Texture and Sensory Evaluations of Frankfurters Made with Different Formulations and Processes

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ABSTRACT

Objective tests for frankfurter textural properties were investigated by varying formulations and processing parameters and then correlating nine sensory textural attributes with eleven instrumental methods. The most discriminative instrumental parameters were compressive force at failure, compressive force at 50% deformation without failure, and maximum shear force. High correlations ($r > 0.80$) were found between compressive forces or shear force and sensory elasticity, firmness, and chewiness; stress relaxation and elasticity; total expressible fluid and juiciness; and expressible moisture and wateriness. Elastic recovery did not correlate with any sensory characteristic.

INTRODUCTION

THE SENSORY QUALITY of 53 commercial brands of frankfurters made from beef, pork, and chicken showed extreme texture variability (Anonymous, 1980) indicating the importance of controlling ingredients and processes to achieve a desired product quality. This requires objective and instrumental techniques to measure various aspects of texture. Ackerman et al. (1971) and Lee et al. (1981a) characterized emulsions by size of fat droplets and Jones and Mandigo (1982) by the thickness of the aggregated protein layer. Townsend et al. (1971) measured raw emulsion viscosity with a Brookfield viscometer and skin strength and elasticity with an Instron Universal Testing Machine. Lee et al. (1981b) correlated compressive force and shear force to the hardness of the fat. Fish loaves were characterized by compression, tensile and relaxation measurements (Weinberg and Angel, 1984). Cooking treatments of comminuted meat products with soy protein were evaluated with a Haake Rotovisco (Bianchi et al., 1985) and frankfurters with an Instron and texture profile analysis (TPA) (Singh et al., 1985). None of these studies evaluated a wide range of sensory qualities or tested their relationships to instrumental techniques.

Several investigators have attempted to measure the texture of commercial frankfurters by various shear, compression, and relaxation tests and to relate these values to a limited range of sensory qualities (Voisey et al., 1975; Huang and Robertson, 1977; Prusa et al., 1982). Using a tooth-shaped puncture probe, Simon et al. (1965) correlated a puncture moduli calculated from force vs distance at failure to sensory panel toughness. Baker et al. (1969, 1972) noted a parallel between sensory toughness and Kramer shear but did not directly correlate them. Carpenter et al. (1966) found a low correlation between Warner-Bratzler or Kramer shear and panel evaluations of tenderness in frankfurters made with different meats and fat types. Keeton et al. (1984) added nonmeat proteins and STPP and varied processing temperatures in frankfurters. They reported that the TPA and sensory panel appeared to be measuring different textural attributes. Montejano et al. (1985) found the best correlations between torsion measurements or TPA and sensory evaluations of protein gels were between true shear strain at failure and TPA cohesiveness and sensory firmness and chewiness. Sensory moisture release was poorly correlated to instrumental techniques. Brady et al. (1985) found some relationships between five TPA parameters and eight sensory traits in beef loaves. However, they conclude further research is needed.

With the increasing variety of ingredients, new processing techniques, and desire to manufacture products with reduced levels of salt and fat, there is a need for more comprehensive instrumental techniques that are known to correlate with perceived sensory attributes. The objectives of this study were to correlate eleven instrumental techniques for measuring textural attributes with nine sensory attributes plus overall textural desirability.

MATERIALS & METHODS

Sample preparation

Frankfurters were manufactured to possess textural differences representative of those present in commercial products. Texture was altered by varying the level of fat and moisture, chopping time, hardness of fat, and rate of cooking. Fresh boneless beef round (3.8% fat), 50/50 beef trimmings, and pork adipose tissue (93.1% fat) were obtained from local abattoirs. Adipose tissue, hand-separated from beef trimmings, was used as a source of beef fat (72.5%). All meats were ground through 1/2 and 3/16 inch plates and stored at 1°C until used. The standard 11 kg batch of frankfurter batter contained 44.8% beef, 22.4% beef or pork adipose tissue, 28.7% ice, 1.68% salt, 1.32% sugar, 1.00% spice, 0.010% sodium nitrite, and 0.036% sodium ascorbate. The ground beef was chopped at low speed (1750 rpm) in a Schnellkutter (Stephen-Koch 25L) for 2 1/2 min with salt, spice mixture, sugar, cure, and half of the ice. Adipose tissue and remaining ice were added and the batter was chopped under vacuum at high speed (3,500 rpm) until the temperature reached 16°C. The batters were stuffed into cellulose casings (23 mm diameter), linked into 12.7 cm lengths, and cooked in a smokehouse with wood smoke and temperature-humidity control until thermocouples inserted into the center of the frankfurters indicated that the internal temperature reached 71°C. They were immediately cooled with a cold water shower and stored at 1°C for sensory and instrument analyses.

Formulation and processing parameters

In the first experiment, the chopping time ranged from 3.5 to 11.5 min (11–14 min normal times) to vary comminution of muscle tissue and the extent of protein solubilization. The different times to reach 16°C were achieved by replacing ice with appropriate amounts of cold water. In the second experiment, moisture levels were adjusted to 61–71% by varying the amount of added ice. For 71% moisture, water, in addition to the standard amount, was added as cold water so that the batter reached 16°C within a 16 min chopping period. In the third experiment, the fat levels were varied from 17–31% by adding different amounts of pork adipose tissue. For the fourth experiment, the influence of fat hardness was studied using pork fat (soft), 1:1 beef-pork fat mixture (medium hard), and beef fat (hard) (Lee et al., 1981a). Finally, normal and fast cooking cycles were used. The normal process was 10 min at 55°C dry bulb (DB) with wood smoke, 20 min at 63°C DB and 55°C wet bulb (WB), 35 min at 77°C DB and 60°C WB, followed by a short 82°C DB and 60°C WB, if needed, to achieve 71°C internal temperature. The fast cooking cycle consisted of 10 min at 55°C DB with wood smoke, 10 min at 74°C DB and 60°C WB, followed by 19.5 min at 82°C WB and 60°C WB.

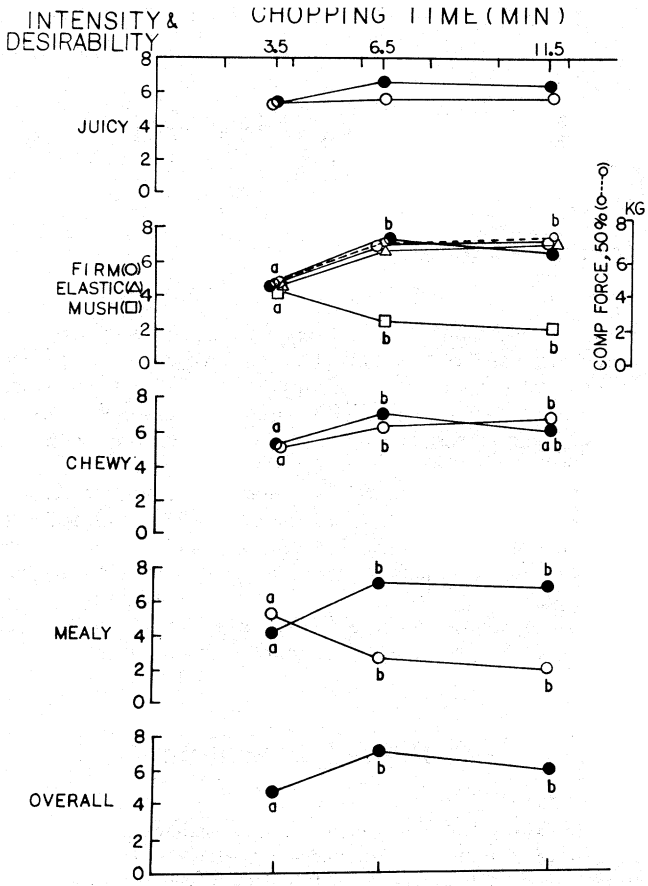

Fig. 1—Effect of chopping time on intensity and desirability of texture. Sensory intensity (—o—), sensory desirability (—•—), compressive force (---o---). A single designation is used for firmness, elasticity, desirability of firmness, and compressive force. Lowest intensity or least desirable = 0; greatest intensity or most desirable = 10. Points on a line with different letters are significantly different ($p<0.05$).

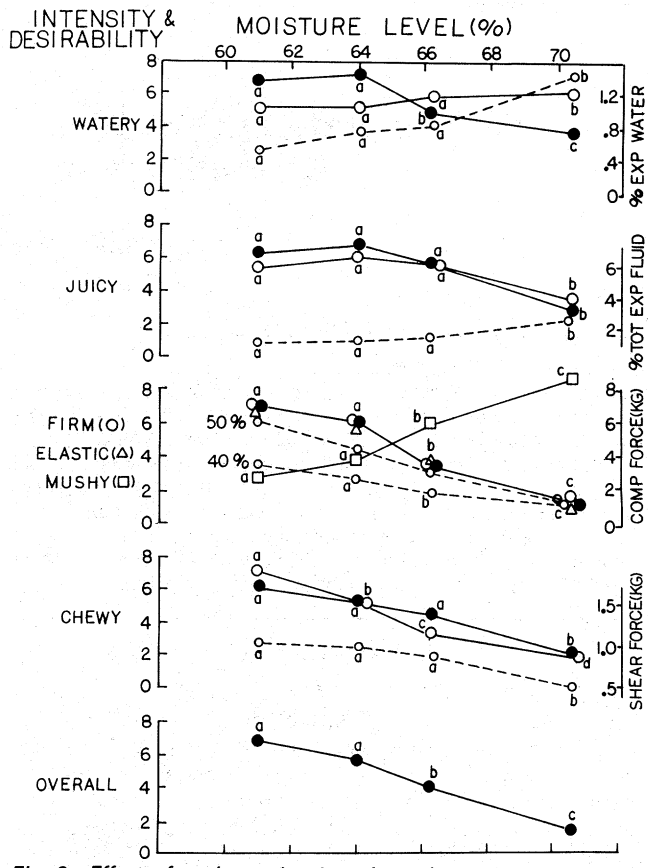

Fig. 2—Effect of moisture level on intensity and desirability of texture and instrumental parameters. Sensory intensity (—o—), desirability (—•—), instrumental parameters (---o---). A single line is used jointly for firmness, elasticity and desirability of firmness. Points on a line with different letters are significantly different. ($p<0.05$).

Proximate analyses

Moisture, ash, and protein (N × 6.25) contents of the frankfurters were determined following AOAC methods (1975). Fat content was determined by a modified Bligh and Dyer method (Lee et al., 1981b).

Sensory evaluation

Texture evaluation was conducted by a panel of 15 adults from the USDA Eastern Regional Research Center who were experienced with sensory evaluations. After a training session to familiarize them with the products and terminology, they were asked to score nine textural characteristics for intensity, and the desirability of that intensity. They were also asked to evaluate overall desirability.

Wateriness was defined as an initial sensation of very loose water having a short duration (e.g. a wet sponge) while juiciness was characterized as a sensation of a progressive increase in the free fluids in the oral cavity during mastication (Jowitt, 1974). Firmness was the initial resistance to bite, elasticity the amount of yielding or rubberiness before rupture. Coarseness referred to the size of particles after initial mastication, while chewiness was the length of time required to masticate the sample for swallowing (Civille and Szczesniak, 1973). Mealiness was defined as the presence of components of different degrees of firmness or toughness (Jowitt, 1974). Greasiness was the feeling of fat in the mouth.

Frankfurter samples, 6.3 cm long, were heating by immersion in boiling water and served hot to the panelists (Whiting and Jenkins, 1981). Panelists were given a maximum of three samples at a session, one of which was the standard formulation and process. The frankfurters were evaluated in individual booths under incandescent lighting. Both intensity and desirability of each textural characteristic were scored on an open scale consisting of a 10 cm line. Each marked point was converted into a numerical value from 0 to 10 according to its location with 0 being low on the intensity scale or undesirable on the desirability scale.

Instrumental evaluation of texture

Eleven testing techniques using the Instron Universal Testing Machine (Model 1122) were: failure point (force and strain at failure or 70% compression), time to rupture (Lee and Patel, 1984), resistance at 40% compressive deformation, resistance at 50% deformation, expressed water at 70% compression as a percentage of the sample weight, percentage expressed fat at 70% compression, percentage of expressed water and fat at 70% deformation, elastic recovery, relaxation rate, shear force at initial failure, and maximum shear force. Five replicate measurements were made for all tests except for the relaxation test which was done in triplicate.

For instrument evaluation, the whole frankfurter was heated to 45°C (internal temperature) by steam and cut into cylindrical pieces (length = diameter = 20 mm) immediately prior to testing. All Instron measurements were done at room temperature at a deformation rate (crosshead speed) of 50 mm/min and a chart speed of 100 mm/min. The maximum force at failure or 70% deformation if the product was too mushy to exhibit a failure point was recorded. The force required to compress a specimen 50% and 40% was also determined. A cyclic compression test was carried out to determine elastic recovery in addition to compressive force at 40% deformation which was measured after the first compressive cycle. Elastic recovery after the second compression cycle was measured as follows, elastic recovery = 100 − % plastic deformation, where plastic deformation = (permanent deformation ÷ compressive deformation) × 100. To determine the relaxation rate, the specimen was compressed until a force of 1.5 kg was obtained. The crosshead was stopped and the reduction in force was followed with time. The stress relaxation rate was the log-log slope of the force-time curve with 1.5 kg set at 0.1 sec.

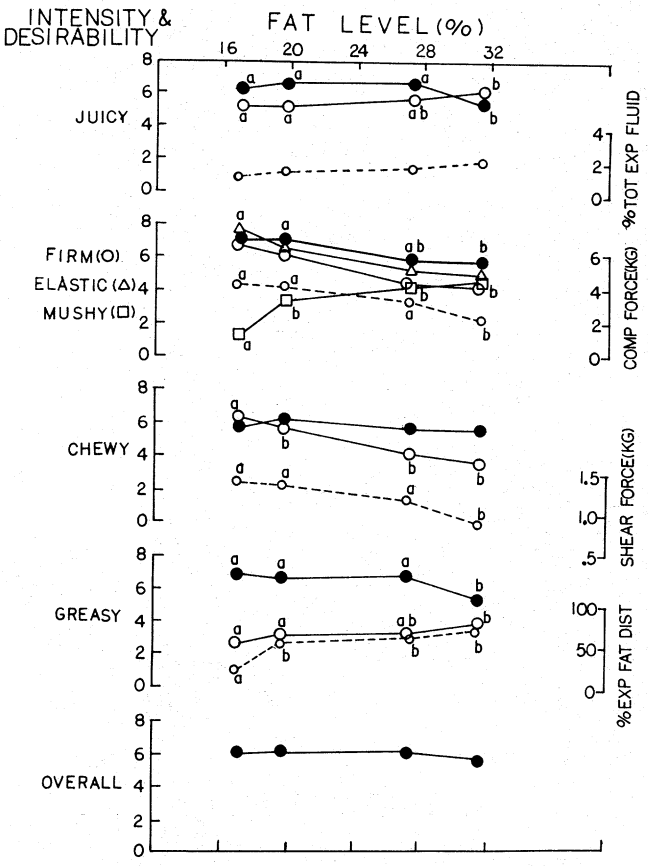

Fig. 3—Effect of fat level on intensity and desirability of texture. Sensory intensity (—○—), desirability (—●—) and instrumental parameters (---○---). Points on a line with different letters are significantly different (p<0.05).

Expressible fluids were measured by placing a preweighed sample (9-10 g) between 3 layers of preweighed Whatman #4 filter paper (9 cm diameter) on the Instron and compressing 14 mm along the sample's 20 mm axis at a rate of 50 mm/min. Total expressible fluid as a percentage of the sample was determined by reweighting the filter papers. The filter papers were then dried overnight at 100°C and reweighed to determine the expressible fat. The difference between total expressible fluids and expressible fat was expressible moisture. Preliminary trials showed that salt and ash made an insignificant contribution to these weights. Expressible water and fat are given as a percentage of the total expressible fluid.

In the shear tests, a frankfurter was sheared longitudinally by a descending flat blade (1 mm thick) while the sample rested on a stationary plate. Initial and maximum peak heights were taken from the chart.

Statistical analyses

For each of the five experiments, simple linear correlation coefficients were determined between intensity and desirability characteristics. One-way analysis of variance was conducted for each characteristic by assigning a value of zero to the standard frankfurter's score for each panelist and taking the arithmetic difference to the other values. Combining all the experiments, means of individual panel scores for each frankfurter and instrumental value were correlated to determine how well the instrumental method could be expected to predict a particular sensory characteristic.

RESULTS & DISCUSSION

Chopping time

Underchopping the batter with resulting poorer protein extraction and gel formation was readily perceived by the panel. Increasing the chopping time from 3.5 to 6.5 min significantly increased the intensity scores for firmness, chewiness, and elasticity (Fig. 1) and decreased scores for mealiness. No further increases in intensity of these characteristics were perceived with 11.5 min chopping. Changes in desirability scores paralleled intensity scores. Overall desirability was highest in frankfurters chopped 6.5 min. There was a high correlation between intensity of firmness and compressive force at 50% deformation (r = 0.96). Compression to failure and shear force were not as well related to changes resulting from degree of chopping. Values from failure tests may be too dependent on the weakest portion of the sample where rupture begins and spreads rapidly throughout the sample. The force at 50% deformation, on the other hand, appears to be a function of the structural integrity of the sample.

Moisture level

An increase in moisture level above 64% in the final product markedly reduced overall desirability of the frankfurters by affecting most sensory and instrumental values (Fig. 2). The panelists distinguished an increasing wateriness and decreasing juiciness and clearly differentiated between the two characteristics. The panel strongly preferred an elastic frankfurter as indicated by the correlation between intensity of elasticity and desirability of elasticity (r = 0.98) and overall desirability (r = 0.99). The intensity and desirability of firmness, elasticity, and chewiness declined when moisture content exceeded 66%.

The intensity of wateriness correlated most highly with the percentage of expressible water (r = 0.89). A high correlation (r = 0.90) also existed between chewiness and maximum shear force. A strong correlation existed between the intensity of firmness and compressive force at both 40% (r = 0.94) and 50% (r = 0.97) deformation. The stress relaxation values also significantly increased from 0.16 to 0.24 kg/min with increasing water content indicating the usefulness of nonfailure test methods. The intensity of elasticity was negatively correlated with stress relaxation rate (r = −0.95) at moisture levels ranging from 64–71%.

Fat level

Intensity of juiciness significantly increased when the fat level increased from 27 to 31% (Fig.3). The maximum desirability of juiciness was attained at fat levels of 20 to 27% and significantly declined at 31% despite increasing scores for intensity of juiciness. This is the only instance where desirability

Table 1—Effect of fats of different hardness on intensity and desirability of textural characteristics

	Source of fat	Hardness index (cm^{-1})	Textural characteristics[a]					Overall desirability[c]
			Juiciness	Firmness	Elasticity	Chewiness	Coarseness	
Intensity	Beef	2.20	5.28	7.96[a]	7.22	6.96[a]	5.55	
	Beef-Pork	1.43	5.57	6.42[b]	5.82	5.59[b]	4.58	
	Pork	0.99	6.27	6.02[b]	6.98	5.86[b]	5.15	
Desirability	Beef	2.20	5.81	6.33	6.19	5.22	5.47[a]	5.21
	Beef-Pork	1.43	5.98	5.74	5.30	6.18	5.28[a]	4.68
	Pork	0.99	6.25	6.38	6.36	6.21	6.68[b]	6.09

[a,b] Intensity or desirability values in each column with different superscripts are significantly different (p<0.05). 0 = low intensity; 10 = greatest intensity
[c] Hedonic scores: 0 (dislike intensely) to 10 (like intensely)

Table 2—Effect of cooking rate on textural and physical properties of frankfurters

	Cooking rate	Sensory score[a]							Overall score[b]
		Wateriness	Juiciness	Firmness	Elasticity	Chewiness	Cohesiveness	Mealiness	
Intensity	Slow	4.38	6.34	7.49	7.21	7.26	5.58	3.25	
	Fast	5.03	5.96	7.59	7.27	7.04	4.66	2.94	
Desirability	Slow	7.21*	6.91*	6.95	6.44	6.18	5.93	6.42*	6.72*
	Fast	6.31*	6.19*	6.24	6.25	5.92	5.77	6.09*	6.22*

	Smoke-house loss (%)	Physical properties											
		Strain	Rupture time (sec)	Compressive Force (kg)			Shear force (kg)		Expressible fluid (%)			Elastic recovery (%)	Relaxation rate (kg/sec)
				40%	50%	70%	Initial	Final	TEF[c]	EW[d]	EF[e]		
Slow	13.9*	0.534	14.7	4.12*	5.66	6.38	1.00	1.31	1.22*	55.0	45.0	86.3	−0.17
Fast	10.3*	0.533	14.1	3.44*	5.28	6.60	0.98	1.32	0.73*	48.4	51.6	82.4	−0.15

* Significantly different values between fast and slow cooking rate ($p<0.05$).
[a] 0 = lowest intensity; 10 = greatest intensity
[b] 0 = least desirable; 10 = most desirable
[c] TEF = Total expressible fluid
[d] EW = Proportion expressible water
[e] EF = Proportion expressible fat

Table 3—Comparison of various instrumental tests for their discriminative ability

Type of tests	F-value
Compression	
Compressive force at failure (70% deformation)	39.46
Compressive force without failure	
50% deformation	33.49
40% deformation	17.01
Strain at failure	6.72
Rupture time	6.78
Total expressible fluid at 70% deformation	11.41
% Expressible water	6.15
% Expressible fat	6.13
Elastic recovery	1.20
Relaxation rate	3.06
Shear	
Shear force	
Initial peak	15.64
Maximum peak	34.76

* F value at $P=0.05$ and degrees of freedom = 64.

of a trait increased and then decreased with increased intensity. Commercial beef-pork frankfurters generally contain 23 to 29% fat (Lee and Patel, 1984). The percentage of total expressible fluid gave the highest correlation with the intensity of juiciness ($r = 0.94$). This confirms previous work which found a correlation of 0.92 (Lee and Patel, 1984).

Firmness, elasticity and chewiness significantly decreased and mushiness increased with increasing fat content. Intensity of firmness was correlated with compressive force at 40% deformation ($r = 0.88$).

Intensity of chewiness was significantly reduced with an increase in fat level, while desirability decreased slightly. Apparently chewiness was not a highly important factor in frankfurter acceptability. The intensity of greasiness increased significantly with a concomitant decrease in desirability when the fat content reached 31%. Greasiness was moderately correlated with percentage of expressed fluid ($r = 0.87$). Interestingly, changes in overall desirability were nonsignificant on the range of fat levels studied, all were judged to be good frankfurters (scores approximately 6).

Fat hardness

The hardness indices (reciprocal of penetration distance, Lee et al., 1981a) of pork fat, beef-pork fat mixture, and beef fat were 0.99, 1.43, and 2.20 cm^{-1}, respectively. Frankfurters with softer fat were perceived as less firm and less chewy (Table 1). A similar observation was made when soybean oil-based fats of different hardnesses were incorporated into meat emulsions (Lee et al. 1981a). Our compressive and shear force measurements were significantly higher with beef fat frankfurters. Slope relaxation values were not significantly different.

Townsend et al. (1971) reported that elasticity, measured as the ratio of energy expended during a 33% compression to the energy recovered after deformation, decreased as fat hardness increased from cottonseed oil to pork fat to beef fat. However, desirability of firmness and chewiness and overall desirability was not significantly affected by the range of fat hardness used this study.

Cooking rate

No significant differences in the intensity of any sensory attribute were found between two cooking rates (Table 2). However, the panel scored the slowly cooked frankfurters significantly more desirable for wateriness, juiciness, mealiness, and overall desirability. The sensory scores for wateriness and juiciness were supported by a higher total expressible fluid. Significantly greater smokehouse water loss may have led to

Table 4—Correlation coefficients between the intensity of textural characteristics and physical parameters[a]

Intensity of textural characteristics	Compressive force			Expressible fluid[b]			Shear force		Relax rate	Protein (%)
	70%	50%	40%	TEF	EW	EF	Initial	Max		
Wateriness	—	—	—	—	0.87	—	—	—	—	—
Juiciness	—	—	—	0.84	—	0.77	—	—	—	—
Firmness	0.83	0.83	0.74	—	—	—	0.82	0.83	0.78	0.81
Elasticity	0.91	0.79	0.70	—	—	—	0.82	0.81	0.80	0.80
Coarseness	—	—	—	—	—	—	0.71	0.75	—	—
Chewiness	0.87	0.87	0.79	—	—	—	0.86	0.86	—	0.85
Mushiness	−0.79	−0.79	−0.70	—	—	—	−0.75	−0.74	−0.84	0.72
Greasiness	—	—	—	—	—	0.88	—	—	—	—

[a] Correlation coefficients were computed using data from all formulations ($p<0.05$).
[b] Factors are defined in Table 2.

the greater 40% compression force values but any differences were not perceived by the sensory panel.

Overall instrumental abilities

The overall ability of the instrumental tests to detect differences in composition or processing parameter was compared in terms of the F value in Table 3. The most discriminative tests were compressive force at failure and at 50% deformation without failure, and shear force at maximum peak height. Tests with moderate discriminative ability were compressive force at 40%, total expressible fluid, and shear force at initial failure.

When the sensory and instrumental data from the five experiments were pooled, significant correlations between the intensity of textural characteristics and instrumental values showed a clustering into two broad groups of attributes (Table 4). Compressive and shear forces and relaxation rates were highly correlated to firmness, elasticity, and chewiness and negatively correlated to mushiness. Elastic recovery did not correlate with any sensory characteristics. The expressible fluid measurements could evaluate wateriness, juiciness and greasiness. Mealiness was only correlated to 70% compressive force ($r = -0.77$).

The correlations for 40 and 50% compressive forces and stress relaxation rates to sensory properties are of note because these are nondestructive tests and involve fundamental measures of a gel-like material (Rizvi, 1981; Peleg, 1983). Tests such as shear and puncture which traditionally have been used for evaluating meat products involved an undetermined combination of true shear, compression, and tensile forces. Although shown to correlate well with sensory evaluations, shear and puncture tests do not have the potential to reveal basic molecular characteristics of a meat product.

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