# TEXTURE IN SOLID AND SEMISOLID FOODS

**Bourne, Malcolm**
*New York State Agricultural Experiment Station and Institute of Food Science, Cornell University, Geneva, NY,USA*

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## Contents



## Summary

Much progress has been made over the last fifty years in understanding what texture is, and how it can be measured, specified and controlled. However, many problems remain unsolved or only partially resolved. We look forward with confidence to the next generation of talented researchers from many disciplines, which will advance this field and lead to the development of better textures and more consistent textural quality in the foods purchased in our supermarkets.



## 1. Introduction

Appearance, flavor and texture are the three major acceptability factors in food consumption because they can impart enjoyment of the food. If these attributes do not meet consumer expectations, the food will not be consumed and the customer is unlikely to purchase that particular brand of product again.

Appearance (color, size, shape) is based on the optical sense and is a response of the eye to the light reflected from or transmitted through the food. Flavor is the body's response to a chemical impact and is sensed in two locations: 1) the olfactory organ in the nose (aroma or smell), and 2) the taste buds in the tongue (taste). These are called the chemical senses. Texture is sensed primarily in the mouth, on the lips, teeth, gums and tongue, although some texture notes can be sensed by other parts of the body, such as the hand. Textural perception occurs directly through the tactile (touch) and kinesthetic

(movement) senses, and indirectly through the senses of vision and hearing. In contrast to color and flavor, there are no specific sensory receptors for texture. Texture is an important quality attribute in almost all foods, and is most important in foods that are bland in flavor or have the characteristics of crispness or crunchiness.

Interest in what comprises texture and how it is measured and controlled is driven by two major concerns: 1) imparting pleasure just before and during mastication and 2) economics. People are prepared to pay a higher price for food when the texture is "just right".

A good example of this human propensity for textures that please can be found in the case of meat from American supermarkets, where different cuts of beef typically range in price from less than three dollars to more than sixteen dollars per kilogram. This wide range in price is largely the result of texture quality—consumers are prepared to pay a high price for tender meat and expect to pay a low price for tough or dry meat.

Considering the many millions of kilograms of beef consumed each year, it becomes obvious that economic factors are a great driving force to achieving desirable textures in beef and other foods.

Almost all researchers agree that "texture" is a sensory attribute and that a number of textural properties exist. The International Organization for Standardization defines texture as "all the mechanical, geometrical and surface attributes of a food product perceptible by means of mechanical, tactile, and, where appropriate, visual and auditory receptors".

Those physical properties of foods that are not sensed by the body (and there are many) should not be described as texture. There are often good reasons for measuring non-texture physical properties, but they should not be confused with textural properties.

A review of the development of definitions of texture and related terms is found in Bourne (1982).

One definition of texture is as follows: "Texture may be defined as that group of physical characteristics that arise from the structural elements of the food, are sensed primarily by the feeling of touch, are related to the deformation, disintegration and flow of the food under a force, and are measured objectively by functions of mass, time, and length". This definition teaches the concept that texture has its roots in structure (molecular, microscopic, and macroscopic) and the manner in which this structure reacts to applied forces. It also emphasizes that texture is a multidimensional property comprising a number of sensory characteristics.

A large number of terms are popularly used to describe textural sensations. Table 1 organizes many of these terms into a manageable system that facilitates understanding their interrelationships. It classifies textural properties into mechanical characteristics (reaction of the food to stress), geometrical characteristics (the feeling of size, shape and arrangements of particles in the food, sometimes called 'particulate properties'), and other characteristics (relating to the sensations of moisture, fat and oil in the mouth).

| Characteristics | Primary parameter | Secondary parameter | Popular terms |
|---|---|---|---|
| Mechanical | Hardness | - | Soft-firm-hard |
| | Cohesiveness | Brittleness | Crumbly-crunchy-brittle |
| | | Chewiness | Tender-chewy-tough |
| | | Gumminess | Short-mealy-pasty-gummy |
| | Viscosity | - | Thin-thick |
| | Springiness | - | Plastic-elastic |
| | Adhesiveness | - | Sticky-tacky-gooey |
| Geometrical | Class | | Examples |
| | Particle size & shape | - | Gritty, grainy, course, etc |
| | Particle shape & orientation | - | Fibrous, cellular, crystalline, etc. |
| Other | Moisture content | - | Dry-moist-wet-juicy |
| | Fat content | Oiliness | Oily |
| | | Greasiness | Greasy |

Table 1. Classification of textural characteristics and their relationship to popular nomenclature.
[Adapted from: Szczesniak A.S. (1963). Classification of textural characteristics. *J. Food Science* **28**, 385-389.]

The importance of structure for the development of texture cannot be overemphasized. Meat, fish, poultry, fruits and vegetables have a cellular structure and the interactions between the cell contents, cell walls and middle lamella that cement the cells together are major determinants of their textural properties. Cereal grains also have a cellular structure, but this is usually destroyed as the grains are processed into finished products. Aguilera and Stanley (1999) present an excellent account of the structural basis of texture.

Most manufactured foods do not have a cellular structure like native foods such as meat and fruit. The companion articles in this series that discuss hydrocolloids (see *Food Hydrocolloids*), suspensions (see *Food Suspensions*), emulsions (see *Food Emulsions*), gels, and solid foods (see *Solid Foods*) describe the elements that contribute to the texture and viscosity of these products as well as some of the problems encountered in preventing the degradation of their structure and texture during storage.

## 2. Food Processing Affects Texture

Much food processing is directed at changing the textural properties of the food, generally in the direction of weakening the structure in order to make it easier to masticate. From the nutritional standpoint, wheat could be eaten as a whole grain, but most people find it too hard to be appealing. Instead, the structure of the wheat kernel is destroyed by grinding it into flour, which is then baked into bread with a completely

different texture and structure than that of whole grain. The texture of leavened bread is much softer and less dense, making it more acceptable to the consumer.

The processing needed to develop desirable textural properties in foods can be expensive. In the United States, the wholesale price of wheat is about 10 to 20 cents/kilogram, while the retail price of bread is usually in the range of $1 to $3/kilogram. The wide disparity in price between bread and wheat indicates the high cost of converting wheat grain into bread and the price that people are prepared to pay to obtain the type of textures they desire. Breakfast cereals made from wheat rolled into flakes cost over $2 per kilogram, which is another indication of the price people will pay to convert grains of wheat into a more texturally desirable form. One of the major reasons for cooking most vegetables before consumption is to soften the vegetable, making it easier to chew.

Although much food processing is deliberately designed to modify textural properties, there are some instances where the textural changes are inadvertent, a side result of processing for some other purpose. These textural changes are frequently undesirable. A good example of this is the extreme softening and severe textural degradation that results from canning or irradiation preservation of fruits and vegetables. In some instances, damage to texture is so great that the resultant product is unsalable, in which case the processing method is not used for that commodity. For example, the dose required to sterilize horticultural crops, about two million rads (20 kilogray), causes such extreme softening of tissue that it has eliminated the incentive to continue research on the safety of irradiation-sterilized fruit.



### 3. Desirable and Undesirable Textures

There is an enormous range of textures in foods: chewiness of meat, softness of marshmallows, crispness of celery and potato chips, juiciness of fresh fruits, smoothness of ice cream, soft toughness of bread, flakiness of fish, crumbliness of cake, melting of jelly, viscosity of thick soup, fluidity of milk and many others. This great range of different rheological and textural properties found in foods arises from the human demand for variety in the nature of their food. There is no one “right” texture. People demand contrasting textures in their food.

Although 99 percent of the population has never heard of the word “rheology”, they are acutely aware of whether they like or dislike the texture of a particular food. Textures generally liked are described as firm, crisp, creamy, juicy, tender, crunchy, and chewy, while textures normally disliked are hard, dry, coarse, crumbly, sticky, gummy, mealy, greasy, and slimy. Scientists have the task of listening to the adjectives people use to describe textural properties of foods, and thereby converting them into scientific terms and devising methods to measure them reproducibly.

The first step is to attempt to determine the relevant issues behind each simple adjective. Desirable features for nearly all foods include:

- Easy hydration and mixing with saliva to make a swallowable paste.
- Absence of sharp hard particles.
- Easy to control manipulation in mouth.

- Absence of “foreign body” sensations.

Specific textural notes have their own descriptors. Three examples are below:
1) The features of crisp and crunchy foods are:

- rigid, non-deformable structure, with brittle fracture
- breaks under simple compression, little grinding or tearing
- rapid breakdown into many small pieces
- low shear strength, low work for mastication
- sound effects important

2) The properties of chewy foods are in marked contrast to crisp foods. The desired features are:

- highly deformable, not rigid, no brittle fracture
- significant shear strength and work required for mastication
- moderate rate of breakdown into swallowable pieces
- requires grinding or tearing in addition to compression
- often a fibrous structure (e.g., meat)

3) Another class of food with different requirements for both crisp and chewy foods would be the soft and smooth semisolid foods such as yogurt and pudding. Their features include:

- smooth homogenous texture, deformable, no brittle fracture, low shear strength
- can manipulate with tongue, little tooth action
- exhibits plastic flow with yield stress above 1G and low slope of shear stress-shear rate plot
- shear thinning or melting effect in mouth needed

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**Biographical Sketch**

**Malcolm Bourne** is Emeritus Professor of Food Science (Active) at Cornell University. His major research interests have been 1) Texture and rheology of foods, 2) Processing technologies for fruits, vegetables and legumes, and 3) International transfer of food technologies; he has published over 125 papers in refereed journals and 30 chapters in books and encyclopedias on these topics. He has four patents. He has been Editor-in-Chief of *Journal of Texture Studies* since 1980. The second edition of his book *Food Texture and Viscosity, Concept and Measurement* (440 pages) was published by Academic Press in 2002. He is frequently invited to give lectures, write papers, and act as a consultant to universities, research institutes, and food industries across America and in many other countries.