

Texture is a sensory property

Alina Surmacka Szczesniak*

22 Wilson Block, Mount Vernon, NY 10552-1113, USA

Received 15 July 2000; received in revised form 3 February 2001; accepted 12 March 2001

Abstract

Realizing that texture is a sensory property gives proper orientation to facets of texture research. Following the breakthrough in the 1960s and 1970s in surfacing the multi-parameter nature of texture and in defining the general principles of texture acceptability, the field has essentially reverted to commodity work. This paper reviews briefly the state of knowledge and points out specific research areas that could constitute new significant breakthroughs. These include defining the components of complex textural characteristics, developing an understanding of the perceptual interplay among texture parameters and between textural and other (e.g. visual clues, taste) modalities, exploring the breakdown pathways in the mouth for various food categories, and repeating earlier studies on consumer attitudes and preferences in the context of 21st century cultures and lifestyles. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Texture; Parameters; Perception; Consumer acceptance; Research needs

1. Introduction

Work on texture dates back to the late 19th and early 20th centuries (Bourne, 1982). It involved construction of simple testing instruments to be followed by biochemical analytical research and some rudimentary sensory evaluations. It was concerned primarily with the elimination of defects. Bread, meat and horticultural products of economic significance, fruits (such as apples and peaches) and vegetables (primarily corn and sweet peas) received the greatest attention.

In the early days research on texture was commodity oriented with no or little interaction among product groups. As a result, there was much confusion even on the definition of texture since each group had its own. Some equated texture with structure, others with tenderness, toughness, crispness, terms which were poorly defined and had different meaning to researchers dealing with different products.

It was not until the late 1950s that texture began to be looked at as a subject in itself (the way flavor had been studied for some time) mainly owing to a group of forward thinking technical research managers at the General Foods Corporation in the USA.

Today, the field has some structure, some principles have been developed and — above all — texture is being looked at not so much as the absence of defects, but as a positive quality attribute denoting freshness of produce, excellence of food preparation and contributing to the enjoyment of eating.

2. Definition of texture

A general agreement has been reached on the definition of texture which evolved from the efforts of a number of researchers. It states that “texture is the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinesthetics”. This definition conveys important concepts such as:

1. *texture is a sensory property* and, thus, only a human being (or an animal in the case of animal food) can perceive and describe it. The so-called texture testing instruments can detect and quantify only certain physical parameters which then must be interpreted in terms of sensory perception;
2. *it is a multi-parameter attribute*, not just tenderness or chewiness, but a gamut of characteristics;

* Tel. +1-914-668-7365.

E-mail address: alinasz@aol.com (A.S. Szczesniak).

3. *it derives from the structure* of the food (molecular, microscopic or macroscopic); and
4. *it is detected by several senses*, the most important ones being the senses of touch and pressure.

3. Texture profiling

Since texture is a multi-parameter attribute, as evidenced by a large number of words used to describe it, it is only logical to try to introduce some order and classify these terms' sensations into certain categories. An attempt at doing this is shown in Tables 1 and 2 for solids and semi-solids (Civille & Szczesniak, 1973; Szczesniak, 1963) and Table 3 for liquids (Szczesniak, 1979).

The classification of textural terms for solids and semi-solids gave rise to a profiling method of texture description (TPA) applicable to both sensory (Brandt, Skinner, & Coleman, 1963) and instrumental measurements (Bourne, 1978; Szczesniak, Brandt, & Friedman, 1963a). With the sensory method the evaluation includes (Fig. 1) several steps outside and inside the mouth, from the first bite through mastication, swallowing and residual feel in the mouth and throat. Its use is based on standard scales for the mechanical para-

eters (Szczesniak et al., 1963a) which are also employed for selecting and training of panel members (Civille & Szczesniak, 1973). As an illustration, Table 4 shows the original standard scale for hardness (Szczesniak et al., 1963a). The scale covers the entire range of hardness found in food products, from cream cheese at the low end to rock candy at the high end. It was recommended that when testing specific products the scale should be expanded in the intensity range covered by the test products. Experience gained in subsequent practical applications of these scales led to some modifications and development of additional scales described in a publication by Munoz (1986).

With the instrumental method, texture profiling involves compressing the test substance at least twice and quantifying the mechanical parameters from the recorded force-deformation curves (Fig. 2). With temperature sensitive foods, e.g. gelatin gels or chocolate, the profiling should be extended to temperature and tests performed at several temperature levels (Szczesniak, 1975a).

Excellent correlations between instrumental and sensory ratings were found in the initial work on TPA (Fig. 3). Subsequent publications by other researchers using the Instron (rather than the General Foods Texturometer exhibiting a sinusoidal manner of force application) generally agree on good to excellent correlations for hardness (based on calculated '*r*' values). Correlations for other parameters are usually less good and product-dependent. This area should be re-examined using comprehensive, rather than product-specific, research protocols.

4. Complexity of textural parameters

Some sensory parameters, especially the mechanical ones, seem to be fairly straight forward. For example, hardness/firmness/softness are on a scale of resistance of the food to the applied compressive forces. However, it is still not known exactly whether the human being reacts to the physical stress or to the strain, and how to simulate with instruments the high strain rates experienced in the mouth, a consideration very important with viscoelastic materials (i.e. most food products). Also importantly, we do not know where on the instrumental scale the boundaries are between hard and firm, and firm and soft.

Some other sensory parameters, e.g. creaminess and juiciness, may not be so straight forward. Work by several researchers on defining creaminess related it to thickness (which depends on physical viscosity) and smoothness (which depends on physical frictional forces) (Guinard & Mazzucchelli, 1996).

Juiciness was historically equated with the amount of juice released on mastication and quantified objectively as such. Then, a second dimension — rate of juice

Table 1
Classification of textural characteristics^a

Mechanical characteristics		
Primary parameters	Secondary parameters	Popular terms
Hardness		Soft → Firm → Hard
Cohesiveness	Brittleness	Crumbly → Crunchy → Brittle
	Chewiness Gumminess	Tender → Chewy → Tough Short → Mealy → Pasty Gummy
Viscosity		Thin → Viscous
Springiness		Plastic → Elastic
Adhesiveness		Sticky → Tacky Gooney
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

^a Szczesniak, 1963 by permission of the Institute of Food Technologists.

release on sequential chews — was added while studying strawberries (Szczesniak & Smith, 1969) and meat (Szczesniak, Sloman, Brandt & Skinner, 1963b) processed in ways that altered their water holding capacity. A

detailed evaluation of a variety of foods of plant origin by an analytical panel suggested that at least five perceptions may be combined in the human brain to form an opinion about juiciness of a food product. These are:

Table 2
Definitions of mechanical parameters of texture^a

	Physical	Sensory
<i>Primary properties</i>		
Hardness	Force necessary to attain a given deformation	Force required to compress a substance between molar teeth (in the case of solids) or between tongue and palate (in the case of semi-solids).
Cohesiveness	Extent to which a material can be deformed before it ruptures.	Degree to which a substance is compressed between the teeth before it breaks.
Viscosity	Rate of flow per unit force.	Force required to draw a liquid from a spoon over the tongue.
Springiness	Rate at which a deformed material goes back to its undeformed condition after the deforming force is removed	Degree to which a product returns to its original shape once it has been compressed between the teeth
Adhesiveness	Work necessary to overcome the attractive forces between the surface of the food and the surface of the other materials with which the food comes in contact.	Force required to remove the material that adheres to the mouth (generally the palate) during the normal eating process.
<i>Secondary properties</i>		
Fracturability	Force with which a material fractures: a product of high degree of hardness and low degree of cohesiveness.	Force with which a sample crumbles, cracks, or shatters.
Chewiness	Energy required to masticate a solid food to a state ready for swallowing: a product of hardness, cohesiveness and springiness	Length of time (in sec) required to masticate the sample, at a constant rate of force application, to reduce it to a consistency suitable for swallowing.
Gumminess	Energy required to disintegrate a semi-solid food to a state ready for swallowing: a product of a low degree of hardness and a high degree of cohesiveness.	Denseness that persists throughout mastication; energy required to disintegrate a semi-solid food to a state ready for swallowing.

^a Civille and Szczesniak, 1973. By permission of the Food and Nutrition Press, Inc.

Table 3
Classification of mouthfeel terms^a

	Category	Typical words
I	Viscosity-related terms	Thin, thick, viscous
II	Feel on soft tissue surfaces	Smooth, pulpy, creamy
III	Carbonation-related terms	Bubbly, tingly, foamy
IV	Body-related terms	Heavy, watery, light
V	Chemical effect	Astringent, burning, sharp
VI	Coating of oral cavity	Mouthcoating, clinging, Fatty, oily
VII	Resistance to tongue movement	Slimy, syrupy, pasty, Sticky
VIII	Afterfeel-mouth	Clean, drying, lingering, cleansing
IX	Afterfeel-physiological	Refreshing, warming, thirst-quenching, filling
X	Temperature-related	Cold, hot
XI	Wetness-related	Wet, dry

^a Szczesniak 1979.

1. force with which the juice squirts out of the product;
2. rate of juice release;
3. total amount released on chewing;
4. flow properties of the expressed fluid;
5. contrast in consistency between liquid and suspended cell debris; and
6. effect on saliva production (Szczesniak & Ilker, 1988).

Table 4
Example of a standard scale — Hardness^a

Panel rating	Product	Brand or type	Manufacturer	Sample size	Temperature
1	Cream cheese	Philadelphia	Kraft Foods	½ in.	45–55°F
2	Egg white	Hard-cooked 5 min	–	½ in. tip	room
3	Frankfurters	Large, uncooked, skinless	Mogen David Kosher Meat Products Corp.	½ in.	50–65°F
4	Cheese	Yellow, American pasteurized process	Kraft Foods	½ in.	50–65°F
5	Olives	Exquisite giant size, stuffed	Cresca Co:	1 olive	50–65°F
6	Peanuts	Cocktail type in vacuum tin	Planters Peanuts	1 nut	Room
7	Carrots	Uncooked, fresh	–	½ in.	Room
8	Peanut brittle	Candy part	Kraft Foods	–	Room
9	Rock candy	–	Dryden & Palmer	–	Room

^a Szczesniak et al., 1963a By permission of the Institute of Food Technologists.

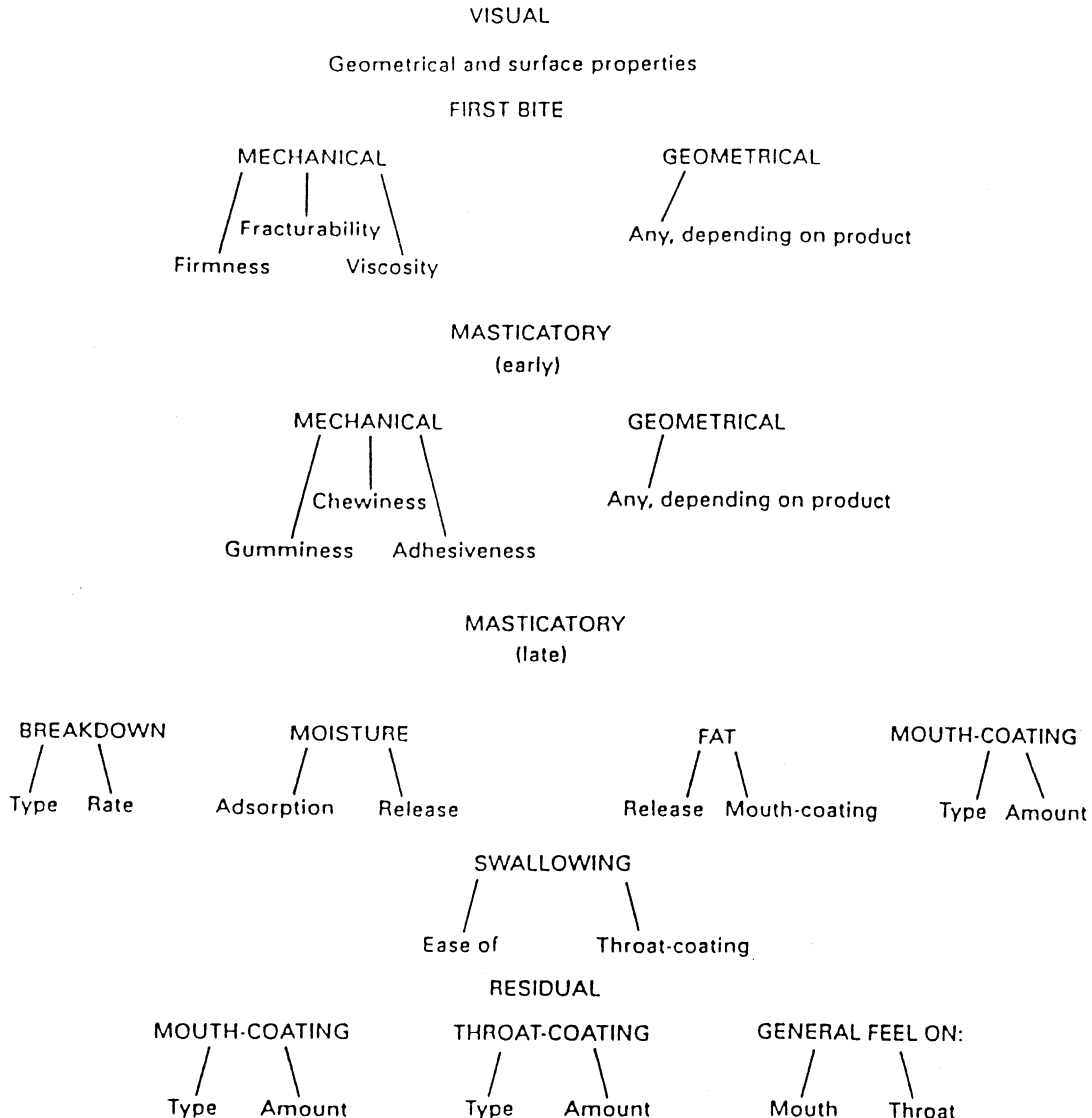


Fig. 1. Schematic of the early sensory texture profiling technique. Brandt et al., 1963. By permission of the Institute of Food Technologists.

5. Perception

5.1. Physiology of the oral cavity

Although some texture assessment is performed visually, the main evaluation occurs in the mouth. The anatomy and physiology of the oral cavity has been studied from the standpoint of general knowledge generation and its application to medical and dental problems. It was reviewed and discussed by several authors (Boyer & Kilcast, 1986a; Heath, 1991; Kilcast & Eves, 1991; Ledley, 1971; Yeatman & Drake, 1973). However, because of its complexity the psychophysiology of texture perception is not well known. A comprehensive review on the subject has been published by Christensen (1984).

In contrast to other sensory food attributes (e.g. taste and color) there are no single and specific receptors for texture because of its multiparameter nature. Some textural (geometrical) parameters are felt when the food is first placed in the mouth. Most are perceived when the food is deformed on chewing with the teeth, manipulated and moved by the tongue around the oral cavity, and mixed with saliva. A number of tissues (e.g. periodontal, skin, in the temporomandibular joint) and receptors (somesthetic, kinesthetic) are involved. They perceive such texture-related sensations as touch/pressure, pain, joint position, etc. Manly, Pfaffman, Lathrop, and Keyser et al (1952) postulated that kinesthetic sensations may be most important for soft foods and periodontal tactile/pressure sensations for hard foods. Information registered by the receptors is instantly carried to the central nervous system and then to the brain by the trigeminal nerve. It has been suggested that the viscoelastic properties of the periodontal tissues are important in the detection of forces applied

in mastication (van Steenberghe & de Vries, 1978, quoted by Christensen, 1984).

5.2. Approaches to perception research

Early work on sensory perception of textural characteristics used non-edible materials of defined rheological properties (e.g. Scott Blair & Coppen, 1940). The same approach was employed by Mioche, Petron, and Auroy (1973) to study the force of mastication using miniaturized load cells placed in the oral cavity. These authors felt that “the use of load cells together with food-stuffs models exhibiting simple predictable characteristics opens up new areas of investigation into texture perception of solid products”. Another new area was opened up by Kilcast at the Leatherhead R.S. in England who utilized electromyography to follow changes in food resistance on mastication (Boyer & Kilcast, 1986b).

More work is needed on how specific textural attributes are perceived in the mouth and how they are affected by mouth temperature, rate of mastication and saliva. A rigorous and analytical approach is needed. Christensen (1984) recommended that “where possible, indirect measures of perception should be replaced by direct measures, and correlative studies should be supplemented with studies that critically test hypothesis”.

To obtain a complete understanding would be a Herculean task, time consuming, economically, scientifically and intellectually taxing. A principle taught to officers in war colleges might be applied here: divide and conquer. Divide the field into priorities based on the economic importance of specific textural characteristics combined with the recognition of the dynamic aspects of texture assessment

5.3. Breakdown path in the mouth

The recognition that texture is a multiparameter attribute is reflected in the development of the profiling methodology for both its sensory and instrumental assessment. The dynamic aspects of texture evaluation in the mouth, however, are presently considered seriously only in sensory profiling.

During the process of mastication in the mouth the food is broken into small particles through a combination of compressive, shearing and tensile forces, wetted and lubricated with saliva, and formed into a bolus suitable for swallowing. This dynamic aspect of texture perception has been treated in a conceptual manner by Hutchings and Lillford (1988) and also discussed recently by Heath and Prinz (1999).

Hutchings and Lillford (1988) presented a hypothesis that each food has a characteristic “breakdown path” in the mouth comprised of three dimensions: structure, degree of lubrication and time. They postulated that this breakdown path affects consumer preference and may

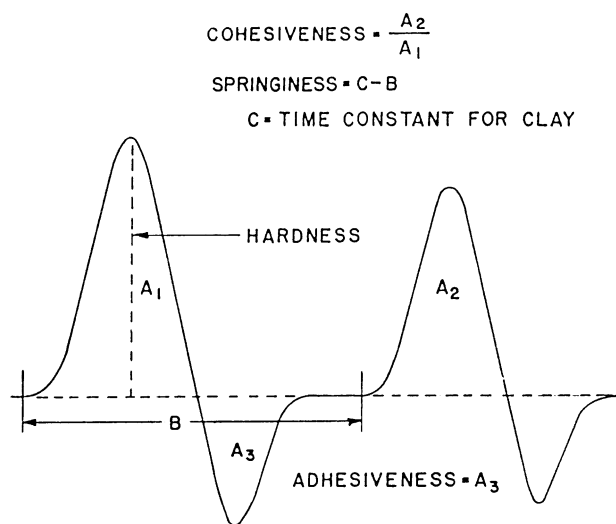


Fig. 2. Generalized instrumental texture profile curve (obtained with the General Foods Texturometer).

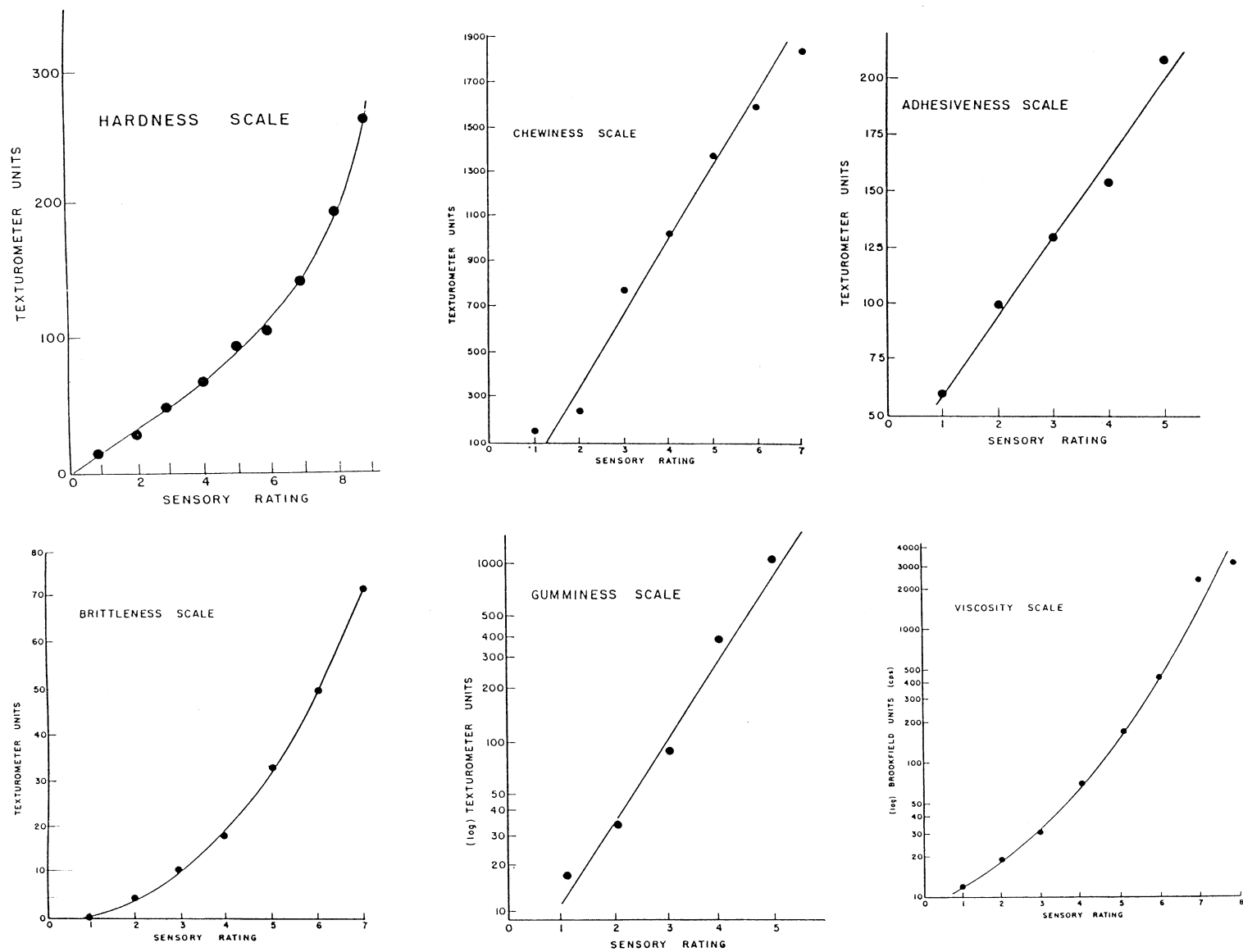


Fig. 3. Correlations between sensory and instrumental values on standard texture scales. Szczesniak et al., 1963. By permission of the Institute of Food Technologists.

be subject to considerable variations. These may include: individual differences among consumers (slow/passive eaters vs. fast/nervous eaters), their age (children vs. adults vs. old people), physiological state (hunger vs. satiety) and eating occasions (hurried vs. leisurely meals). These authors also provided details of what should be considered in pursuing the validation of this hypothesis and of the presented model.

Without doubt, the dynamic aspects of texture assessment should be studied in depth and defined both qualitatively and quantitatively for various food classes. Computer imaging and simulation techniques may be very applicable and helpful here.

5.4. *Gestalt*

The word ‘Gestalt’ is defined in Webster’s dictionary as “a structure or configuration of physical, biological or psychological phenomena so integrated as to constitute a functional unit with properties not derivable from its parts in summation”. When applied to the study of perception the concept of ‘Gestalt’ rejects atomistic or elemental analysis of the stimulus and implies an indivisible connectiveness. It has come to mean (1) that a word used to denote a perception may actually refer to the sum of several individual sensations (this has been illustrated earlier on the example of ‘juiciness’), and (2) that the presence of one stimulus may influence judgment on the perception of another stimulus (e.g. the color of a beverage will influence its flavor perception).

The early psychorheologists, especially the distinguished father of food rheology Dr. George Scott Blair and his co-workers, were very cognizant of the Gestalten in their work that attempted to correlate physical measurements on cheese and dough with the expert sensory description by experienced cheese makers and bakers. They concluded that the Gestalten were not analyzable and defied logic (Scott Blair, 1963). The psychologist David Katz, working in the late 1930’s in the breadmaking industry, concluded that the term ‘body’, which was most generally used, was a composite mixture of four sensory properties: (1) the degree of stickiness; (2) the degree of elasticity in the sensory sense of bounce or springiness; (3) the level of resistance to tearing; and (4) the extensibility or ductility. Katz has made two important observations (1) that the nature and number of sensory perceptions may be different from physical properties, and (2) that the integration of perceptions is subconscious (quoted by Szczesniak, 1990a). No quantitative relationships were developed by these early researchers because of the tediousness of calculations and the tremendous time investment required. Today, the use of computers should make possible significant advances in this line of research by enabling the researchers to perform computations in a manner not possible in the past.

6. Consumer and texture

Comprehensive studies on consumer attitudes to texture were conducted by the General Foods group and appeared in the literature in the 1960s and 1970s (Szczesniak, 1971, 1972; Szczesniak and Kahn, 1971; Szczesniak and Kleyn, 1963). The researchers combined their backgrounds in food science, sociology and consumer testing to develop some general principles applicable to understanding consumer likes and dislikes and to guiding product development work. The techniques used were word association and in-depth consumer interviews. Although it appears that the developed general principles are still valid today, this type of studies should be repeated to identify what changes in consumer thinking about texture might have occurred in the intervening years due to changing life styles, changing food habits, greater sophistication of consumers and greater appreciation by the food industry of the positive and saleable aspects of texture (Szczesniak, 1990b).

6.1. *Factors shaping attitudes to texture*

The first important finding in the early studies was that, for the most part, texture is taken for granted and consumers do not comment on it unless asked specific questions, or unless texture is definitely off or inappropriate, expectations are violated or non-food associations are triggered. This is important to remember when conducting consumer tests. The second key finding was that texture has quality associations. It is indicative of freshness (limp lettuce, shriveled apples, stale bread are considered not fresh) and excellence in food preparation. Some concerns about health effects are also associated with off textures, although other sensory cues, such as odor, are the primary signals of spoiled food that may be injurious to one’s health when eaten.

Attitudes to texture are shaped by physiological factors, socially and culturally learned expectations, and psychological factors (Szczesniak & Kahn, 1971). People like to be in full control of the food placed in their mouth. Stringy, gummy or slimy foods or those containing unexpected lumps or hard particles are rejected for fear of gagging or choking. Consumers, especially those in the lower socio-economic classes and especially women, are very conscious of how they look while eating and difficult to manipulate textures evoke negative attitudes. Associations with non-edible objects and with unpleasant past events will also lead to rejection of certain textures. Learning about foods is a continuing process and adults — particularly those of higher socio-economic status — learn to accept new, exotic, sophisticated foods at almost any stage of life. The recent explosion of Oriental foods and restaurants in the USA is an example. In this context, the American consumer

has learned to consume firm, crisp cooked vegetables which in the past were expected to be soft and almost mushy.

The age of the consumer appears to have an influence on his/her attitude to and appreciation of texture. Past work (Szczesniak, 1972) indicated that teenagers had a higher degree of texture awareness. These teenagers are now adult consumers willing to experiment with and accept different textures.

6.2. Factors in acceptance

Factors affecting acceptance of texture may be divided into those residing in the consumers, those residing in the food, and those residing in the eating situation.

The primary factor associated with the consumer is the age, especially the two extremes: babies and young children, and the geriatric population. The interplay between texture acceptance and developmental sequence of oral functions and motor skills has been discussed by Szczesniak (1972) based on consumer interviews and the classical observational study of child development by A. Gesell and her associates. Babies and young children reject textures that are difficult to manipulate in the mouth at a particular stage of physical development. The baby food industry is well aware of the principles and practices them with great economic success, but some refinements in terms of texture optimization may be in order.

The population of industrialized countries is ageing rapidly, with the percentage of people in their 70s and 80s increasing at an especially fast pace. In the USA the 85+ years age group is the fastest growing segment of the population. In 1998 there were more than 62,000 centenarians and, by some estimates, that number could reach 1 million by the year 2050. In general, older people are less willing to learn new things and, thus, in terms of texture acceptance and preference may be very conservative. Some have trouble chewing either because of poor dentition, or because of weak muscles and poor coordination. Problems with swallowing and with 'dry mouth' because of reduced saliva production are common. The most prevalent swallowing disorder is dysphasia. It may have anatomical or neurological causes and often follows radiation treatment. It is a life-threatening condition and involves problems of bolus transportation into the airways.

Observations have been made that some foods are easier than others for these patients to swallow (see p.170 in Szczesniak, 1987). More work with well designed research protocols is needed in this area. There is also a link between texture and nutrition (ibid). Foods with textures specifically designed for the elderly may constitute a significant business opportunity in the 21st century.

The general health of the consumer and the medication taken which may affect saliva production and its

chemical composition, food digestion, movement through the GI tract and elimination may also have an effect on acceptance of specific textures (e.g. those with considerable roughage content).

Factors in the food that affect texture acceptance are of particular interest to the food industry. An important factor to consider is the 'image' the product is intended to convey. A product that is positioned as a nutritious food that is soothing, relaxing and pampering to the consumer should be soft and creamy. A product that is intended to be consumed as a snack in situations that call for activity, energy and aggressiveness should be firm and crisp, or chewy.

Munoz and Civille (1987) reported that "consumers do not expect to work hard for the sensory and nutritional returns in foods. Only if a product is yielding a pleasant flavor...or positive texture attributes (persistence of crispness or crunchiness) are consumers willing to invest more than 20 chews." They also confirmed earlier studies by Szczesniak and Kahn (1971) that the size of a serving appears to influence the acceptance of textural characteristics.

The psychological element of expectation, based on appearance of the product or past experience, if not met has a strong influence on reducing the level of texture acceptance. We all remember biting into an apple expecting it to be crisp and juicy, and finding out with displeasure that it is soft and mealy. It ends up in the garbage. But softness is accepted and expected in a baked apple. An open texture with thin cell walls in a sponge cake suggests a soft texture that will readily absorb saliva and be easy to form into a bolus. Its acceptance will be quickly diminished when the consumer finds it to be dry and coarse in the mouth.

A word should be said about *texture tolerance*. How far can textural characteristics deviate from the expected norm depends on product category, on the specific product and on its predominant characteristic. With some products (e.g. cottage cheese) texture tolerance may be quite large, while with other products (e.g. potato chips) it may be quite small. In general, products that are valued for their crispness or crunchiness are associated with narrow tolerance of texture variation.

Eating occasions were also identified in the early consumer studies (Szczesniak & Kahn, 1971) to have a strong influence on texture awareness and preference. Texture tolerance was found to be most limited at breakfast time, with preferred textures being those that lubricate the mouth, that are easy to control and manipulate in the mouth, and that can be swallowed and digested easily. Overall, textures most acceptable at weekday breakfast are those that are familiar. Dinner is the meal when texture is most appreciated and enjoyed, and when the consumer is receptive to experimenting with new textures. There is high tolerance for many textures because the traditional dinner consists of several

courses and there is no fear of going hungry if one food item is disliked. Texture preference follows the pattern of the meal, with the most important textures being associated with the main course. The dessert is the place for ‘fun’ texture characteristics, such as gooey and sticky. Overall, as the day advances acceptance of characteristics (for both texture and flavor) associated with wholesomeness declines and acceptance of characteristics associated with enjoyment rises.

For an additional viewpoint on the role of texture in food acceptability, reference should be made to Lillford (1991).

6.3. Liked and disliked characteristics

Which characteristics are liked or disliked depends primarily on physiological factors which are common to all peoples, and on cultural factors which may vary between cultures. All characteristics appear to have specific con-

notations. They were described in detail by Szczesniak and Kahn (1971). Table 5 summarizes the key liked and disliked textural characteristics in the USA. Topping the list of liked characteristics is crispness and crunchiness, active and stimulating characteristics that prompt the consumer to further eating. Generally disliked are characteristics that make the product difficult to control and manipulate in the mouth: tough, lumpy, slimy.

Table 5
Generally liked and disliked textured characteristics (Szczesniak & Kehn, 1971)

Liked	Disliked
Crisp	Tough
Crunchy	Soggy
Tender	Lumpy
Juicy	Crumbly
Firm	Slimy

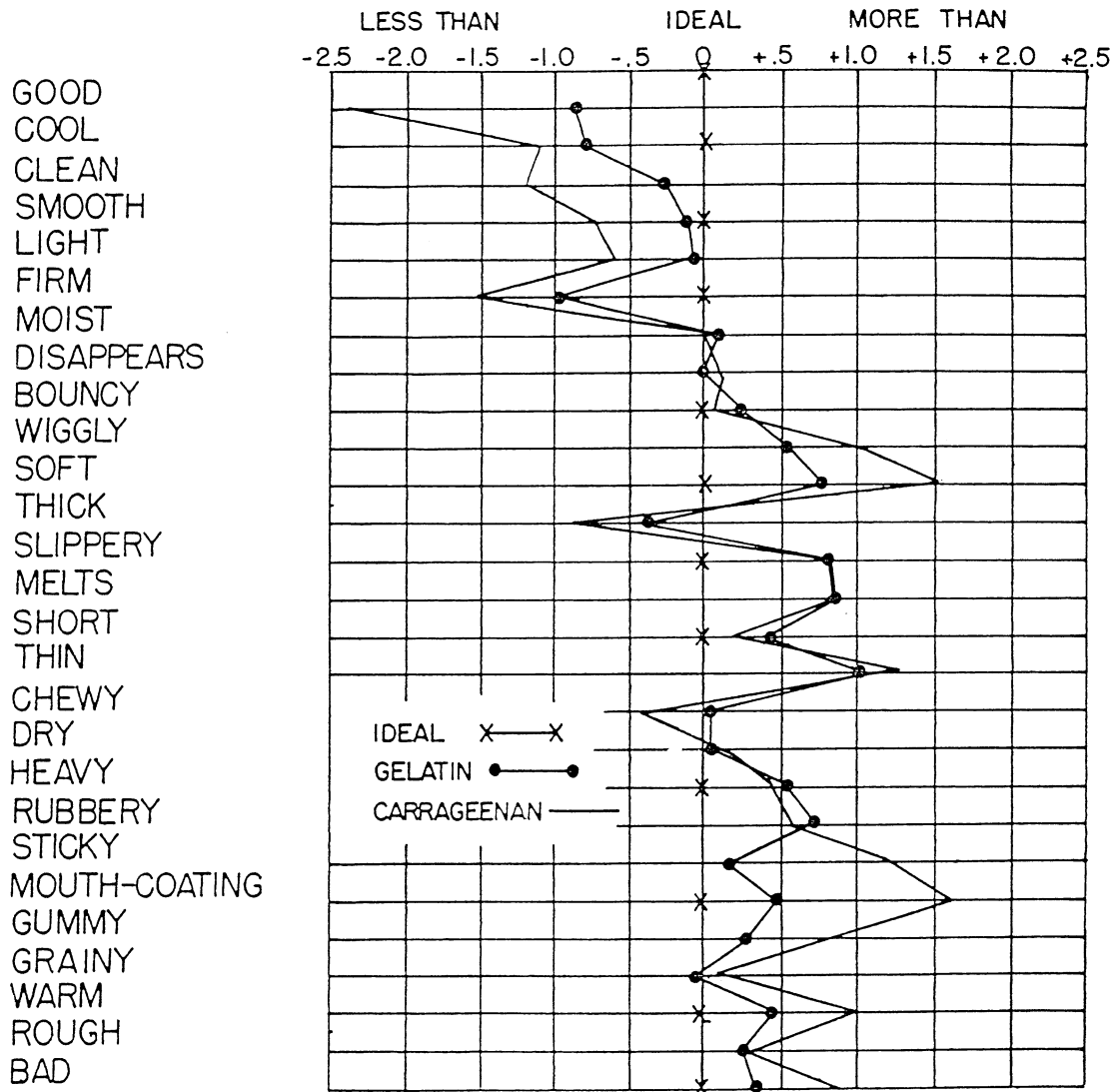


Fig. 4. Consumer texture profile. Szczesniak et al., 1975. By permission of the Institute of Food Technologists.

In the context of highly acceptable and valued textures mention should be made of *textural contrast*, which is viewed by consumers as optimizing the eating experience and reflecting the excellence of food preparation. Textural contrast can occur within a product (e.g. in a sandwich or a layered cake), on the plate (e.g. steak, mashed potatoes, carrots), or within a meal (soup, main course, dessert). Liking of textural contrast increases with maturity. Young children usually prefer to finish one type of food on the plate before starting on another, or mash everything together before eating.

The most pleasant combinations involve strong differentiation such as crisp/creamy. Other principles of textural contrast are that it should be anticipated, should have stability and 'integrity', should not violate good table manners and should be comfortable to eat (Szczesniak & Kahn, 1981).

7. Finding an ideal texture

There are a number of tests used by sensory scientists to determine product acceptability with special reference to individual characteristics such as texture and areas of potential improvement. Economics, project objectives and individual preferences of sensory practitioners determine which test type will be used. Some novel mathematical business-oriented methods of texture optimization were developed by Moskowitz (e.g. Moskowitz & Jacobs, 1987).

Fig. 4 illustrates a simple way of defining an 'ideal' texture and the deviation of test products from that target using the concept of consumer texture profiling (Szczesniak et al. 1975). A trained panel is first used to develop a lexicon of terms applicable to the product type of interest. These terms should be understandable to the consumer and have the same meaning. Next, the words are arranged in random order and the terms 'good' and 'bad' are inserted in the beginning and the end, respectively. A group of consumers, seated in quiet surroundings, is asked to rate on a suitable scale the characteristics of an 'ideal' product for that category, and then rate the test samples presented to them. The obtained results can be displayed in a number of ways. Expressing differences from the 'ideal' (as shown in Fig. 4) is the clearest way to identifying specific areas for improvement. Determining which characteristics correlate with 'good' and which correlate with 'bad' identifies those that impact positively or negatively on product acceptance. Our research has shown (1) that the consumer can identify the characteristics of an 'ideal' product in a meaningful and reproducible manner, and (2) that bringing the product closer to the 'ideal' in its texture profile increases the degree of liking.

Texture selected for a specific product should be compatible with the image the product is intended to convey, a principle which has already been discussed in Section 6.2.

8. Concluding remarks

Much of the progress made in texture research has been accomplished through interdisciplinary research (Szczesniak, 1975b). First initiated in George W. Scott Blair's time by cooperation between representatives of physical chemistry/rheology and psychology, later carried on by food scientists, sensory scientists and practitioners, sociologists and engineers/rheologists in addition to physical chemists and physiologists, these cooperative efforts should continue and be strengthened by addition of computer scientists and mathematicians.

A number of specific questions need concentrated research efforts. The purpose of this Technical Summit meeting was to identify such areas through a multi-disciplinary effort.

References

- Boyer, A. M., & Kilcast, D. (1986a). Food texture and dental science. *Journal of Texture Studies*, 17, 221–252.
- Boyer, A. M., & Kilcast, D. (1986b). Electromyography as a novel method for examining food texture. *Journal of Food Science*, 51, 859–860.
- Bourne, M. C. (1978). Texture profile analysis. *Food Technology*, 32(7), 62–66 72.
- Bourne, M. C. (1982) *Food Texture and Viscosity* (pp. 19–22), NY: Academic Press.
- Brandt, M. A., Skinner, L. Z., & Coleman, J. A. (1963). Texture profile method. *Journal of Food Science*, 28, 404–409.
- Christensen, C. M. (1984). Food texture perception. *Advances in Food Research*, 29, 159–199.
- Civille, G. V., & Szczesniak, A. S. (1973). Guidelines to training a texture profile panel. *Journal of Texture Studies*, 4, 204–223.
- Guinard, J.-X., & Mazzucchelli, R. (1996). The sensory perception of texture and mouthfeel. *Trends in Food Science and Technology, Reference Edition*, 7, 213–219.
- Heath, M. R. (1991). The basic mechanics of mastication: main adaptive success. In J. F. V. Vincent, & P. J. Lillford (Eds.), *Feeding and the texture of food*, Society for Experimental Biology Seminar Series 44 (pp. 143–166).
- Heath, M. R., & Prinz, J. F. (1999). Oral processing of foods and the sensory evaluation of texture. In A. J. Rosenthal (Ed.), *Food texture, measurement and perception (Chapt. 2)* (pp. 18–29). Gathersburg: Aspen Publishers Inc.
- Hutchings, J. B., & Lillford, P. J. (1988). The perception of food texture — the philosophy of the breakdown path. *Journal of Texture Studies*, 19, 103–115.
- Kilcast, D., & Eves, A. (1991). Integrating texture and physiology — techniques. In J. F. V. Vincent, & P. J. Lillford *Feeding and the texture of food*. Society for Experimental Biology Seminar Series 44 (pp. 168–183).
- Ledley, R. S. (1971). Dental forces and mastication. *Journal of Texture Studies*, 2, 3–17.
- Lillford, P. J. (1991). Texture and acceptability of human foods. In J. F. V. Vincent, & P. J. Lillford *Feeding and the texture of food*. Society for Experimental Biology Seminar Series 44 (pp. 231–243).
- Manly, R. S., Pfaffman, C., Lathrop, D. D., & Keyser, J. (1952). Oral sensory thresholds of persons with natural and artificial dentitions. *Journal Dental Research*, 31, 305–312.

- Mioche, L., Peyron, A., & Auroy, P. (1993). The use of intraoral load cells in the study of texture perception. *Journal of Texture Studies*, 24, 361–373.
- Moskowitz, H. H., & Jacobs, B. E. (1987). Consumer evaluation and optimization of food texture. In H. H. Moskowitz (Ed.), *Food texture — instrumental and sensory measurement* (pp. 293–328). New York: Marcel Dekker Inc.
- Munoz, A. M. (1986). Development and application of texture reference scales. *Journal of Sensory Studies*, 1, 55–83.
- Munoz, A. M., & Civille, G. V. (1987). Factors affecting perception and acceptance of food texture by American consumers. *Food Review International*, 3(3), 285–322.
- Scott Blair, G. W. (1958). Rheology in food research. *Adv. Food Res.*, 8, 1–61.
- Scott Blair, G. W., & Coppen, F. M. (1940). The subjective judgement of the elastic and plastic properties of soft bodies. *British Journal of Psychology*, 31, 61–79.
- Szczesniak, A. S. (1963). Classification of textural characteristics. *Journal of Food Science*, 28, 385–389.
- Szczesniak, A. S. (1971). Consumer awareness of texture and of other food attributes II. *Journal of Texture Studies*, 2, 196–206.
- Szczesniak, A. S. (1972). Consumer awareness of and attitudes to food texture II. Children and teenagers. *Journal of Texture Studies*, 3, 206–217.
- Szczesniak, A. S. (1975a). Textural characterization of temperature sensitive foods. *Journal of Texture Studies*, 6, 139–156.
- Szczesniak, A. S. (1975b). General Foods texture profile revisited — ten years perspective. *Journal of Texture Studies*, 6, 5–17.
- Szczesniak, A. S. (1979). Classification of mouthfeel characteristics of beverages. In P. Sherman (Ed.), *Food texture and rheology* (pp. 1–20). London: Academic Press.
- Szczesniak, A. S. (1987). Relationship of texture to food acceptance and nutrition. In J. Solms, D. A. Booth, R. M. Pangborn, & O. Raunhardt (Eds.), *Food acceptance and nutrition* (pp. 157–172). New York: Academic Press.
- Szczesniak, A. S. (1990a). Psychorheology and texture as factors controlling the consumer acceptance of food. *Cereal Foods World*, 35, 1201–1204.
- Szczesniak, A. S. (1990b). Texture: is it an overlooked food attribute? *Food Technology*, 44(9), 86–88,90,92,95.
- Szczesniak, A. S., & Ilker, R. (1988). The meaning of textural characteristics — juiciness in plant foods. *Journal of Texture Studies*, 19, 61–78.
- Szczesniak, A. S., & Kahn, E. E. (1971). Consumer awareness of and attitudes to food texture I. Adults. *Journal of Texture Studies*, 2, 280–295.
- Szczesniak, A. S., & Kahn, E. E. (1981). Texture contrasts and combinations: a valued consumer attribute. *Journal of Texture Studies*, 15, 285–301.
- Szczesniak, A. S., & Kleyn, D. H. (1963). Consumer awareness of texture and other food attributes. *Food Technology*, 17, 74–77.
- Szczesniak, A. S., & Smith, B. J. (1969). Observations on strawberry texture. A three-pronged approach. *Journal of Texture Studies*, 1, 65–89.
- Szczesniak, A. S., Brandt, M. A., & Friedman, H. (1963a). Development of standard rating scales for mechanical parameters of texture and correlation between the objective and sensory methods of texture evaluation. *Journal of Food Science*, 28, 397–403.
- Szczesniak, A. S., Sloman, K., Brandt, M. S. & Skinner, E. Z. (1963b). Objective measurement of texture of fresh and freeze-dehydrated meats. *Proceedings of the 15th research conference of the American Meat Institute Foundation* (pp.121–138).
- Szczesniak, A. S., Loew, B. J., & Skinner, E. Z. (1975). Consumer texture profile technique. *Journal of Food Science*, 40, 1253–1256.
- Yeatman, J. N., & Drake, B. K. (1973). Physiological aspects of texture perception, including mastication. In A. Kramer, & A. S. Szczesniak (Eds.), *Texture measurements of foods* (pp. 10–16). Dordrecht, Holland: D. Reidel Publishing Co.