KOREAN. J. FOOD SCI. TECHNOL.
Vol. 7, *No.* 3 (1975)

◆ Review ◆

Desired Textures of Food Analogs and Methods of Measuring Their Textural Properties

by

Malcolm C. Bourne

Professor of Food Science and Technology
Cornell University

대용 식품의 텍스츄어 특성 및 그의 측정 방법

말콤 C. 부르네

코넬대학교 식품이공학 교수

ABSTRACT

Analogs and extenders should have mouthfeel and chewing characteristics that are similar to the food they are replacing or extending. Instrumental methods can measure some of the physical properties that constitute "texture" but only sensory methods can provide a complete description and quantification of the textural properties of a food. Instrumental methods and sensory methods for measuring texture are reviewed.

INTRODUCTION

The food processing industry can be considered as a branch of chemical engineering because it uses the unit operations that are so familiar to chemical engineers. Heat transfer, mixing, fluid flow, filtration and size reduction are just a few of the unit operations in the food processing industry that are very familiar to chemical engineers; however, the food processing industry has some complications that are not present in conventional chemical engineering work. The food processor is dealing with perishable, biological materials. Although most of the changes that occur during processing are chemical reactions, there are severe restrictions on the chemicals that can be added to the foods to control these reactions and also the amounts that can be added.

The specifications for the final product are not as objective as we would like because the final product must please the human palate. This important factor of pleasing the human palate presents both a frustrating and challenging aspect to the food processor, frustrating because it brings us into the area of human psychology, human senses, and the way they change, which is a very complex area, and challenging because we need to solve these problems in order to bring acceptable food to people.

Another difference between food processing and conventional chemical engineering is that the food processor is generally working with very impure systems (from the chemists' viewpoint); for example, over 450 compounds have been identified in citrus fruit. Yet another complicating factor in natural foods is that of structure. The cellular organization in natural foods can keep some potential reactants separated and the cellular organization itself frequently contributes to texture.

A fundamental concept in the thinking of the food technologist is that, with few exceptions, people select the food that they eat primarily for the enjoyment that comes from eating it and only secondarily, if at all, for the nutritional value of the food. It is for this reason that food technologists and the food processing industry pay so much attention to what we call the quality attributes of food which are: appearance (color, size, shape), flavor (oder, taste), and texture. Unless these quality attributes of a food meet the standards that the consumer expects the food will be rejected rather than consumed.

Every piece of food has to pass through the mouth before it reaches the gastrointestinal tract where the nutritional value can be utilized. The mouth is a highly sensitive, highly discriminating, highly biased and often unpredictable monitor that selects the foods that are to pass through it. The mouth is not concerned with the nutritional value of the food and yet it must be satisfied before the food can reach the stomach. It is for this reason that I believe we should not talk about the nutritional value of a food because the nutritional value of the food is zero until it reaches the gastrointestinal tract. I believe it would be preferable to talk about the *apparent* nutritional value because this would constantly remind us that until a food has passed through this prejudiced and highly sensitive mouth the nutritional value is zero.

There are many nutritious foods available that are not eaten in quantity because of their low acceptability. How many people eat cooked soybeans, although they are an excellent food? On the other hand we are reminded of foods readily available in our supermarkets that are widely used because they have high acceptability, yet their nutritional value is low. The importance of the acceptability of a food cannot be overemphasized. The food industry knows from long and frequently bitter experience that unless the quality factors are present the food will fail in the market-place.

TEXTURE

Since the dictionary definition of texture is of little help when it comes to discussing the texture of foods, food technologists have had to make their own definition. There are a number of definitions. One definition that summarizes most of the present thinking is the following: "The textural properties of a food are that group of physical characteristics that are sensed by the feeling of touch, are related to the deformation, disintegration and flow of the food under the application of forces, and are measured objectively by functions of force, time and distance."

This definition points out that texture consists of a number of related properties. It is not a one-point measurement. Table 1 shows one system for texture of foods that shows that there are a number of properties. We should speak of textural properties (in the plural) rather than texture (a single property). The next part of the definition points out that texture relates to physical characteristics and not the chemical characteristics of flavor and odor. Also, the physical characteristics are related to the rheological properties of deformation and flow and the way in which the food disintegrates in the mouth. Objective measurements generally measure force, time, or work, which are functions of mass, time and distance. Physical characteristics, such as optical and electrical properties and temperature are excluded from this definition.

The textural properties of a food are sensed, for the most part, in the mouth during the process of mastication which in itself is a very complex sequence of processes. During mastication forces well over 50 kg may be exerted in successive reciprocating compressions at a variable speed that follows approximately a sinusoidal curve at a rate of 50-100 cycles per minute, and for the duration of the process of mastication (Shama and Sherman, 1973). In the case of eating one peanut the mastication might last a few seconds, but for a complete dinner it may last for a half-hour or more.

There is a wide variation among foods in the degree of importance to which texture contributes to the

Table 1. Relations between textural parameters and popular nomenclature

Mechanical Characteristics		
Primary parameters	Secondary parameters	Popular terms
Hardness		Soft→Firm→Hard
Cohesiveness	Brittleness	Crumbly→Crunchy→Brittle
	Chewiness	Tender→Chewy→Tough
	Gumminess	Short→Mealy→Pasty→Gummy
Viscosity		Thin→Viscous
Elasticity		Plastic→Elastic
Adhesiveness		Sticky→Tacky→Gooey
Geometrical Characteristics		
Class	Examples	
Particle size and shape	Gritty, Grainy, Coarse, etc.	
Particle shape and orientation	Fibrous, Cellular, Crystalline, etc.	
Other Characteristics		
Primary parameters	Secondary parameters	Popular terms
Moisture content		Dry→Moist→Wet→Watery
Fat content	Oiliness	Oily
	Greasiness	Greasy

(Szczesniak 1963)

overall quality of that food. In some foods texture plays a minor role in quality, for example, beverages and thin soups. In a great number of foods texture is prominent but shares more or less equally in importance with flavor and appearance. Most fruits and vegetables fall in this group. And finally, there are those foods in which texture is the all-important quality factor, for example, meat. If meat is tough it is of poor quality and commands a lower price no matter how good it tastes. With potato chips the crispness of the chip is the most important quality attribute. The food analogs for products of animal origin, subject of discussion today, fall right in this final group of fcods where texture is of critical importance.

The importance of texture in food acceptance is high lighted by the appearance in 1969 of an international journal that is published quarterly by the D. Reidel Publishing Co., Dordrecht, Holland. The Journal of Texture Studies is devoted to reporting original research, reviews, discussion papers and abstracts of the literature in the field of rheology, psychorheology, physical and sensory of foods and pharmachceuticals. The editors are Professor Sherman of the University of London and Dr. Szczesniak, Senior Research Specialist in the Corporate Research Department of the General Foods Corporation, New York.

Szczesniak and Kleyn (1963), Szczesniak (1971) and Yoshikawa et al. (1970) have given word association tests to large numbers of people and concluded from these tests that texture is a discernible characteristic, that it is more evident in some foods than in others, that foods that elicit the highest number of texture responses are either bland in flavor or possessing the characteristic of crunchiness or crispness, and that the awareness of texture is generally equivalent to that of flavor. They also found that women, and people in higher economic brackets show a greater awareness of the textural properties of foods. Szczesniak and Kahn (1971) interviewed homemakers and found that texture is frequently taken for granted as long as it is satisfactory, but when the textural properties do not meet the expectations there is a very sharp increase in awareness of texture and sharp criticisms of textural deficiencies. These authors state: "If the texture of a food is the way people have learned to expet it to be ... then it will scarcely be noticed. However, if the texture is not as it is expected to be ... it becomes a focal point for criticism and rejection of the food. Care must be taken not to underestimate the importance of texture just because it is taken for granted when all is as it should be."

DESIRABLE TEXTURES IN ANALOGS AND EXTENDERS

Analogs and extenders should have textural properties that they attempt to simulate. In the case of meat products this means than they should be highly deformable, possess a measurable shear strength (toughness), no brittleness or brittle fracture, an intermediate amount of work required for mastication, some grinding or tearing in addition to compression for proper mastication, the sensation of moistness or juiciness when the product is first bitten and the maintenance of this sensation of moistness as long as mastication continues.

Meat and meat products must have a certain amount of toughness to be acceptable, but if the work necessary for mastication, or the shearing strength becomes too high the meat becomes excessively tough and people complain. This concept is illustrated in figure 1 where the enjoyment factor in eating a product is plotted against textural quality. There is a plateau region in the center that is about right. The goal of the food technologist is to determine the degree of toughness (and of each textural parameter) that corresponds to maximum acceptability, and then to manipulate the processing and formulation variables to deliver this quality. The location of the plateau can vary according to the product, for example with meat we would expect the texture to be of medium toughness and yet that same medium tough texture would be considered excessively tough and the cause of strong complaint if it were found, for example, in custard.

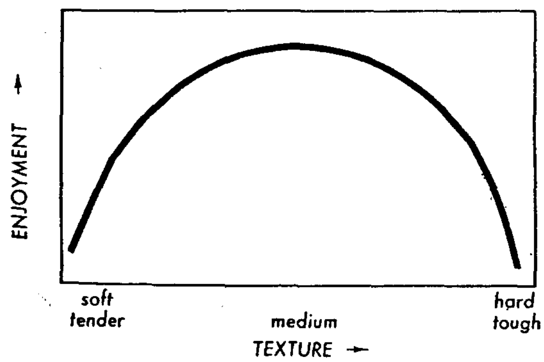

Fig. 1 Schematic representation of enjoyment of a food as a function of its toughness or hardness.

Figure 2 shows the results of a texture measurement of two kinds of cookedbeef and a vegetable meat analog. These curves are actual tracings from charts of an Instron Universal Testing machine. After cooking the meat was cut into cylinders 1 cm in diameter and 1 cm high and compressed down to 2mm in height between extensive flat parallel surfaces (80% compression). This compression was done twice in a reciprocating manner at constant speed. The first compression is called "first bite" and the second compression cycle is called the "second bite".

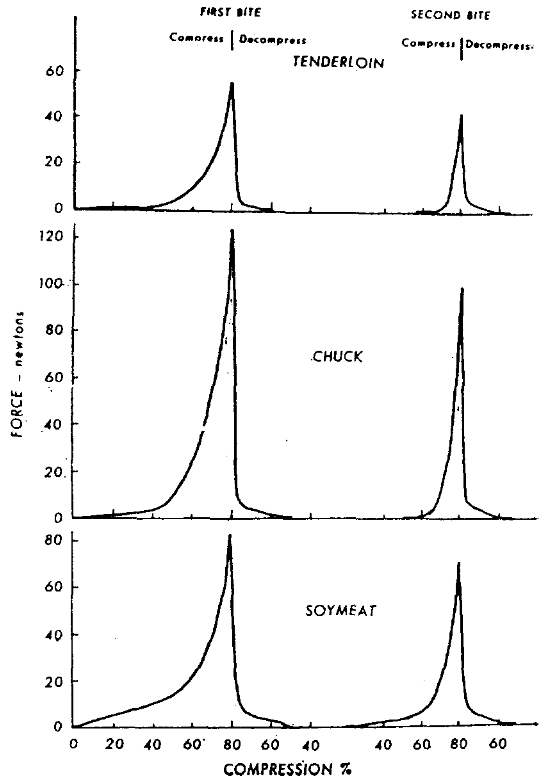

Fig. 2 Texture profile of cooked beef and soy fiber analog. Cylinders of product 1cm high and 1cm diameter are compressed to 0.2cm height two times, representing the first and second bites.

Notice the similarities of the three products. During the initial compression there is extensive deformation of the product under a very small force and then the force builds up rapidly as the fibers are torn and broken, reaching a maximum at the end of the compression. The force falls off quickly when the compression plate is reversed in direction. On the second bite, the curve is somewhat similar to the first except that it is smaller, the maximum force is smaller, and the area under the curve (which is the work done in compression) is less.

Now examine the differences in the three products. Tenderloin is a high quality tender meat that commands a high price. The maximum force that is encountered is about 55 Newtons; in contrast, in the chuck which is a rather tough cut of meat, the maximum force is just over 120 Newtons, while the soymeat has a maximum force intermediate between these two at 80 Newtons. In this regard the soymeat has a satisfactory value. The ratio of the area on the first bite to that of the second bite is an index of chewiness, or how quickly the food chews to a condition ready for swallowing. The ratios of the areas under the curves for the first and second bites are approximately the same for all three products indicating that the chewiness is similar, although the toughness is different.

Thus far the soymeat has compared favorably with the chuck and the tenderloin, but there are three very important properties where it compares unfavorably with the meat:

(1) The initial deformation of the tenderloin is very small, for the chuck, a little larger and for the soymeat very much larger as shown by the slope of the curve of the first bite from zero to 20% compression. In this case the soymeat instead of falling between the tenderloin and the chuck is considerably higher than the chuck.

(2) Consider the first part of the curve on the second bite. The second bite would consist solely of a small pip on the chart where the compressing plate touched the surface of the flattened product if the product was completely inelastic and failed to recoverfrom the compression. The distance that the product recovers (defined as springiness or elasticity by Friedman et al. 1963) is measured as the distance from complete compression(80%) back to where the compressing plate first contacted the food, which is where the force registers above zero. For the tenderloin this is 1.4mm; forthe chuck, 2.0mm, and for the soymeat analog, 5.2mm. The value for the soymeat lies on the high side of the chuck's value instead of lying between the value of the tenderloin and the chuck. The numerical values of the textural properties of beef and soy fiber analog obtained in this test are summarized in table 2.

(3) One more important difference between this analog and beef cannot be found in this test the sensation

Table 2. Comparison of textural properties of cooked beef and soy fiber analog

	Tenderloin	Chuck	Soy Fiber Analog
FIRST BITE			
maximum force (Newtons)	53	124	83
work (area, arbitrary units)	0.70	1.91	1.92
force to 10% compression (Newtons)	0.02	0.08	1.8
force to 20% compression (Newtons)	0.06	0.24	3.9
SECOND BITE			
maximum force (Newtons)	41	99	71
work (area, arbitrary units)	0.20	0.59	0.76
springiness (mm)	1.4	2.0	5.2
RATIOS (second bite/first bite)			
peak force	0.77	0.80	0.86
area (work done)	0.28	0.31	0.43

(From Texture Profile Test on 1 cm diameter cylinders, 1 cm high compressed to 0.2 cm im Instron) of moistness or juiciness. Both the tenderloin and chuck give a sensation of moistness in the mouth throuhout the mastication period whereas the soymeat initially feels a little dry and the sensation of dryness in the mouth becomes more pronounced as mastication continues. Many persons eating soymeat analog comment that it feels like chewing cotton; this is a reflection of the lack of sensation of moistness in the mouth and the poor hydration of the fibers. This sensation of moistness does not mean that the moisture contents(as determined by chemical analysis) are unequal. They might very well be equal. What we are talking about here is the release of moisture from these fibers into the mouth and the blending of the fibers with the saliva. This is not necessarily related to the total moisture content of the product.

Since the structure of meat is extremely complex it will be a difficult job to imitate completely every textural property of meat in analogs and extenders. The objective is to make these analogs as close as possible to meat in each textural parameter. With the soybean fiber analog the factors of toughness and chewiness have been matched quite well but other propertiesremain to be matched. The task of complete matching provides a challenging set of problems to both the chemist and the food technologist.

Much has been written during the last decade on the development of high protein content flours from various sources such as trash fish, microbial cells and oilseeds. These flours are a food ***ingredient.*** They are not foods because they are not eaten in that state. Finding solutions to the problems of converting these potential sources into stable dry powders of high nutritional value, light color, and low flavor impact required a sustained high quality research effort. In my opinion the problems of texturizing these flours into ready-to-eat-foods that have widespread acceptability and reasonable cost will be even more difficult and more challenging than the problems that were encountered in producing the flours.

The point is sometimes raised that our modern methods of texturizing foods give us the opportunity to develop completely new types of textures in foods never found in natural products. In view of the fact that most people are conservative in their eating habits and are not willing to change patterns that have been built up over many years it is my opinion that brand-new textures that are radically different from those already present in foods are unlikely to be accepted in the short term. There is a possibility that in the long term these might be accepted by making them available to children, building up the market as these children grow to adulthood and in turn feed such foods to their children, but I am very pessimistic about the potential success of radically new textures in foods for the short term and I am somewhat pessimistic for the long term.

Another point to be considered in developing textured foods is that the product that is highly acceptable to one group of people may not be acceptable to another group because of differences in eating patterns and life styles. This type of problem is exemplified in table 3 which shows the force that can be exerted between the teeth of male and female Eskimos and Americans. The Eskimos eat a lot of tough, dry, hard meat and develop strong muscles in the jaw whereas the Americans each a large amount of foods that have been softened by processing and do not develop the same jaw strength as the Eskimos. It can be seen, for instance, that the average Eskimo female can exert as much force between the teeth as the best American

Table 3. National differences in strength of the jaw

Subject	Pounds Force Exerted Between Teeth			
	Male		Female	
	Mean	Max.	Mean	Max.
Primitive Tribe (Eskimo)	270	348	200	326
Civilized Tribe (American)	120	200	85	165
Civilized Tribe (with dentures)	about 60			

male.

On these grounds it seems likely that a food that an Eskimo would consider very desirable in texture would be considered excessively tough and chewy by an American while a food that is considered of desirable texture by an American would be considered excessively soft and mushy by an Eskimo. Dentures reduce the maximum force that can be exerted between the teeth quite considerably. Consequently people wearing dentures generally want their food to be more soft and more tender than do people who have their natural teeth.

METHODS FOR MEASURING TEXTURE

A. Objective Methods

Szczeniak(1963) has classified objective measurements of food texture in three groups:

(1) Fundamental tests—these measure fundamental rheological properties such as viscosity, Young's modulus of elasticity, shear modulus, etc. Fundamental tests were designed by engineers for measuring the strength of materials and the flow properties of solids. Unfortunately, foods do not beahve like engineering materials. They are not elastic, not homogenous and not isotropic. Very large strains are used in chewing foods, unlike the small strains that are used in testing engineering materials. Consequeny, although fundamental tests are used as a basis for other tests they seldom correlate well with the results given by a panel.

(2) Imitative tests which endeavor to imitate the conditions to which the food is subjected in practice. The most highly developed instrument in this class is the General Foods Texturometer (Friedman et al, 1963) shown in figure 3. Bite-sized pieces of foods are compressed in this instrument twice in a reciprocal motion using sinusoidal speed for compression. The force that is generated is plotted on a high speed strip chart recorder. The chart can then be analyzed to give the properties of hardness, cohesiveness, elasticity, adhesiveness, brittleness, chewiness, gumminess.

(3) Empirical tests measure properties that from practical experience have been shown to be related to textural quality. A classification of these methods is given in table 4. The great

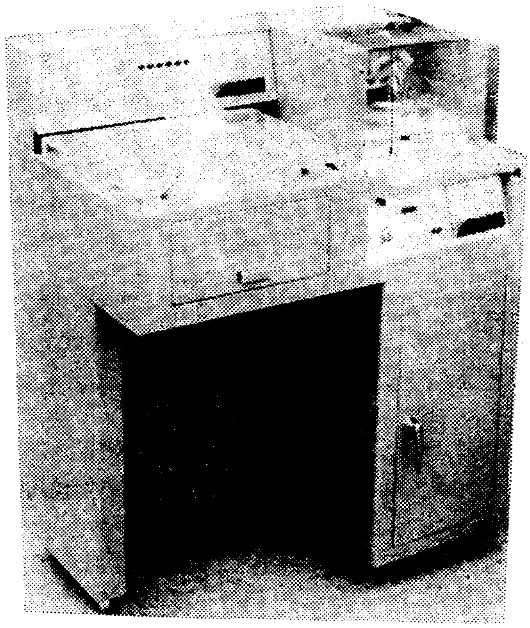

Fig. 3 The General Foods Texturometer.

number of instruments that have been described in the literature attest to both the great interest in texture measurement and the difficulty of developing instruments that will satisfactorily measure the textural properties that are needed. Although a great variety of instruments have been tried for measuring texture only a limited number shown any promise of being useful for meat and meat products. Commercial instruments that are used for meat and meat products are listed below.

Warner-Bratzler Shear (Bratzler, 1932)—A cylindricalshaped test sample is cut from the meat so that the fibers lie longitudinally in the test specimen. The cylinder is usually 1/2 or 1″ in diameter. It is sheared through by means of a stainless steel blade .050″ thick and the maximum force encountered during the shearing is measured on a spring sccle. The instrument is shown in figure 4.

The Food Technology Texture Test System commonly known as the Shear Press (Kramer et al, 1951, Kramer, 1961) has been used for meat products. The

Table 4. Objective methods for measuring texture

Method	Measured Variable	Dimensional Units	Examples
1. Force	Force (F)	mlt^{-2}	
a. Puncture	Force (F)	mlt^{-2}	Magness Taylor
b. Extrusion	Force (F)	mlt^{-2}	Shear Press, Tenderometer
c. Shear	Force (F)	mlt^{-2}	Warner-Bratzler Shear
d. Crushing	Force (F)	mlt^{-2}	Warner-Bratzler Shear
e. Tensile	Force (F)	mlt^{-2}	Warner-Bratzler Shear
f. Torque	Force (F)	mlt^{-2}	Rotary Viscometers
g. Snapping	Force (F)	mlt^{-2}	Brabender Struct-o-graph
2. Distance			
	a. length	l	Penetrometers
	b. area	l^2	Grawemeyer Consistometer
	c. volume	l^3	Bread Volume
3. Time	Time (T)	t	Ostwald Viscometer
4. Energy	Work (F×D)	ml^2t^{-2}	…………
5. Ratio	F or D or T measured twice	dimensionless	Specific gravity
6. Multiple	F and D and T	mlt^{-2}, l, t	Instron, Ottawa System, GF Texturometer
7. Multiple Variable	anything	unclear	Durometer
8. Chemical Analysis	concentration	dimensionless (%)	Alcohol Insoluble Solids
9. Miscellaneous	anything	anything	Optical Density, Crushing Sounds

(Adapted from Bourne 1966)

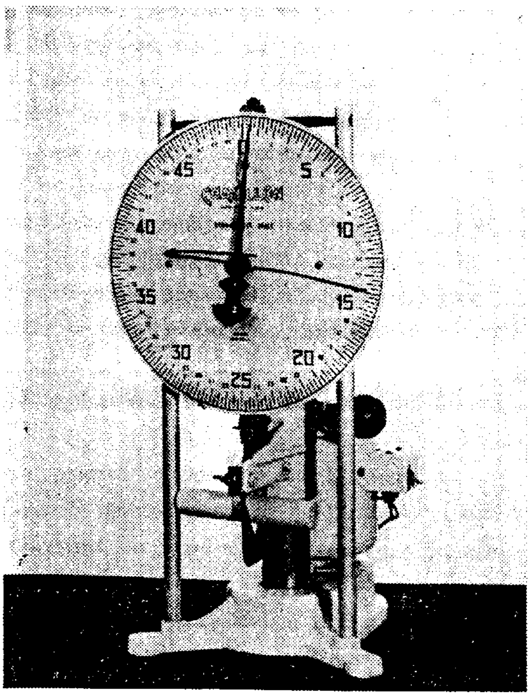

Fig. 4. The Warner-Bratzler Shear.
The wood cylinder represents the sample of meat to be sheared.

test cell consists of a rectangular aluminum box with internal dimensions of 2-5/8″by 2-3/4″ by 2-1/2″ with 1/8″ wide slits in the bottom. A set of ten aluminum bars 1/8″ wide passes down through this box, meshing through the slits in the bottom, compressing, then extruding and finally shearing the food. See figure 5. In this instrument maximum force is measured. A recorder can be attached to this instrument to give a complete force-time curve of the test. The force-time curve that results may provide a measurement of textural qualities other than maximum force.

The Shear Press and Warner-Bratzler Shear usually give statistically significant correlations with panel evaluations of meat tenderness but the numerical values of the correlation coefficients are not so high as we would like to obtain. Methods for measuring meat texture have been reviewed by Szczesniak and Torgeson(1965). Corey(1970) has discussed some of the problems involved in measuring the textural properties of meat analogs. Stanley(1975) has reviewed recent developments in analyzing the texture of meat.

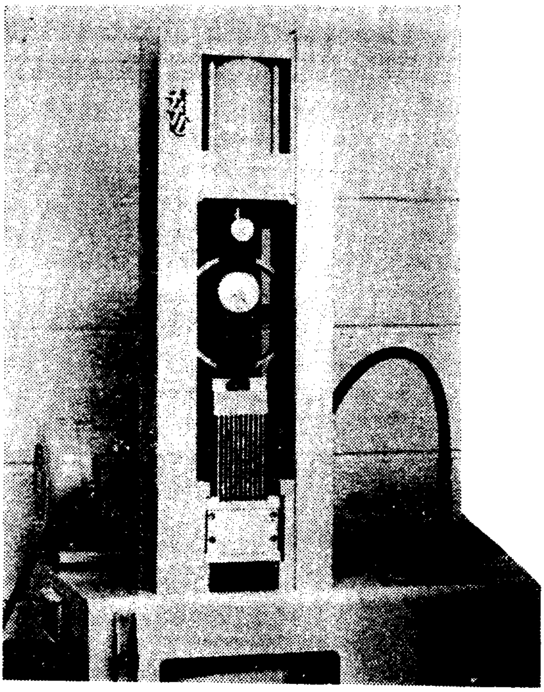

Fig. 5. The Food Technology Texture Test System. Formerly known as the Kramer Shear Press.

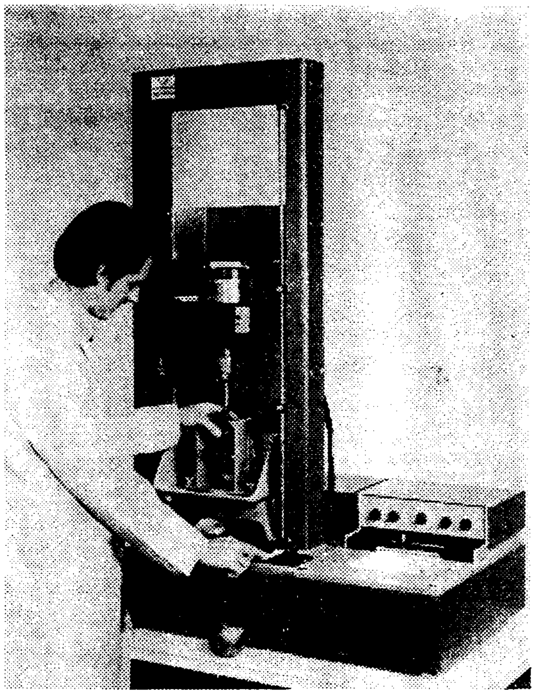

Fig. 6 The food model of the Instron Universal Testing Machine.
(Courtesy of Instron Corporation)

A new entrant in the field of measuring texture of chewy foods is the Armour Tenderometer (Hansen, 1971, 1972). This instrument measures the maximum force required to push a set of ten large pins into a piece of beef and it is claimed this force reading is a reliable index of the tenderness of the meat after cooking. This instrument was awarded the Institute of Food Technologists' Industrial Achievement Award in 1973. Although it was designed to predict the tenderness of cooked beef from a measurement on the uncooked carcass, it is possible that it may become of use for measuring the texture of meat analogs, although no reports have been published on this potential use.

The Instron Universal Testing machine (Hindman and Burr, 1949) has been adapted for measuring textural properties of foods(Bourne et al, 1966). Briefly, this machine consists of two parts: a) the drive mechanism which drives a moving crosshead in a vertical direction by means of twin lead screws at selected speeds in the range .05 to 50cm per minute; and b) the load sensing and recording system which consists of electric bonded-wire strain gauges whose output is fed to a strip chart recorder. Bench models of this machine can measure forces from less than 1 Newton to 5,000 Newtons (100g to 500kg) and larger models can measure forces from less than 20 kg to more than 100 kilo-Newtons (2 grams to 10, 000 kilograms). The Instron machine can accep t any test cell and perform almost any kind of test that uses rectilinear motion, including the Warner-Bratzler Shear, Shear Press and a number of other test cells. It is widely used for research purposes including studies on the texture of meat and meat analogs (see figure 6).

Another universal type of testing machine was recently developed by the Engineering Research Service of the Canada Department of Agriculture (Voisey, 1971). This is similar in many respects to the Instron in design and construction and like the Instron will accept a large variety of test cells. It is the Ottawa Taxture Measuring System(OTMS). See figure 7.

B. Subjective Methods

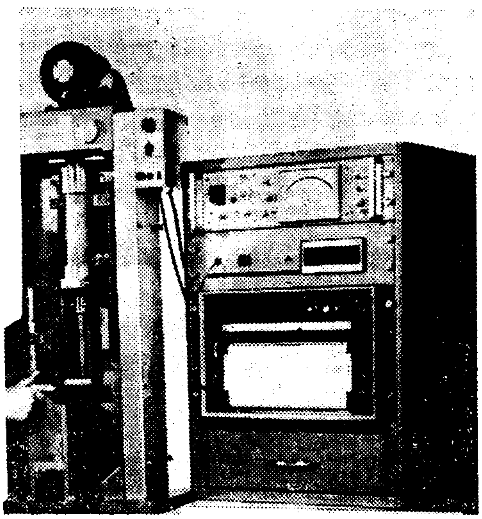

Fig. 7 The Ottawa Texture Measuring System. (Courtesy of Mr. Voisey)

Subjective methods for measuring texture are difficult, time-consuming and expensive because they require that people chew the food and give their opinion of the textural properties. Despite these difficulties sensory measurement is widely used because all the objective methods must finally be calibrated against the human palate. No matter what your instruments tell you about the textural properties of a food, if the mouth says that it does not like that food the food will not be consumed. In developing analogs and extenders it is important that the sensory measurement of texture be kept in mind because sensory methods provide a frame of reference from which effective instruments are selected and calibrated. Also, sensory methods can detect textural properties that cannot yet be measured effectively by instrumental methods.

The most comprehensive and highly developed system of evaluation of texture is the General Foods Sensory Texture Profiling Technique (Brandt et al, 1963, Szczesniak, 1963, Civille et al, 1973). (Another set of papers on this technique is due to be published in J. Texture Studies in late 1974). In this technique a panel of about six persons is trained to scale and measure quantitatively and in sequence all the textural properties that are sensed during the complete mastication of a food. In a sense this technique trains the human mouth to act with the precision and reproducibility of an analytical instrument.

Standard scales for hardness, fracturability, viscosity, gumminess, chewiness and adhesiveness allow the panel to estimate quantitatively these properties in foods. The standard scale for hardness is shown in table 5. Similar scales exist for the other properties. In addition to mechanical properties there are geo metrical characteristics which are qualitative and partly quantitative, consisting of those characteristics that relate to particle size, shape and orientation, including such characteristics as flaky, fibrous, pulpy, cellular, aerated, puffy, crystalline, powdery, chalky, grainy, gritty, coarse, lumpy and beady. Finally there are the chemal characteristics that include the factors of moistness, dryness and oiliness. The terms moistness and oiliness do not mean the actual moisture content of fat content of the food as would be

Table 5. Standard hardness scale in the GF Sensory Texture Profile

Panel Rating	Product	Brand or Type	Manufacturer
1	Cream cheese	Philadelphia	Kraft Foods
2	Egg white	hard-cooked, 5 min	....
3	Frankfurters	large, uncooked, skinless	Mogen David Kosher Meat Products Corp.
4	Cheese	yellow, American, pasteurized process	Kraft Foods
5	Olives	exquisite giant size, stuffed	Cresca Co.
6	Peanuts	cocktail type in vacuum tin	Planters Peanuts
7	Carrots	uncooked, fresh	....
8	Peanut brittle	candy part	Kraft Foods
9	Rock candy	....	Dryden & Palmer

(from Szczesniak et al, 1963)

determined by chemical analysis, but the sensation of moistness and oiliness as felt in the mouth during mastication.

When a panel has been trained in these basic scales, it is given a sample of food to eat and it develops a score sheet based on the order of appearance of textural charcteristics (see table 6). In the initial sensations which are perceived on the first bite the mechanical characteristics of hardness, fracturability and viscosity are measured and any of the geometrical characteristics and moistness and oiliness are measured and scored. During the second or masticatory phase those sensations perceived during the chewing process, the mechanical characteristics of gumminess, chewiness, adhesiveness, any of the geometrical characteristics and oiliness and moistness are scored. The final phase of mastication describes the sensations experienced just before, during and immediately after swallowing. This includes the rate of breakdown of the food, the manner in which it which it breaks down, the manner of moisture absorption of the food and any mouth coating and other effects.

Table 6. Sensory Texture Profile Ballot

TEXTURE PROFILE BALLOT

Product:____________ Name: ____________ Date: ____________

Initial (perceived on first bite)
- a) Mechanical
  - Hardness (1-9 scale)
  - Fracturability (1-7 scale)
  - Viscosity (1-8 scale)
- b) Geometrical
- c) Other

Masticatory (perceived during chewing)
- a) Mechanical
  - Gumminess (1-5 scale)
  - Chewiness (1-7 scale)
  - Adhesiveness (1-5 scale)
- b) Geometrical
- c) Other

Residual (change made during mastication)
- Rate of breakdown
- Type of breakdown
- Moisture absorption
- Mouth coating

(courtesy of Dr. Szczesniak)

The ballots shown in table 6 can be used in that form for determining the nature of the texture of a particular commodity. For product development work such as would be needed in developing analogs, a second ballot should be developed from the one shown in table 6, eliminating those factors that are of no importance and expanding in more detail those textural qualities that are important. An example of this is shown in table 7, which is the texture profile that was developed for arepa(wiedely-used staple Colombian food based on corn). In the comparative texture profile ballot a control which is the goal or standard product is compared to experimental products and textural property is rated as more than, equal to or less than the control. The magnitude of the deviation from the control is graded on a ±5 point scale for each textural property. This enables a researcher to determine which formulations and experimental variables bring the texture profile of the sample closer to the control and which take it further away from the control. It enables him to select those combinations of experimental conditions that give the smallest deviation

Table 7. Comparative texture profile ballot for arepa

	−	Control O	+
I. Initial Sensation			
a) Measure force to: bite off with incisors pull out with hand			
b) Hardness			
c) Sideways sliding of center			
d) Toughness of skin			
e) Doughiness of center			
f) Dryness of skin			
g) Moistness of center			
II. Mastication			
a) Chewiness (number of chews)			
b) Adhesiveness			
c) Pasitness of center			
d) Graininess of center			
e) Toughness of skin			
f) Roughness of skin pieces			
g) Dryness of skin pieces			
h) Moistness of center			
III. Final Sensations			
a) Rate of breakdown of skin			
b) Rate of breakdown of center			
c) Moistness of paste			
d) Graininess of paste			
e) Dryness of skin particles			
f) Roughness of skin particles			
g) Presence of coarse particles other than skin			
h) Absorption of moisture by mass			
i) Absorption of moisture by pieces of skin			
j) Mouthcoating of mass			
k) Presence of skin particles arcund mouth			
l) Scratchiness of residual 'skin particles			

INSTRUCTIONS: Put an X in "O" column if sampe is equal to control
Put IX to 5X in (+) column if sample is more than control
and in (−) column if less than control
X=Slightly different
XXXXX=Strongly different

(from Bourne et al, 1974)

between each texture parameter and the control.

The texture profile ballot for arepa (table 7) developed by Bourne et al in Colombia (1974) has twenty-eight different textural properties that the panel could identify and quantify. In Colombia this panel is being used to develop protein-fortified arepa flours that have the textural properties similar to the traditional product.

This sensory exture profiling technique is recommended for development of food analogs with textures that resemble the product they are intended to replace. The ballot also shows why it is necessary to go to the expense of using sensory methods to evaluate textural properties. It would obviously be impossible to duplicate by any instrumental methods that are available at the present time all the measurements listed on table 7.

The texture profile for arepa clearly demonstrates the need for using the scientific discipline of physics, psy chology, chemistry and engineering simultaneously in order to solve the group of complex problems involved in texturizing protein concentrates into acceptable foods.

REFERENCES

Bourne, M. C., Moyer, J. C., and Hand, D. B. 1966. Measurement of food texture by a universal testing machine. Food Technol. **20**, 522–526.

Bourne, M. C., Mercedes, Ana, Sandoval, R., Villalobos, Margy, and Buckle, Teresa S. 1974. Training a sensory texture profile panel and development of standard rating scales in Colombia. J. Texture Studies(in press).

Brandt, Margaret A., Skinner, Elaine Z., and Coleman, J. A. 1963. Texture profile method. J. Food Sci. **28**, 404–409.

Bratzler, L. J. 1932. Measuring the tenderness of meat by means of a mechanical shear. M.S. Thesis, Kansas State College.

Friedman, H. H., Whitney, J. E., and Szczeseniak, Alina S. 1963. The Texturometer a new instrument for objective texture measurement. J. Food Sci. **28**, 390–396.

Civille, Gail V., and Szczesniak, Alina S. 1973. Guidelines to training atexture profile panel. J. Texture Studies **4**, 204–223.

Corey, H. 1970. Texture in foodstuffs. CRC Critical Reviews in Food Technol. May 1970, 161–198.

Hansen, L. J. 1971. Meat tenderness testing. U.S. Pat. 3,602,038.

Hansen, L. J. 1972. Development of the Armour Tenderomenter for tenderness evaluation of beef carcasses. J. Texture Studies **3**, 146–164.

Hindman, H., and Burr, G. S. 1949. The Instron tensile tester. Trans. Am. Soc. Mech. Eng. **71**, 789–796.

Kramer, A. 1961. The Shear Press, a basic tool for the food technologist. Food Scientist **5**, No. 1, 7–16.

Kramer, A., Burkhardt, G. J., and Rogers, H. P. 1951, The Shear Press: a device for measuring food quality. The Canner **112**, 34–40.

Shama, F., and Sherman, P. 1973. Evaluation of some textural properties of foods with the Instron Universal Testing Machine. J. Texture Studies **4**, 344–353.

Stanley, D. W. 1975. Recent developments in analyzing the texture of meat. *In* Advances in Food Toxture, DeMan, and Voisey (Editors). Avi Publishing Co., Westport, Conn.

Szczesniak, Alina S. 1963. Objective measurements of fo od texture. J. Food Sci. **28**, 410–420.

Szczesniak, Alina S. 1971. Consumer awareness of texture and of other food attributes. J. Texture Studies **2**, 196–206.

Szczesniak, Alina S., and Kahn, E. L. 1971. Consumer awareness of and attitudes to food texture. I. Adults. J. Texture Studies 2, 280–295.

Szczesniak, Alina S., and Kleyn, D. H. 1963. Consumer awareness of texture and other foods attributes. Food Technol. **17**, 74–77.

Szczeseniak, Alina S., and Torgeson, Kathryn. 1965. Methods of meat texture measurement viewed from the background of factors affecting tenderness. Adv. Food Res. **14**, 33–165.

Voisey, P. W. 1971. The Ottawa texture measuring sytem. Can. Inst. Food Technol. 4, 91–103.

Yoshikawa, S., Nishimaru, S., Tashiro, T., and Yoshida, M. 1970. Collection and classification of words for description of food texture. I. Collection of words. J. Texture Studies 1, 437–442.

APPENDIX

Names and Addresses of Suppliers of Instruments Discussed in this Paper

1. General Foods Texturometer-Elnik Instruments Inc., 410 Gariboldi Aeenue, Lodi, NJ 07844
2. The Warner-Bratzler Shear-G-R Electric Manufacturing Co., Route # 2, Manhattan, KS 66502
3. Food Technology Texture Test System-Food Technology Corp., 12300 Parklawn Drive, Rockville, MD 20852
4. Instron Tester-Instron Corporation, 2500 Washington Street, Canton, MA 02021
5. Ottawa Texture Measuring System-Canners Machinery Ltd., Simcoe, Ontario, Canada