

## PHYSICAL AND SENSORY PROPERTIES OF MEATSTICK PRODUCTS AS AFFECTED BY FORMULATION AND DRYING: SENSORY-INSTRUMENTAL RELATIONSHIPS

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### ABSTRACT

*Shelf-stable meats are of interest to industry and are important in military ration development. Stability is commonly achieved through control of pH and water activity. However, reduction in moisture as a means to lower  $a_w$  can significantly affect texture. Other ingredients, such as fat, can also potentially affect texture and possibly mitigate hardening due to lowered moisture. Meatsticks dried to three water activities, 0.88, 0.90, and 0.92, each from batters at three fat levels, 14, 17, and 21%, were produced, yielding products varying in both moisture and fat content. Products were subjected to mechanical and sensory testing and image and color analysis. Meatstick modulus, shear force,  $L^*$  value, and percent of area of cut surfaces covered by separated fat were correlated with sensory assessments of interior hardness, hardness with skin, color, and visual fat, respectively. These parameters were significantly influenced by composition, particularly fat and protein contents and fat-protein interaction.*

### INTRODUCTION

Shelf-stable foods are increasingly in demand commercially and are of great importance to the military, which has stringent shelf-life requirements. Additionally, there is a current effort to provide more "fresh-like", minimally processed ration items. Shelf-stable sandwiches comprise a major category in

this area. These items consist of water activity-controlled bread containing a similarly water activity-controlled meat filling. However, textural effects due to lowered water activity can be significant, and can be complicated by the presence of other ingredients.

Lowering water activity by reducing moisture content in a polymeric matrix generally produces a firmer product with increased glass transition temperature (Levine and Slade 1992), although this effect can be partially mitigated by non-water ingredients that function as plasticizers (Barrett *et al.* 1995; Kalichevsky *et al.* 1992, 1993; Ollette *et al.* 1991). Lowered moisture content in processed meats has been shown to produce firmer or less deformable products (Barrett *et al.* 1998; Chen *et al.* 1993; Claus *et al.* 1989). However, Barrett *et al.* (1998) showed that firming due to reduced moisture could be lessened by the addition of glycerol.

Reports of the effects of fat level on processed meat texture have varied. Several investigators have reported decreased firmness upon reduction of fat in frankfurter and sausage products (Cofrades *et al.* 1997, 2000; Crehan *et al.* 2000; Carballo *et al.* 1996 a, b; Shand 2000; Fernandez *et al.* 1996; Claus and Hunt 1991; Foegeding and Ramsey 1987), usually attributed to higher moisture content in the reduced fat product, as fat is replaced by water. However, Park *et al.* (1989, 1990), Barbut and Mittal (1996) and Mittal and Barbut (1993), using Texture Profile Analysis, and Hand *et al.* (1987), using shear tests, reported increased resistance to deformation or failure in lower fat frankfurters. Bishop *et al.* (1993) determined that the effect of fat reduction on firmness depended on whether fat was replaced by water.

The microstructure of processed meats (wieners) was studied by Kempton and Krupp (1983), who described the organization of these products as fat globules encased in a protein matrix. These authors furthermore described a seemingly "inverted" structure in highly-chopped products in which fat comprised a nearly continuous phase.

Our objectives in the present research were to test an array of meatstick products in which fat and moisture levels varied and to determine: relationships between product physical/sensory properties and composition; relationships between instrumental and sensory properties; and which sensory properties most influenced how close a product was to a panel-determined "ideal" sensory profile.

### MATERIALS AND METHODS

#### Meatstick Production

Meatsticks were produced at Goodmark Foods Co. (Garner, NC) from the formulation shown in Table 1. Lean beef (15% fat; 65% moisture; 18%

protein), pork trimmings (50% fat; 39% moisture; 10% protein), and other ingredients were mixed in ratios to produce raw batters calculated to contain 14, 17 and 21% fat content.

TABLE 1.  
MEATSTICK BATTER FORMULATIONS<sup>1</sup>

	14% fat	17% fat	21% fat
Beef <sup>2</sup> (Iowa Beef Processors)	79.0	70.0	60.0
Fatty Pork <sup>3</sup> (Smithfield Food)	4.90	13.9	23.9
Water	10.0	10.0	10.0
Salt (Morton)	2.5	2.5	2.5
Seasoning Mix (Griffith)	1.7	1.7	1.7
Dextrose (Staley)	1.0	1.0	1.0
Smoke Flavoring (Red Arrow)	0.5	0.5	0.5
Starter Culture (Quest International)	0.36	0.36	0.36
Sodium Erythorbate (Ashland Chemical)	0.03	0.03	0.03
Sodium Nitrite (Ashland Chemical)	0.01	0.01	0.01

<sup>1</sup>Percent, prior to drying

<sup>2</sup>15% fat

<sup>3</sup>50% fat

The meat was ground through a 5 mm die, then salt and half of the formulation water were added and the mix stirred in a dual-shaft paddle mixer for 6 min. Remaining formulation water was added and the mix stirred for an additional 6 min. The meat mix was then reground through a 5-mm die and stuffed into 27 × 95 mm cellulose casings. Product was maintained at 32C,

90% RH until a pH of 4.8 was attained (12-14 h), then dried at 54C dry bulb/10C wet bulb for 1 h, 66C dry bulb/49C wet bulb for 30 min, and 77C dry bulb/10C dry bulb until an internal temperature of 71C was achieved (approximately 20 min). The meatsticks were then maintained at 71C dry bulb/10C wet bulb until the desired water activity (each formulation was dried to target water activity levels of 0.88, 0.90 and 0.92) was achieved. The  $a_w$  of samples was checked every 15 min by grinding meatsticks in a Waring blender and evaluating ~5 g portions using a Decagon Devices Aqualab CX2T at 25C; specimens were evaluated in triplicate. Product was cooled by a cold shower to 20C, peeled, and packed in trilaminate pouches. The product was maintained at 4C pending analysis.

#### Assessment of Physical Properties

**Moisture Content Measurement and Calculation of Composition.** Weighed specimens (approximately 12 g) consisting of thin slices taken from 3 meatsticks were vacuum dried at 70C for 24 h. Moisture content, W, was calculated by

$$W = [(\text{initial weight} - \text{final weight}) / \text{initial weight}] \times 100.$$

The composition of the meatsticks was calculated based upon computation of initial percentages of moisture, fat, protein and other constituents in the batters (from formulations and industry standards for beef and fatty pork composition) and recalculation of percentages after loss of known quantities of water during drying.

**Mechanical Property Measurements.** Meatsticks were assumed to be incompressible "gel"-like materials and were analyzed by uniaxial compression with determination of modulus corrected for increases in cross sectional area during deformation (Nussinovitch *et al.* 1990). This procedure was employed by Barrett *et al.* (1998) to evaluate similar meatstick products. Samples were sliced into 15 mm thick slices, cored into 15 mm diameter cylinders (which removed the surface skin), and compressed to 50% strain using a Texture Technologies (Scarsdale, NY) TA-XT2 Texture Analyzer. Deformation rate was 0.3 mm/s. Data were automatically acquired by a Zenith 286 computer. Deformability modulus, E, was calculated by

$$E = \text{"corrected stress" / Hencky's strain} = [F(t)(H_0 - \Delta H(t)) / A_0 H_0] / [\ln(H_0 / (H_0 - \Delta H(t)))],$$

where  $F$  = compressive force,  $H$  = specimen height,  $t$  = time, and  $A_0$  and  $H_0$  are original specimen cross-sectional area and height, respectively. Six replicates were compressed.

Half of the specimens were allowed to relax for 30 s, and asymptotic residual modulus ("solidity") was calculated as:

$$E_A = [F_0/A\varepsilon(1-1/k_2)],$$

in which  $F_0$  is the initial (unrelaxed) force,  $A$  is area,  $\varepsilon$  is Hencky's strain, and  $k_2$ , a shape characteristic indicating the relative steepness of the decline in force over time, is determined from the relaxation linearization procedure:

$$F_0 t / [F_0 - F(t)] = k_1 + k_2 t,$$

in which  $k_1$  and  $k_2$  are fitted constant (Nussinovitch *et al.* 1990).

A Minitab (State College, Pa) version 10.2 statistical program was used for modulus and relaxation parameter calculations.

The other three replicates were decompressed at 0.3 mm/s, and percent recoverable work (a measurement of elasticity) was calculated by dividing the area under the decompression curve by that beneath the compression curve (Kaletunc *et al.* 1991). Integration was accomplished automatically by the TA-XT2 program.

Shear tests were conducted in order to determine the resistance of product containing skin. Six cm long sections of meatstick (long axis down and perpendicular to the blade) were sheared using a 2 mm wide shear blade traveling at 3 mm/s. Peak force (corresponding to skin rupture) was recorded. Four replicates were sheared.

**Image Analysis.** An Olympus Cue 2 image analysis system operated with a macro lens was used to determine the percent area covered by fat in cut surfaces of the meatsticks, similar to the procedure used by Barrett and Ross (1990). Magnification was such that the cross section of the meatstick samples filled the video screen, and the largest optical square that could fit with all corners inside the cross section was selected for analysis. Gray level threshold values that produced a binary image matching that of the projected image, i.e., that represented white (fat) areas accurately, were selected. The same settings were used for all samples and replicates. The image analysis program automatically calculated percent white area, which was taken as a measurement of separated fat. Six replicates were obtained for each sample.

**Colorimetry.** A Nippon Denshoku NR-3000 colorimeter, Tokyo, Japan, was used to determine lightness (reflectance  $L^*$ ) of cut surfaces of the

meatsticks. Three sample cross sections were analyzed, with three readings averaged for each sample.

### Assessment of Sensory Properties

Sensory texture was assessed by a trained descriptive panel consisting of five males and five females with ages ranging from 30 to 61. The panel had previously received training in the use of the General Foods Texture Profile Method (Szczesniak 1963; Szczesniak *et al.* 1963; Brandt *et al.* 1963) and in the use of modulus-free, magnitude estimation to judge attribute intensities (Stevens 1953; Moskowitz 1977). Additionally, panelists were exposed in pretests to a variety of processed-meat foods as well as to representative specimens of the meatstick samples. Based on these pretrial observations, a list of salient sensory textural attributes and associated definitions were determined (Table 2).

Specimens were generally ~1.5 cm cubes cut from the interior of the meatstick, with no skin attached. The exception was determination of "hardness with skin", in which panelists evaluated ~4 cm lengths of meatsticks, with skin attached, and with bite through the skin (i.e., perpendicular to the axis of the meatstick). Panel evaluation included visual assessment of the cut surfaces of the meatsticks, partial compression of the samples with the molar teeth, and mastication up through swallowing. Except for samples evaluated with skin, no particular specimen orientation was dictated.

Panelists employed the psychophysical method of modulus-free magnitude estimation to assess the perceived intensity of each attribute. Using this procedure, each subject assigned an arbitrary numerical rating to the first sample tested to represent the perceived magnitude of the attribute in that sample. Subsequent judgements of attribute magnitudes were assigned in a ratio manner with respect to the first sample. Judgements of "hardness with skin" and "hardness without skin" were made relative to the same modulus. Sensory panels were conducted in split sessions (so that no more than five samples were evaluated at once) with one specimen tested at both sessions in order to link the magnitude estimates between the sessions. This linkage was achieved by presenting the common stimulus as a "control" in the second session, with moduli chosen and assigned based on each panelist's magnitude estimates for that attribute and stimulus from the first session. Panels were replicated three times.

Sensory data were treated using a modulus equalization procedure (Moskowitz 1977) in order to adjust for differences among panelists in their choice of a modulus. Using this procedure, geometric means were calculated across all samples for each attribute, panelist, and replicate. In addition, a grand geometric mean was calculated across all samples and subjects for each attribute and replicate. Raw magnitude estimates for each panelist were then multiplied

TABLE 2.  
SENSORY APPEARANCE AND TEXTURE ATTRIBUTES

Attribute	Definition
<i>Visual</i>	
Color	The perceived degree of darkness of the cut surface.
Amount of fat	The perceived amount of fat on the cut surface.
<i>Partial Compression</i>	
Springiness	The perceived degree to which the sample returns to its original shape after slight compression with the molar teeth.
<i>First Bite</i>	
Hardness	The perceived force required to compress the sample between the molar teeth (cored samples w/o skin).
Skin hardness	The perceived force required to bite through samples containing skin with the incisor teeth.
Denseness	The amount of material per unit volume perceived during a single bite with the molar teeth.
Cohesiveness	The perceived degree to which the sample holds together as a single mass upon biting with the molar teeth.
<i>Mastication</i>	
Moistness	The perceived amount of water and/or oil in the sample.
Chewiness	The total perceived force required to reduce the sample to a consistency ready for swallowing when chewed at a constant rate.
Cohesiveness of the mass	The perceived degree to which the sample holds together as a single mass during chewing.
Amount of connective tissue	The perceived volume of connective tissue (gristle) in the sample.
<i>Residual</i>	
Oily mouthcoating	The perceived degree of oil left on the teeth and palate after swallowing.

by the ratio of the grand geometric mean to the panelist geometric mean for each attribute and replicate, thus establishing a common scale for all magnitude estimates. SPSS (SPSS, Inc., Chicago) version 11.0 was used for sensory data analysis.

For product development guidance, panelists also assigned an "optimal" magnitude estimate for each attribute so that an "ideal" sensory profile for the products could be constructed. Although such judgments are typically reserved for consumer tests, consumers often have difficulty making such judgments for novel or unfamiliar products (Cooper *et al.* 1989). Data for these ideal estimates were subjected to the same transformation/normalization procedures used for attribute magnitude estimates.

#### Statistical Determination of Relationships and Significant Factors

Minitab statistical software was used to determine sensory-instrumental relationships, dependence of physical properties on formulation variables, and correspondence between the difference sums of squares array and arrays of mean magnitude estimates of individual sensory attributes, all by regression analysis.

Regression analysis was also used to determine sensory-instrumental and SSQ-geometric mean relationships with significance values exceeding 95% ( $P < 0.05$ ). Multivariate regression of physical characteristics versus percent moisture, percent fat, percent protein, and interaction terms was used to determine which formulation variables and interactions (at  $P < 0.05$ ) determined product properties.

## RESULTS AND DISCUSSION

### Meatstick Physical Properties

**Composition.** The calculated compositions of the meatsticks after drying are shown in Table 3. A range of samples with moisture contents varying from 38 to 51% and fat levels varying from 19 to 31% (with moisture and fat contents generally negatively associated) were obtained. Protein level varied between 17 and 23%.

**Mechanical Properties.** Sample deformability modulus, shear force, and percent recoverable work are shown in Table 4 and significance of formulation effects on these properties are shown in Table 5.

Significantly affecting modulus (Table 5) were fat and protein level (both negatively), and to a greater (positive) extent, the fat level-protein level interaction. Such a result suggests that the form of the fat-protein interaction or

structure (i.e., encapsulation of fat in the meat matrix) is a major contributor to strength. Very high fat levels, particularly those beyond that which can be physically emulsified, may be expected to soften a structure. It was expected that protein level, by itself, would be a positive contributor to modulus; but, again, biopolymer interactions and structure rather than ingredient level, per se, determine strength. Also, protein content varied to a much lower extent than did either fat content or water content.

TABLE 3.  
MEATSTICK COMPOSITION<sup>1</sup>

	water	fat	Percent: protein	other <sup>2</sup>
14% fat content batter, dried to 0.88 a <sub>w</sub>	43	22	23	12
14% fat content batter, dried to 0.90 a <sub>w</sub>	47	21	21	11
14% fat content batter, dried to 0.92 a <sub>w</sub>	51	19	20	10
17% fat content batter, dried to 0.88 a <sub>w</sub>	40	27	21	12
17% fat content batter, dried to 0.90 a <sub>w</sub>	43	26	20	11
17% fat content batter, dried to 0.92 a <sub>w</sub>	49	23	18	10
21% fat content batter, dried to 0.88 a <sub>w</sub>	38	31	20	11
21% fat content batter, dried to 0.90 a <sub>w</sub>	41	30	19	10
21% fat content batter, dried to 0.92 a <sub>w</sub>	46	27	17	10

<sup>1</sup> calculated based on formulation, reported compositions of raw beef and pork, and finished product moisture contents.

<sup>2</sup> flavorings, salts, etc.

Residual modulus ("solidity") was strongly dependent on deformability modulus ( $r^2 = 0.96$ ;  $P \leq 0.001$ ), and averaged 68% of deformability modulus magnitudes. Effects of composition on residual modulus are similar to those of composition on deformability modulus.

Percent recoverable work (Table 4) was negatively affected by the level of each individual parameter and positively affected by interactions (Table 5). The structure and organization of constituents (i.e., encapsulation of fat, hydration of protein) were contributors to matrix elasticity.

TABLE 4.  
INSTRUMENTAL MEASUREMENTS OF DEFORMABILITY MODULUS,  
SHEAR FORCE, PERCENT RECOVERABLE WORK, LIGHTNESS, PERCENT FAT  
AREA, AND NUMBER OF FAT PARTICLES<sup>1</sup>

Dried to:	From 14% fat content batter	From 17% fat content batter	From 21% fat content batter
0.88 a <sub>w</sub>	E = 154 (30) <sup>2</sup> SF = 32.3 (6.5) RW = 31.2 (1.6) L* = 37.7 (2.0) %F = 2.55 (.99) #F = 10.5	E = 255 (20) SF = 51.7 (3.6) RW = 29.9 (1.2) L* = 39.1 (0.3) %F = 3.17 (1.5) #F = 11.5	E = 246 (39) SF = 50.5 (9.4) RW = 28.8 (2.6) L* = 42.3 (1.3) %F = 6.35 (2.2) #F = 20.5
0.90 a <sub>w</sub>	E = 151 (19) SF = 31.1 (3.9) RW = 33.6 (1.5) L* = 41.0 (2.8) %F = 5.03 (2.9) #F = 12.8	E = 224 (27) SF = 45.2 (5.7) RW = 35.9 (0.7) L* = 39.9 (1.5) %F = 3.92 (2.1) #F = 17.7	E = 185 (26) SF = 37.4 (4.6) RW = 36.4 (4.6) L* = 41.9 (2.7) %F = 7.47 (2.2) #F = 25.5
0.92 a <sub>w</sub>	E = 138 (38) SF = 23.9 (3.8) RW = 34.4 (1.5) L* = 41.3 (2.5) %F = 5.30 (2.7) #F = 13.2	E = 186 (40) SF = 37.4 (7.8) RW = 38.0 (1.2) L* = 42.6 (1.0) %F = 4.55 (1.3) #F = 15.0	E = 133 (25) SF = 26.9 (4.8) RW = 36.9 (0.3) L* = 45.6 (0.5) %F = 9.25 (3.4) #F = 28.0

<sup>1</sup> E refers to deformability modulus (kPa); SF refers to maximum shear force (N); RW refers to percent recoverable work; L\* refers to instrumental lightness; %F refers to percent of sample area occupied by separated fat; #F refers to number of fat particles in the sample area

<sup>2</sup> standard deviation

**Instrumental Visual Properties.** Sample lightness (L\* value) and percent of cut surface covered by fat are shown in Table 4. Significance of formulation effects on these properties are shown in Table 5.

Instrumental lightness increased significantly with fat level (as was also determined by Claus and Hunt (1991) and Hand *et al.* (1987)), and decreased significantly with both fat level-protein level and fat level-water level interactions. Lightness was most likely determined by separated fat on cut surfaces. Interactions between fat and either protein or water would be expected to decrease the extent of fat separation and also possibly contribute to a darker appearance.

TABLE 5.  
SIGNIFICANT EFFECTS OF FORMULATION FACTORS  
ON MECHANICAL/PHYSICAL PROPERTIES

Mechanical Property	Factor	t-ratio	p
Deformability Modulus	fat level	-4.76	0.041
	protein level	-4.48	0.046
	fat x protein	5.43	0.032
Percent Recoverable Work	fat level	-5.68	0.030
	water level	-5.78	0.029
	protein level	-5.71	0.029
	fat x protein	4.86	0.040
	fat x water	6.34	0.024
	protein x water	5.57	0.031
Percent Fat Area	fat level	12.1	0.007
	protein level	6.03	0.026
	fat x protein	-11.9	0.007
	fat x water	-8.02	0.015
I* value	fat level	4.80	0.041
	fat x protein	-4.58	0.044
	fat x water	-4.17	0.050

Similarly, measured fat area was positively affected by fat and protein levels and negatively affected by fat-water and fat-protein interactions. It is possible that the positive effect of protein level on fat area may have been attributable to a small amount of "gristle" that was included in the lighter-area image analysis determinations.

**Meatstick Sensory Properties**

Mean magnitude estimates of the judged sensory attributes of the meatsticks are shown in Table 6. Statistically significant effects of formulation on sensory attributes are shown in Table 7.

Sample moistness was only (and positively) influenced by increasing water content. Sample hardness, like modulus, was negatively affected by increasing levels of all ingredients. Sensory fat results, like image analysis results, were positively affected by fat level and negatively affected by fat-protein interaction.

Illustrative of the effect of ingredient structuring/combination on product properties is the relationship between fat-to-protein ratio and perceived hardness (Fig. 1), which has a maximum at a fat-to-protein ratio of approximately 1.3.

It is possible that, at low levels, fat contributes to hardness or strength through formation of an emulsion-like structure, but that high fat levels cannot be entirely encapsulated by the matrix — a phenomenon similar to that reported by Kepton and Krupp (1983) for "inverted" meat emulsions.

TABLE 6.  
MAGNITUDE ESTIMATES OF SENSORY PROPERTIES

Attribute	Sample <sup>1</sup>									
	1	2	3	4	5	6	7	8	9	ideal
Color	92.7 (3.9) <sup>2</sup>	90.8 (2.4)	60.7 (1.6)	78.0 (2.3)	76.0 (2.1)	58.1 (1.8)	63.0 (1.7)	56.5 (2.9)	44.9 (1.8)	65.5 (2.4)
Visible amount of fat	58.8 (2.8)	54.2 (2.7)	65.7 (2.3)	62.9 (2.5)	59.4 (2.1)	68.8 (3.9)	69.4 (2.8)	62.9 (2.6)	72.6 (3.6)	56.0 (2.2)
Springiness	58.2 (3.1)	62.6 (3.7)	63.1 (2.7)	62.4 (2.8)	64.5 (3.3)	57.8 (3.1)	58.7 (4.6)	67.2 (3.0)	61.1 (3.9)	63.9 (2.5)
Hardness wo/skin	59.2 (3.8)	79.8 (3.5)	69.5 (2.3)	60.2 (3.1)	78.2 (2.3)	66.2 (3.3)	47.2 (2.5)	64.6 (4.0)	62.0 (3.2)	56.7 (2.1)
Hardness w/skin	115.7 (12.5)	135.1 (12.3)	95.2 (7.8)	95.8 (9.6)	115.7 (9.9)	87.5 (7.8)	77.7 (7.6)	95.8 (10.5)	80.7 (8.1)	68.2 (6.2)
Denseness	59.3 (3.5)	76.5 (3.3)	63.4 (3.2)	56.9 (2.4)	72.3 (3.0)	67.2 (3.1)	50.0 (3.4)	66.2 (3.3)	62.9 (3.6)	61.9 (2.8)
Cohesiveness (first bite)	61.4 (2.4)	60.2 (3.9)	60.7 (3.2)	61.2 (2.5)	63.0 (2.9)	60.5 (2.9)	62.9 (2.7)	70.8 (2.8)	63.0 (5.2)	64.4 (2.5)
Moistness	66.4 (2.5)	52.5 (3.4)	62.2 (1.6)	67.3 (2.2)	59.2 (1.8)	69.4 (2.2)	81.3 (2.9)	74.8 (2.7)	77.4 (3.0)	78.0 (2.2)
Chewiness	64.4 (2.5)	66.7 (3.8)	67.5 (2.6)	60.9 (3.1)	72.5 (2.9)	67.5 (3.6)	53.4 (3.4)	70.6 (3.2)	65.0 (2.9)	62.0 (2.4)
Cohesiveness (chewing)	58.2 (3.2)	56.4 (3.1)	59.5 (2.8)	65.6 (2.7)	61.2 (2.5)	61.5 (2.5)	66.4 (3.5)	68.3 (2.8)	65.1 (3.8)	67.4 (2.7)
Oily mouthcoating	70.8 (2.1)	63.6 (2.8)	70.3 (1.7)	64.6 (2.8)	71.1 (1.9)	70.7 (2.2)	65.9 (2.4)	73.0 (2.4)	77.3 (2.2)	61.3 (2.3)

<sup>1</sup> 1—0.88 a<sub>w</sub>, from low fat content batter; 2—0.88 a<sub>w</sub>, from medium fat content batter; 3—0.88 a<sub>w</sub>, from high fat content batter; 4—0.90 a<sub>w</sub>, from low fat content batter; 5—0.90 a<sub>w</sub>, from medium fat content batter; 6—0.90 a<sub>w</sub>, from high fat content batter; 7—0.92 a<sub>w</sub>, from low fat content batter; 8—0.92 a<sub>w</sub>, from medium fat content batter; 9—0.92 a<sub>w</sub>, from high fat content batter

<sup>2</sup> Standard error

TABLE 7.  
SIGNIFICANT EFFECTS OF FORMULATION FACTORS  
ON SENSORY PROPERTIES

Sensory Property	Factor	t-ratio	p
Hardness	fat level	-4.90	0.039
	water level	-5.48	0.032
	protein level	-4.75	0.042
Moistness	water level	5.90	0.028
Visible fat	fat level	5.51	0.031
	fat x protein	-4.44	0.047

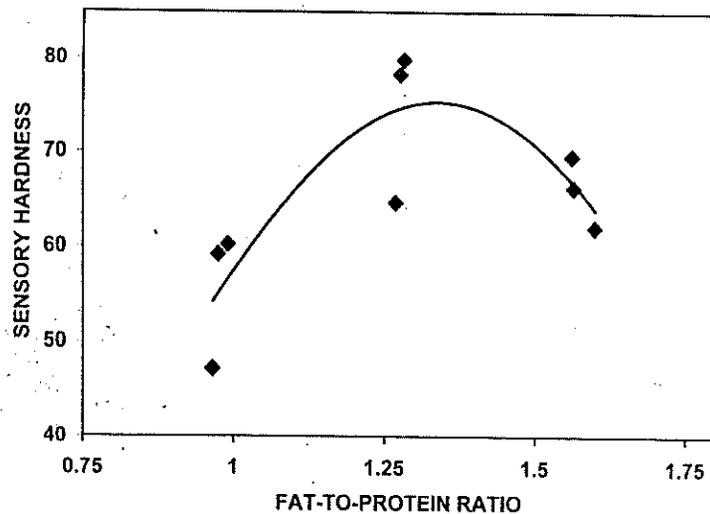


FIG. 1. SENSORY HARDNESS WITHOUT SKIN (MEAN MAGNITUDE ESTIMATE)  
VERSUS FAT-TO-PROTEIN RATIO

Shows maximum perceived hardness at an intermediate fat-to-protein ratio.

Correlations

Statistically significant sensory-instrumental correlations are illustrated in Fig. 2, 3, 4 and 5. Hardness without skin was well predicted by deformability modulus ( $r^2 = 0.70$ ;  $P = 0.006$ ; Fig. 2); hardness with skin was well predicted by shear force ( $r^2 = 0.74$ ;  $P \leq 0.001$ ; Fig. 3); visible separated fat was well predicted by image analysis area measurements ( $r^2 = 0.76$ ;  $P \leq 0.001$ ; Fig. 4); and perceived color was well predicted by instrumental lightness determinations ( $r^2 = 0.88$ ;  $P \leq 0.001$ ; Fig. 5).

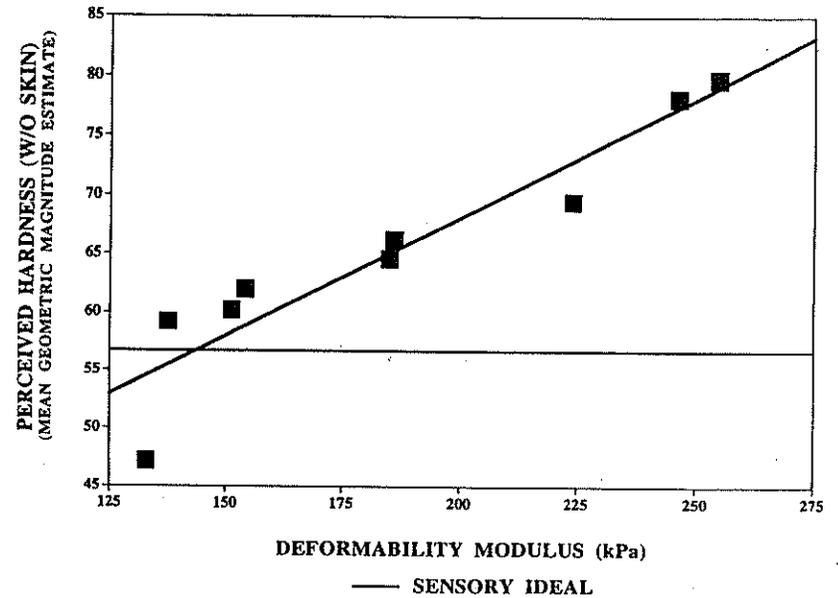


FIG. 2. MEAN GEOMETRIC MAGNITUDE ESTIMATES OF PERCEIVED HARDNESS  
(WITHOUT SKIN) VERSUS DEFORMABILITY MODULUS

Mechanical tests involved uniaxial compression of radially placed sample cylinders.

Line shows panel-determined optimal level.

The panel-determined ideal levels of these attributes are also shown in the figures, although it should be kept in mind that these data are not consumer-based and, therefore, should not be generalized beyond the scope of their internal relationship to the trained panel attribute ratings. In general, less firm

(more deformable and more easily sheared) products and meatsticks with minimal visible fat were viewed to be closer to an ideal for the intended product. Ideal color intensity corresponded to an intermediate lightness level within the sample range.

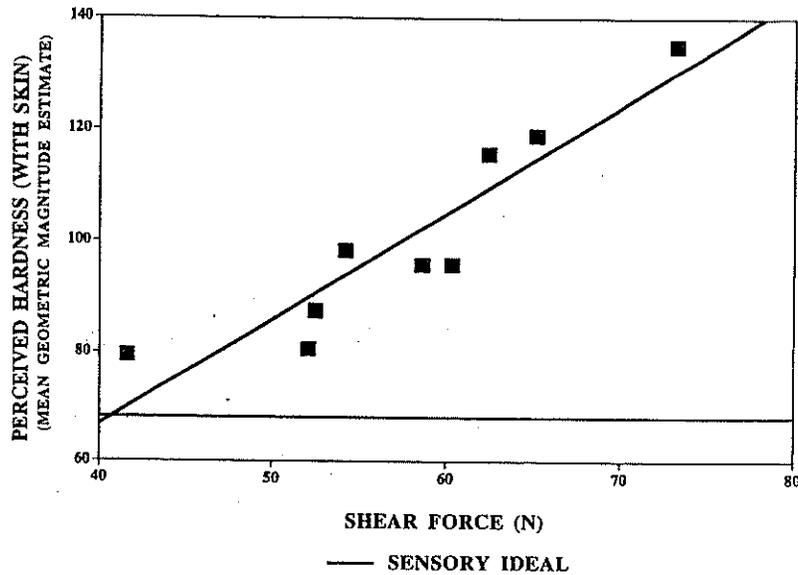


FIG. 3. MEAN GEOMETRIC MAGNITUDE ESTIMATES OF PERCEIVED HARDNESS (WITH SKIN) VERSUS BREAKING STRENGTH  
Mechanical tests involved shearing of longitudinal samples placed perpendicular to the blade. Line shows panel-determined optimal level.

**Attributes Affecting Correspondence With the Ideal Sensory Profile**

Sums of squares of the differences between the sample sensory profiles and the ideal sensory profile are shown in Table 8. While SSQ was not significantly, linearly, associated with any specific ingredient or specific ingredient interaction, how closely a product corresponded to the ideal was strongly influenced by its ratings for certain sensory attributes. That is, certain sensory attributes were more important in determining how the products compared to the ideal.

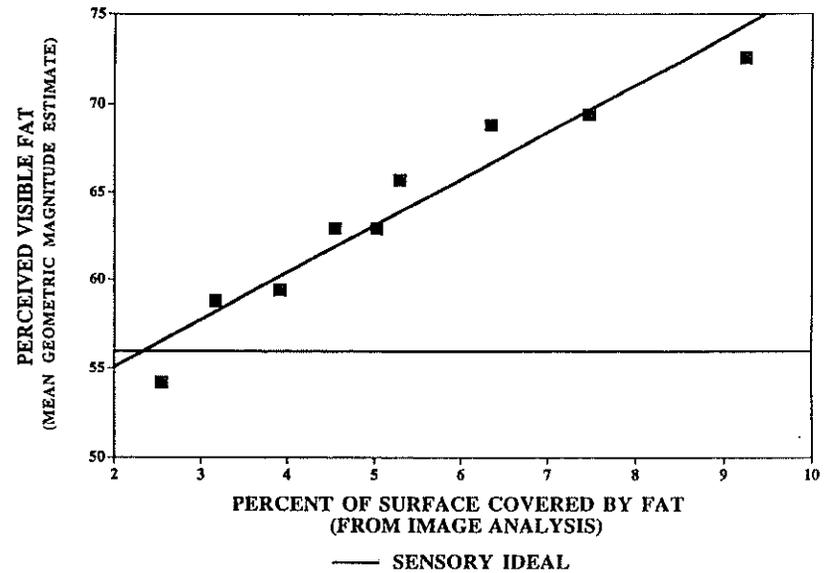


FIG. 4. MEAN GEOMETRIC MAGNITUDE ESTIMATES OF PERCEIVED VISIBLE FAT VERSUS PERCENT AREA COVERED BY FAT (ASSESSED BY IMAGE ANALYSIS)  
Line shows panel-determined optimal level.

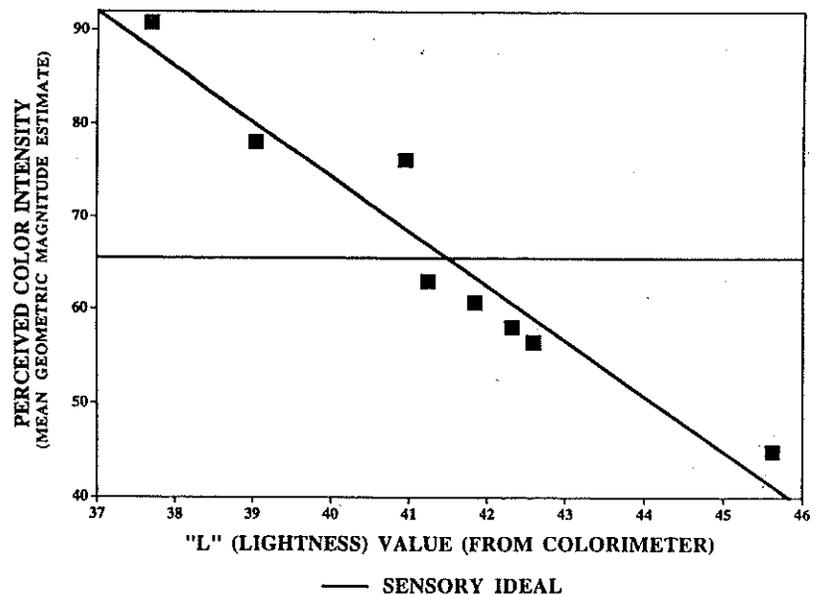


FIG. 5. MEAN GEOMETRIC MAGNITUDE ESTIMATES OF PERCEIVED DARKNESS VERSUS L\* VALUES MEASURED BY COLORIMETRY  
Line shows panel-determined optimal level.

TABLE 8.  
SAMPLE RANKING BY DIFFERENCE SUMS OF SQUARES

Ranking	Sample	SSQ
1	14% fat content batter, dried to 0.92 $a_w$	683
2	21% fat content batter, dried to 0.90 $a_w$	993
3	14% fat content batter, dried to 0.90 $a_w$	1151
4	21% fat content batter, dried to 0.92 $a_w$	1170
5	17% fat content batter, dried to 0.92 $a_w$	1255
6	21% fat content batter, dried to 0.88 $a_w$	1636
7	14% fat content batter, dried to 0.88 $a_w$	3381
8	17% fat content batter, dried to 0.90 $a_w$	3885
9	17% fat content batter, dried to 0.88 $a_w$	6693

Difference sums of squares were positively correlated with hardness scores ( $t$ -ratio = 2.51;  $P$  = 0.04) and denseness scores ( $t$ -ratio = 2.48;  $P$  = 0.042), demonstrating that products with higher perceived hardness or denseness were relatively more different from the ideal product. SSQ was also negatively correlated with moistness ( $t$ -ratio = -3.75 and  $P$  = 0.007). The latter relationship can be explained by the fact that moistness might be associated with product plasticization, or softness, and thus have a relationship with SSQ that is opposite that of either hardness or denseness.

### CONCLUSIONS

Fat level affected physical, mechanical, and sensory properties, often through its interaction with protein and water. Instrumental and physical measurements, within the range of samples evaluated, were strongly correlated with levels of certain sensory attributes. Perceptions of hardness and moistness were correlated with how statistically different samples were from a theoretical ideal. Such findings could guide further product development efforts, in that formulations that decrease perceptions of firmness and increase perceptions of juiciness or moistness are more likely to yield acceptable products.

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