individual measurements of density were made on each of three replications of the various combinations. The data are summarized in Tables XII and XIII.

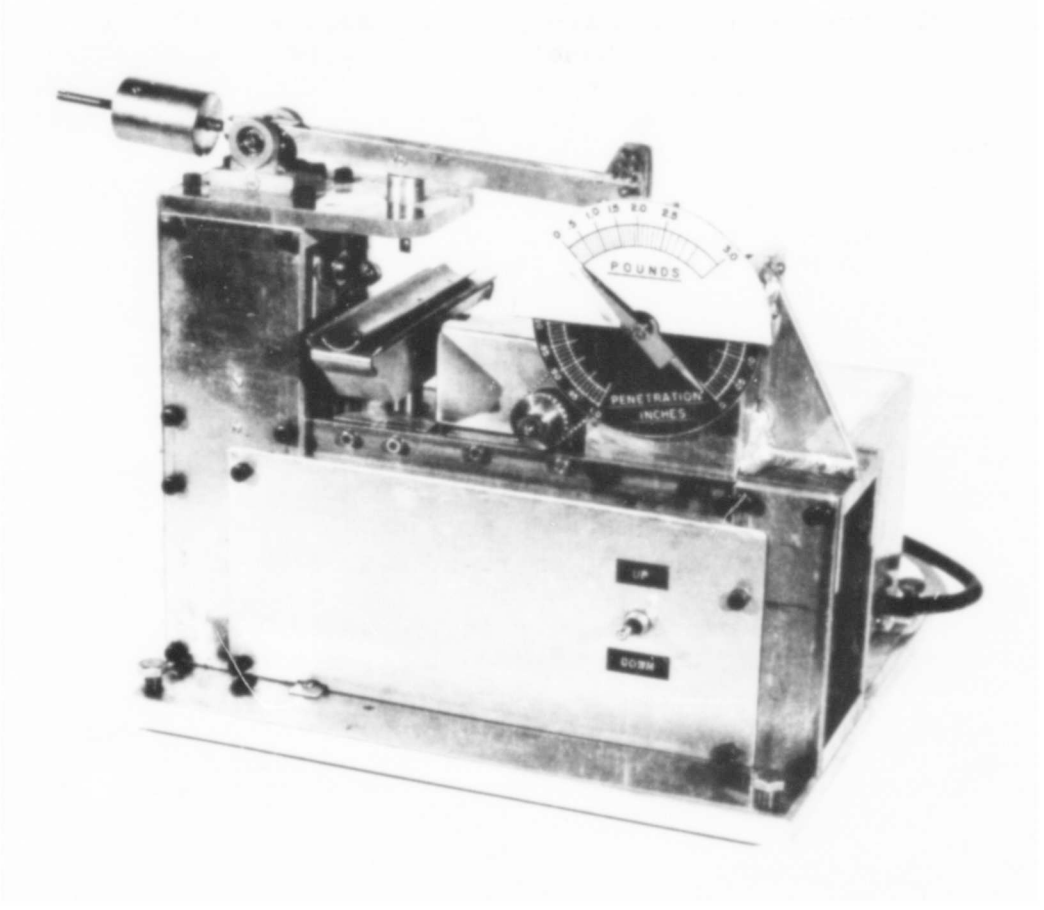

Figure 1. Instrument for frankfurter puncture test

Table XII

Apparent Densities of Vacuum Chopped Frankfurters Processed at less than 14 (L), 25 (M), and 50 (H) % R. H.[a]

Frankfurter	Test No.[b]	Emulsion Chopped at[c] 0 in. Mercury L (g/cc)	0 in. Mercury M (g/cc)	0 in. Mercury H (g/cc)	14 in. Mercury L (g/cc)	14 in. Mercury M (g/cc)	14 in. Mercury H (g/cc)	28 in. Mercury L (g/cc)	28 in. Mercury M (g/cc)	28 in. Mercury H (g/cc)
A	1	0.93	0.96	0.96	0.99	1.01	0.99	1.06	1.06	1.05
	2	0.94	0.95	0.96	0.99	1.00	1.01	1.06	1.06	1.05
	3	0.97	0.93	0.95	1.02	1.00	1.00	1.06	1.07	1.06
	Avg.	0.94	0.95	0.96	1.00	1.00	1.00	1.06	1.06	1.05
B	1	0.94	0.91	0.94	1.00	0.97	0.99	1.05	1.04	1.02
	2	0.92	0.92	0.92	0.98	0.96	0.99	1.05	1.04	1.03
	3	0.94	0.91	0.92	1.01	0.98	0.99	1.05	1.03	1.03
	Avg.	0.93	0.91	0.93	0.99	0.97	0.99	1.05	1.04	1.03
C	1	0.92	0.92	0.99	0.99	0.97	1.00	1.06	1.05	1.03
	2	0.92	0.91	0.94	0.99	0.97	1.01	1.06	1.05	1.04
	3	0.95	0.92	0.93	1.00	0.97	0.98	1.06	1.06	1.01
	Avg.	0.93	0.92	0.95	0.99	0.97	1.00	1.06	1.05	1.03

[a] L, M, and H were prepared from separate meat blocks.

[b] 1, 2, and 3 refer to product prepared on different days.

[c] Ten individual measurements on each set were combined to calculate the value shown for each combination of composition, preparation, and processing humidity.

Table XIII

Apparent Densities of Non-Vacuum Chopped Frankfurters[a]

Frankfurter	Test No.[b]	Emulsification Method[c] Cut-Mix (g/cc)	Cut Mix and Mincemaster (g/cc)	Mixer and Mincemaster (g/cc)
A	1	0.94	0.95	0.97
	2	0.93	0.96	0.98
	3	0.94	0.94	0.99
	Avg.	0.94	0.95	0.98
B	1	0.92	0.93	0.97
	2	0.94	0.94	0.97
	3	0.93	0.96	0.96
	Avg.	0.93	0.94	0.97
C	1	0.93	0.93	0.98
	2	0.92	0.95	0.94
	3	0.92	0.94	0.95
	Avg.	0.92	0.94	0.96

[a] The frankfurters were processed at 25% R.H.

[b] 1, 2, and 3 refer to product prepared on different days.

[c] Ten individual measurements on each set were combined to calculate the values shown for each combination of composition, preparation, and processing humidity.

The data listed in Tables XII and XIII indicate that apparent density of the frankfurter was essentially unrelated to the emulsion composition and processing humidity, probably because of the low sensitivity of the measuring technique. Density was proportional to the amount of vacuum applied during preparation of the emulsion.

Air evacuation during emulsification (Schnellkutter) resulted in final densities of greater than 1.0 for these formulations while visually reducing the size and number of voids in the meat mass. The data, excluding evacuation products, indicate that emulsification via the mixer and Mincemaster resulted in a relatively dense product.

These results further suggest that the apparent density was related to the quantity of air entrapped in the sample thereby indirectly measuring this aspect of frankfurter quality.