

TECHNIQUES AND METHODS FOR MEASURING THE TEXTURE OF PROCESSED AND FRESH AGRO-FOOD PRODUCTS – A REVIEW

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Abstract. The measurement of texture is a widely used method in postharvest and food research. The majority of the textural characteristics of fresh foods, such as vegetables and fruit, are frequently employed as maturity indicators in order to meet long-term storage, transportation and customer fulfillment requirements. Understanding the textural features is also crucial for controlling processing processes like drying, heating, and frying on processed foods. The sensory qualities of the texture have been evaluated using a variety of methods. The methods for measuring texture that are most frequently used are objective tests using a variety of tools. The set of physical qualities referred to as a food's textural properties includes those that arise from the structural elements of the food, are primarily perceived through touch, are associated with the distortion, disappearance, and the response of food under the action of a force and are evaluated objectively by functions of quantity, distance or time. Due to their well-balanced supply of nutrients, including sugars, organic acids, vitamins, pro-vitamins, and minerals, as well as non-nutritional, advantageous components like fiber and secondary metabolites, fresh fruit and vegetables are vital dietary items for human nutrition. Production processes need to be managed sustainably while producing high-quality products. At harvest, the maturity stage is typically an important factor not only affecting the product quality at harvest but also the susceptibility of the product postharvest. In postharvest, the main task is maintaining the good quality of perishable products for as long as possible to avoid food waste and economic losses. Consequently, knowledge of factors related to produce quality in the pre-harvest, harvest, and post-harvest stages is relevant for the producer, harvest manager, storage manager, packaging facility personnel, local markets, global distributors, wholesalers, and consumers. The word quality is consistently used throughout the production-to-consumption chain, but its definition changes depending on where in the chain you are. Yet, in each of these stages, quality refers to the product's level of excellence and lack of defects (absence of defects and blemishes, cultivar-typical ripeness, freshness, a non-harmful amount of residues considering pesticides and other chemicals, and cleanliness). Texture represents one of the four principal factors defining food or fruit quality, together with appearance, flavor, and nutritional properties, and plays a key role in consumer acceptability and recognition of agro-foods.

Keywords: fresh agro-food products, rheology and texture, vitamins, minerals.

1. The meanings of texture

Food technologists have developed a definition of texture that most closely matches the needs of a food technologist. This definition is divided into two categories: commodity-oriented and feel definition. For example, a food scientist defines texture as the smoothness of ice cream but excludes elements like hardness and melting characteristics. Texture in the context of bread grading refers to the consistency of the crumb and the distribution of gas bubble size, but excludes the bread's softness or hardness. A sight definition states that meat texture is the macroscopic appearance of the tissues if we refer to how smooth or fine the grain is, while a feel definition suggests that the skin texture of cooked meat does not include the properties of toughness, moistness, or juiciness [1-3].

These definitions are important for the quality of meat, as they provide insight into the relationships between parts of the food. Texture is also used to create criteria that apply to all types of meals, preserving feelings of temperature or discomfort. [4] defines texture as a combination of physical traits that are primarily perceived through touch, which can be quantified objectively using mass, time, and distance. He suggests two keywords to replace the word texture: haptesthesia, a discipline of physiology which refers to how materials behave mechanically and rheology, a part of physics that describes the characteristics of food. Rheology studies the behavior of bodies that possess at least one of the properties of elasticity, viscosity, or plasticity. [4] contrasts these two concepts with the study of light, which has two branches: optics and vision, which investigates the psychological and physiological reactions of humans to light. The analogy is depicted schematically in Figure 1.

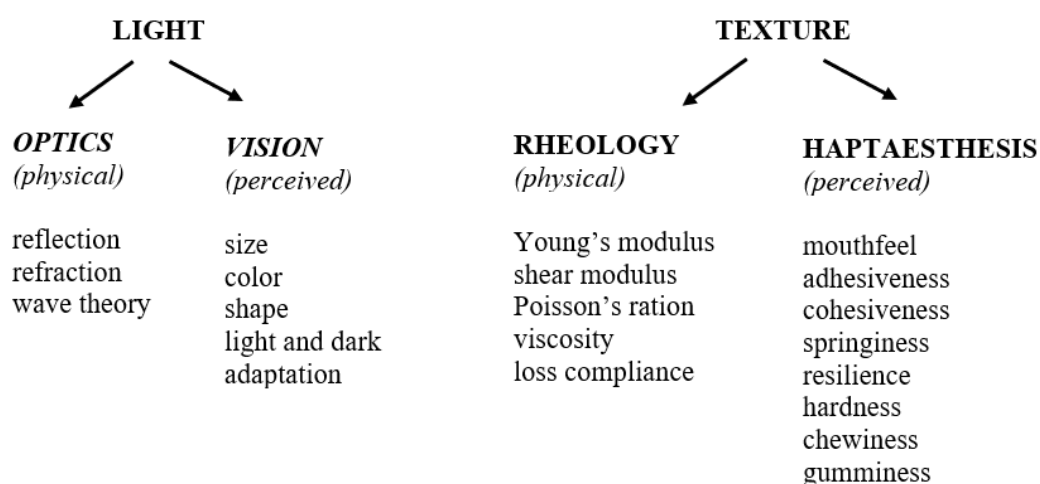


Fig. 1. A comparison of how people perceive light and texture using physical measurement (Muller, 1969a).

It is preferable to discuss textural qualities, which infer a collection of related attributes rather than texture, which infers a single parameter, because texture is made up of a variety of diverse physical feelings [5]. Many people who work with food still refer to a food's texture as if it were a

single characteristic similar to pH. Understanding that texture is a diverse range of dietary characteristics is crucial. Table 1 shows some relationships between food textural characteristics and commonly used terminology to characterize these characteristics. The definition that results from these ideas is as follows. The organization of physical characteristics known as a food's textural properties are those that result from the structural components of the food, are primarily perceived through touch, are connected to the deformation, decomposition, and ripple of the agro-food product under a pressure, and are objectively quantified by processes of quantity, time and displacement.

Table 1.

Textural parameters and common nomenclature relationships [6, 7].

Mechanical characteristics

Initial criteria

Supplementary elements

Common terms

Hardness

Firm, soft, and hard

Cohesiveness

Brittleness

Brittle, crunchy, and crumbly

Chewiness

Soft, chewy, and tough

Gumminess

Brief, mealy, pasty, and gummy

Viscosity

Slimy and viscous

Elasticity

Plastic, elastic

Adhesiveness

Sticky, tacky, gooey

Springiness

Resilience

Geometrical characteristics

Class

Examples

Size and form of the particles

Gritty, grainy, coarse etc.

Shape and orientation of the particle

Crystalline, cellular, fibrous, etc.

Additional traits

Initial criteria

Supplementary elements

Common terms

Moisture content

Dry, humid, wet, and watery

Fat content

Oiliness

Oily

Greasiness

Greasy, creamy, slick, and fatty

2. Texture and Structure

Structural organization at the molecular, microscopic, and macroscopic levels has a significant impact on textural quality. Starch grains seep out when cell walls break, giving the flesh an unattractive pasty, gummy, sticky texture. On the other hand, breaking the apple's cell walls is preferred for the cell sap to flow into the mouth and provide the fruit with juiciness. Another illustration of the relationship between texture and structure is shown in Figure 2, which compares the microstructure of a matched seed and an uncooked, hydrated lima bean seed (RHS). When the raw seed is strained, the tissue breaks across the cells, with the exception of the first, the second, and third, the fourth, and fifth, the sixth, and seventh [6, 10].

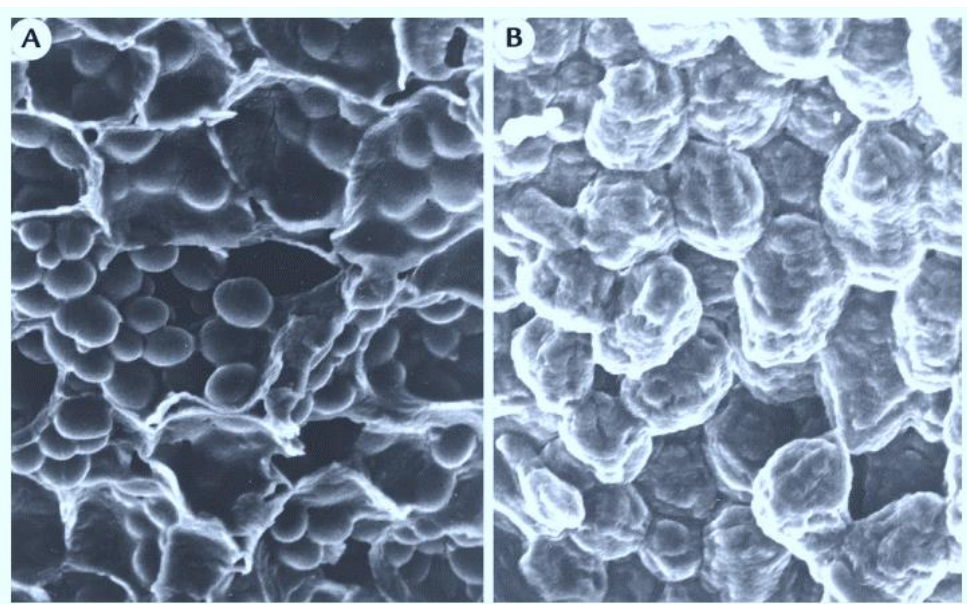


Fig. 2. A hydrated lima bean seed's broken surface as seen in a scanning electron micrograph. A- uncooked LHS within the shattered cells, starch grains are visible. B- RHS, 20 minutes of boiling. Cell walls do not splinter. The unbroken flexible cell walls are pressed against by starch granules [6].

3. Rheology and Texture

Rheology studies the behavior of bodies that possess at least one of the following properties: elasticity, viscosity, or plasticity. The basic concern of rheology is the response of bodies to mechanical demands, and rheology can be defined as the science of fluid flow and material deformation. Many agro-food products are complex fluids. Their rheology, along with their flavor and texture, determines the qualities of the products and ultimately their popularity among consumers. Mayonnaise is an example. It contains vegetable oil, vinegar or lemon juice and egg yellow. Drops of vegetable oil are

stabilized in lecithin lemon vinegar or lemon juice, which is a natural surfactant contained in egg yellow. Because it contains one liquid dispersed in another, mayonnaise is an emulsion. Mayonnaise more or less retains its shape under the action of gravity, but it will flow easily under the influence of weak forces. Therefore, it has a low flow effort (the voltage under which it will not flow). The value of the flow effort is controlled by the size of the drops (about 10 μm for a good mayonnaise) as well as by the surface tension on the surface of drops [6, 8].

Food rheology studies the deformation and flow of raw materials, products involved in intermediate processes and final products in the food industry [9]. By "food industry" we should broadly understand the behavior of food at home.

For the food technologist, rheology is crucial since it has a wide range of uses across the three main areas of food acceptability:

1. Presentation- because certain structural and mechanical characteristics of some meals can be inferred from their appearance, such as how well maple syrup pours from the bottle and covers the pancake, there is a little amount of rheology in look.

2. Taste-rheology has no direct role in this category, although how food breaks down in the tongue can influence how quickly flavor components are released.

3. Rheological qualities are important for assessing food quality by touch. They affect the way foods are perceived, such as the deformation and flow properties of chewed food. [6] suggests that this is key to understanding food quality.

Rheology is important for evaluating food quality, as it does not correlate with sensory measurements of texture and empirical tests [6, 8]. Structural changes during mastication are also important, as they are the most significant changes that are sensed in the mouth.

4. Texture measurement methods and techniques

One of the important characteristics that the fresh and processed food industries use to evaluate a product's acceptance and quality is texture. In the food value chain, texture features are also utilized to monitor and manage quality, from choosing the right time to harvest to evaluation of how handling and further processing operations affect product quality as well as consumer choices.

Food texture qualities are typically affected differently by postharvest operations and handling conditions, such as storage temperature [11]. Practices used in food formulation are frequently linked to either desirable or unfavorable changes in texture [12].

Food texture qualities can be assessed by descriptive sensory (subjective) or instrumental (objective) assessments. Sensory analysis is a key factor in the development and use of empirical mechanical tests to assess food texture. Several instrumental techniques have been used over time to evaluate texture of the food. The used techniques and equipments are frequently influenced by the cost and knowledge that is available within the firm [11].

According to Lawless, any of the rheological and structural (geometric and surface) aspects of a food that can be perceived by mechanical, tactile, and, if necessary, visual and auditory senses are collectively referred to as its texture [2, 13]. Some of the most recent reviews have focused on certain food products including meat, fruit, fish, and dairy, while others have explored particular food texture elements like oral processing, low- and high-intensity ultrasound application, and sensory and instrumental assessment [3, 7]. Table 2 displays the various test types that are used to evaluate food texture. They can be divided into two types of testing: subjective tests conducted by individuals, and objective tests conducted by instruments.

Table 2.

Several techniques for evaluating food texture [2, 6].

Objective		Sensory	
<i>Direct</i>	<i>Indirect</i>	<i>Oral</i>	<i>Nonoral</i>
Fundamental	Optical	Mechanical	Fingers
Empirical	Chemical	Geometrical	Hand
Imitative	Acustical	Chemical	Eyes
	Other		Other

Fundamental method -Basic approaches entail measuring well defined physical characteristics of food that, when measured correctly, are unaffected by the measurement technique. With general-purpose testing machines, fundamental parameters for solids can be measured, but this requires a well planned experimental setup and is time-consuming. Moreover, food is typically diverse and does not behave simply elastically [9]. These tests assess rheological features that are precisely described. It's crucial to remember that this group of tests might not be particularly useful

for determining what is felt in the mouth during food mastication. The perspectives of a food technologist and a materials scientist are completely at odds with one another. The materials strength must be evaluated in order to build a structure that can withstand the demands to which it is subjected. The strength of the food is measured by breaking it down into a fine state, which provides pleasurable sensations during the process of comminution [17, 18].

Empirical methods- these tests capture ill-defined variables that have been linked to textural quality in real-world applications. This is the category of technologies that is most frequently used in the food industry. Devices have been developed within different sectors of the industry that are appropriate to specific product types. The tests are often rapid, easy, and use equipment that is readily available [6, 15].

Imitative methods - these tests reproduce the conditions to which the food material is subjected in reality. Due to the fact that these tests are not basic tests, they might be viewed as a subclass of empirical tests. Figure 3 shows a graphic representation of how empirical, fundamental, and imitative tests are related to one another. The shortcomings of each fundamental, empirical, and imitative technique should be eliminated, and their best features combined, in the perfect texture assessment instrument.

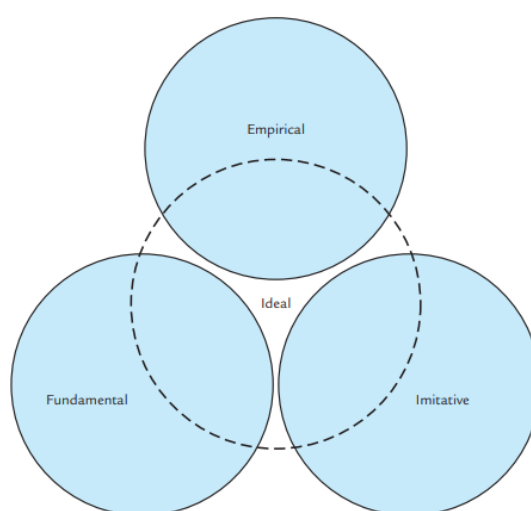


Fig. 3. An ideal texture measuring apparatus, derived from fundamental, empirical and imitative instruments [6, 8].

5. Instrumental measurement of food texture

Since the dynamics of breakdown while eating are substantially determined by the mechanical behavior of food [12], the mechanical/rheological properties of meals are the foundation of the majority of objective measurement studies. Experimental designs can be categorized as foundational, empirical, and imitative. Scientists and engineers have developed experiments to measure the texture of food, but they are not as helpful as traditional tests in determining the sensations experienced by mouth. Imitative or empirical tests have been used to measure the texture, while other destructive or non-destructive procedures and tools to evaluate fresh and processed meals [19, 20].

5.1. Destructive methods

a) Bending and Snapping Test (Three-Point Bending Test) – in this test, a force is exerted by an anvil to the center of the sample, such as cornflakes, potato crisps, or biscuits [21-23]. The crosshead speed fluctuates between 1 and 120 mm/min. Bending and snapping tests are done on a barmaterial, with two most common types schematically presented in Figure 4. A piece of food is supported by two bars on the left side and bent until it snaps by a third compression bar that glides between the two supports [6].

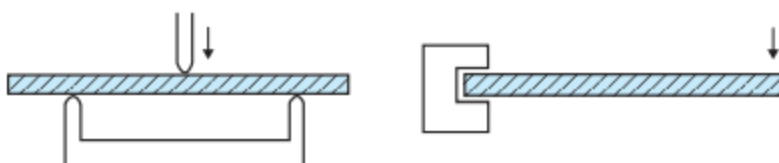


Fig. 4. Two techniques for conducting bending and snapping tests [6].

b) Puncture and compression method - compression tests measure how much pressure is needed to pierce a meal. Lipowitz developed the food puncture tester in 1861, which was the first type of texture measurement equipment. The test is distinguished by the use of a force measuring device, the penetration of the probe, and the usual maintenance of a constant depth of penetration. Professor Morris [24] created the first horticultural product penetration testing in 1925. The Magness-Taylor puncture test (M-T), is now the standard method for determining the hardness of fruit flesh, is based on the fruit flesh's force-deformation characteristics that replicate the consumer's mouthfeel [25, 26]. The maximal force is measured in this test as a representation of the firmness of the fruit. The most popular techniques for assessing the qualities of food texture are the compression test and

the puncture test. The foods under examination can be semi-solid or solid. For instance, the foods that compress well include grains, apple rings, cornflakes, cheese, extrudates of cellular cornstarch, breadcrumbs, carrots, etc.

The Texture Profile Analysis (TPA) test is used to measure the movement of a jaw by twice compressing a bite-sized piece of food [27] found that textural parameters are important for sensory evaluation. Double-compression cycles are used in TPA testing, which mimics the chewing or mastication process. The food sample is frequently chopped into cylindrical shapes for testing of irregular shapes. For instance, 20 mm in length and diameter cylinder samples were cut out of mushrooms by [28] (caps and stipes, respectively). The most food texture characteristics can be assessed with the TPA test [28-30].

The TPA test is a principle that involves placing a bite-size sample of food on a baseplate and compressing it two times by a platen attached to a drive system (Figure 5). High compression is used to imitate the chewing action of teeth [6].

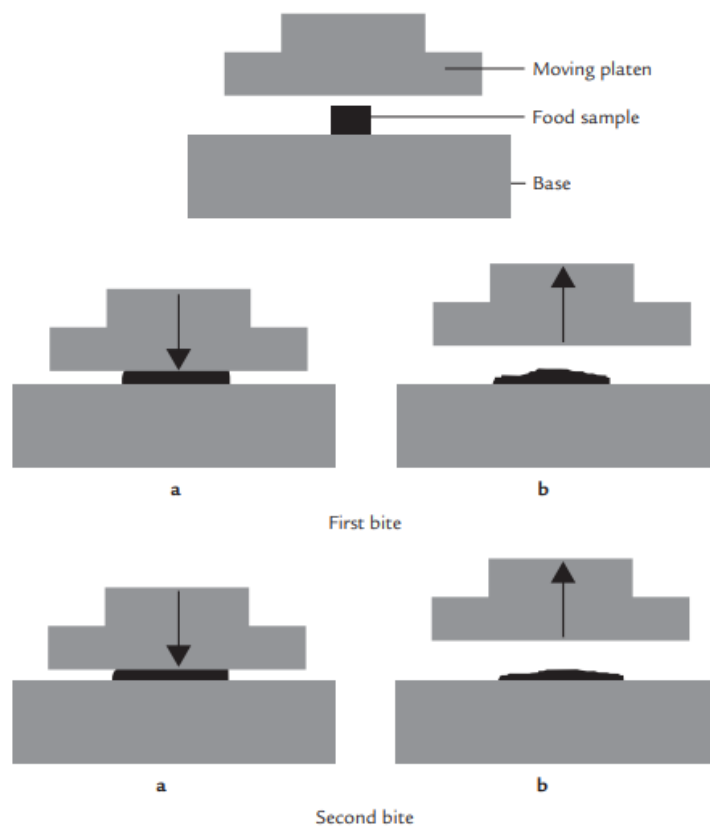


Fig. 5. The principle Texture Profile Analysis test [6].

The TPA parameters are apparently unbiased evaluations of the textural qualities of the tested food. However none of these can be regarded as intensive material qualities because they are all specimen size-dependent. Additionally, because the TPA parameters magnitudes are greatly influenced by the arbitrary test conditions, particularly the specimen and probe's geometries and the set deformation level, assigning them a textural term results in logical contradictions, making their relationship to the food's actual properties even harder to determine [31]. The instrumental TPA parameters indeed describe the same properties in different foods and sometimes as in ripening juicy fruits and soft cheeses. A list of mechanical and physical properties determined by testing, such as yield stress, strain at failure, stiffness, and toughness, can replace TPA parameters. The material properties by sensory evaluations should be used to study the distribution of verbal responses, expressed in their chosen terms [31].

c) Test of stress-relaxation. Stress-relaxation techniques are typically used to study the viscoelastic properties of semi-solid foods like cheese [33], fish [32], sausage [34], etc. The samples are subjected to a compression at a certain rate, according to [32-34]. Force is recorded during the relaxation time, that is between 1 and 10 minutes. The relaxation modulus connects the decaying stress and the applied stain, and is frequently calculated using a generalized Maxwell model. Maxwell, Figure 6c and Kelvin-Voigt elements are used to create a mental image of viscoelasticity patterns. Figures 6a and 6b show an elastic solid acting as a spring and a piston made of a Newtonian fluid moving within a fluid-filled dashpot, respectively. The Maxwell element is represented by combining springs, dashpots and Maxwell in series, while Figure 6e shows a spring being coupled in parallel with numerous springs and dashpots in series. Numerical values can be derived from analysis of stress-strain curves. St. Venant slider is a third component of the applied limiting force models. When the stress is more than the limiting frictional force, there is no resistance and the material slides with ease. Drake (1971) added the concept of traction failure, which is illustrated by two parallel surfaces that are adjacent and drift away as a result of material failure. Electrical circuits are used to describe elastic, viscous, and viscoelastic materials, while mechanical models are used in the rheological literature to understand their movement of springs and dashpots [6, 10].

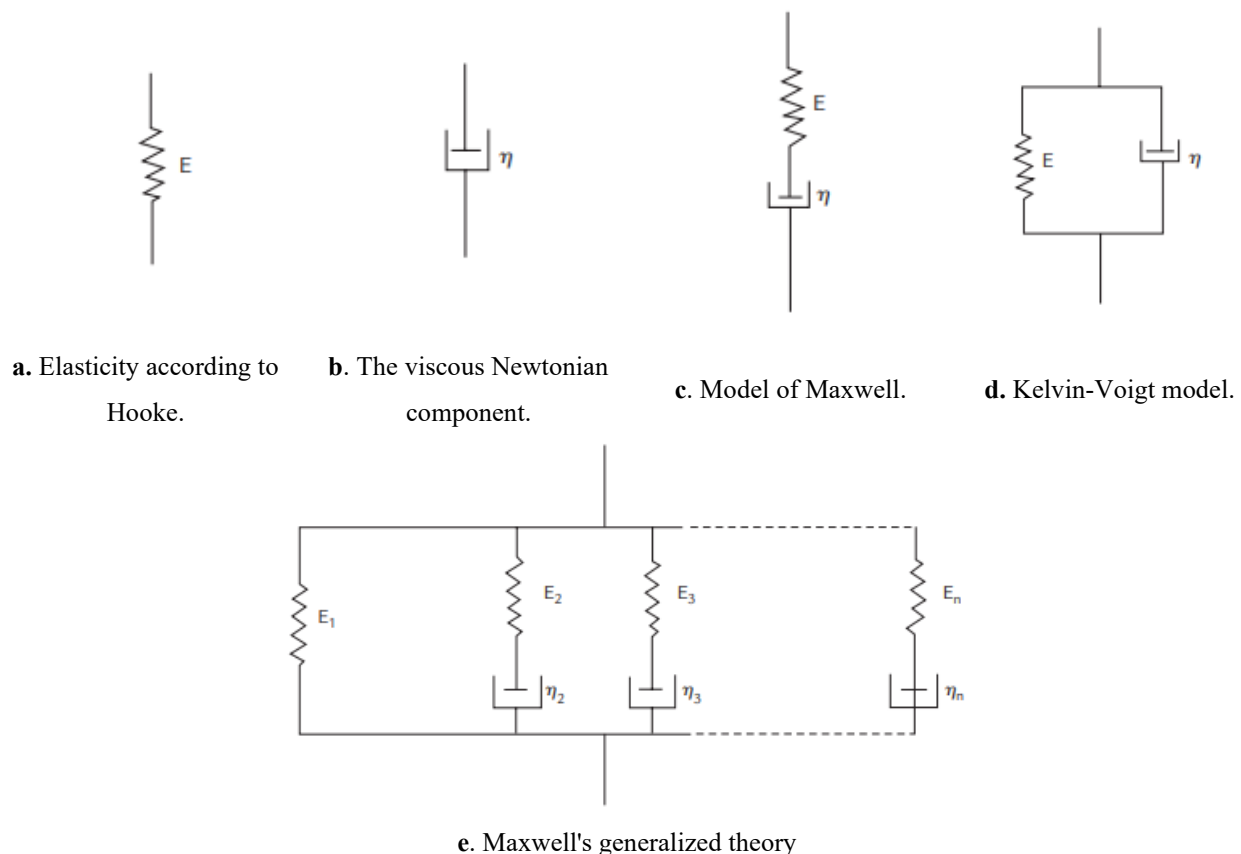


Fig. 6. A few fundamental viscoelasticity concepts and models [6].

d) Warner–Bratzler shear force (WBSF) method. Shear is the sliding parts of a body relative to each other in a parallel direction to the plane of contact. It's an influence of tangential force to the section on which it acts. Shear is used by food technologists to describe any cutting action that causes the product to be divided into pieces. Is not the same as true shear. Figure 7 depicts the distinction between true shear and cutting.

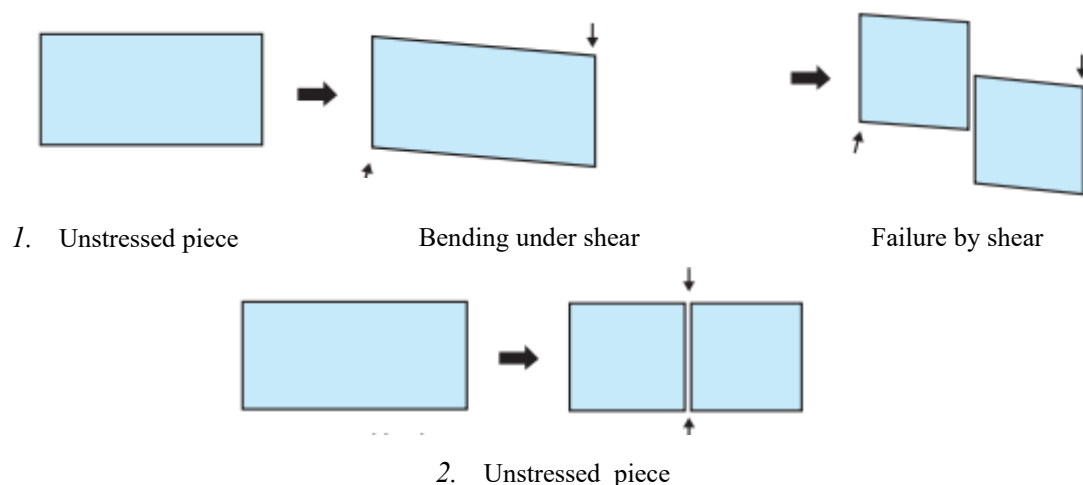


Fig. 7. Comparison of (1) true shear failure with (2) cutting–shear failure [6].

The WBSF test, since 1930, is the most often used tool for determining how tender meat is [35, 36]. The head or blade can be installed to several texture analysis tools, including the Texture Analyzer [37].

e) Tests using a combination of mechanical and acoustic methods. According to [38-40], a lot of solid products exhibit brittle fracture behavior, which is accompanied by a sound or vibration. That can be related to their texture properties. As a result, scientists have integrated acoustic signal analysis with mechanical testing like compression, penetration, and three-point bending tests.

Items with a low mechanical resistance to compression and signals with lower average amplitude and higher peaks were evaluated as being less crusty. The noises produced by the crispiest flakes, on the other hand, were equally dispersed in the frequency range and had a mild mechanical resistance. They also had a bigger average amplitude and fewer high peaks [41]. In order to assess the crispness of fruits like apples, this mechanical-acoustic combining method has been effectively used [42, 43], and it has been shown to correlate with human sensory experience [44]. The Texture Analyzer (TA-Xt plus) for texture assessment has recently gained popularity among researchers because the AED has evolved into a more exclusive component of the tool. Other devices are used for vibration detection. This method has been used to research many food products, such as potato chips, cabbage leaves, pears, persimmons, and grape flesh [45-48].

f) Imitative methods. Sometimes referred to as tooth methods, destructive techniques that imitate biting during eating follow the motion of the incisor or molar bite (Figure 8) [49]. In order to compress snacks, for instance, [50] used tooth-like probes, which were found to be just as effective as conventional tests of penetration. The obtained results at slow and fast speed of tooth-like probe could be complementary. The parameters obtained at slower test speeds were more closely related to human perception and that the in-mouth fracture pattern was better evaluated at faster compression speeds [51]. Other recent research shows that artificial saliva can be utilized in instrumental mastication to define the textural characteristics of semi-solid meals. This method can be used to keep track of the textural changes that starch-based food products go through during oral digestion, according to experiments.

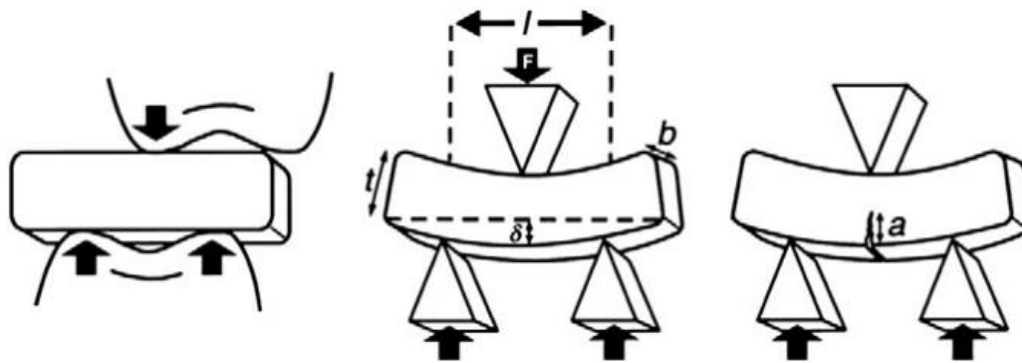


Fig. 8. An example of a food sample loading, supported by cusps (prior to loading, while bending like a beam to a displacement, and following breaking).

5.2. Non-destructive methods

Monitoring and regulating the quality of a product is mostly dependent on non-destructive testing of the texture of fresh and processed foods. Table 3 lists a few instances of non-destructive approaches being used to measure food texture.

Table 3.

Using non-destructive methods to analyze food textures [3, 16].

Technique	Texture property	Food product (s)
Force-deformation that is quasi-static	Firmness	Fruits and vegetables
Impact response	Firmness, mealiness	Apple, kiwifruit, peach
<i>Finger</i> method (compression)	Indentation force	Catfish file
Bioyield detection	Firmness	Apple
Acoustic vibration	Texture index	Cabbage
Acoustic impulse resonance	Flesh firmness	Pear, apple
Laser Doppler vibrometer	Elastic properties	Persimmon, pear
Velocity of sound transmitting in samples	Firmness	Kiwifruit
Video analysis	Rigor mortis	Sturgeon
Electronic nose	Firmness (ripeness)	Apple, pear, mandarin
Ultrasonic	Hardness, softness, firmness, mealiness	Cheese, fruits
Nuclear magnetic resonance imaging (NMR)	Ripeness, mealiness	Apple

MRI stands for magnetic resonance imaging (MRI)	Softening/firmness	Pear
Waveguide spectroscopy	Firmness	Kiwifruit
Fluorescence	Mealiness	Apple
Visible/near/mid-infrared spectroscopy	Mealiness, firmness, tenderness	Fruits, cucumber, beef
Hyperspectral scattering technique	Firmness	Apple and peach
Time-resolved (domain) reflectance spectroscopy	Firmness	Fruits
Raman spectroscopy	Tenderness	Beef
Light back scattering images	Firmness	Apple

a) Mechanical techniques. Measurements of quasi-static force-deformation, impact response, finger compression, and bioyield detection are a few non-destructive mechanical techniques employed in the study of food texture [52-54]. The mechanical approaches and the indirect ones are frequently mixed, much like destructive measurement is. For instance, a minor impact may be used to excite the product, and the vibration (between 20 and 20,000 Hz) may then be monitored with the help of a laser vibrometer, piezoelectric sensor, or microphone [55, 56].

b) Optical techniques. Because they are typically quick, non-destructive, and non-invasive, these kind of techniques are greatly appreciated for detection and classification in fruit. One group of optical methods, in visible or mid-infrared spectroscopy, are the most extensively studied non-destructive ways for evaluating the quality of food when taking into account the vast amount of literature. Researchers tested the firmness of fruit and vegetables and the tenderness of meat using infrared spectroscopy [57, 58].

Recent comparisons of some non-destructive texture measurement techniques have been conducted. Several studies showed that combined measurement systems provided more comprehensive and complementary information and were therefore more successful in predicting food quality than individual sensors [3].

c) Ultrasound techniques. Ultrasound technology is one of the indirect methods of measuring food texture [60]. This is a quick and accurate method for correlating specific quality-related indices and characteristics during growth and maturation, as well as during storage and shelf-life, until food is ready for consumption.

Ultrasonic techniques are very inexpensive, straightforward, and energy-efficient, making them an alternative option for inspecting foods [61]. The energy of the signal received is influenced by the mechanical properties of the tissue, its physicochemical quality indices, and each variation in the fruit's quality characteristics [62]. Fruits and vegetables, porous food products, and other products can all have their quality assessed using ultrasound technology [10, 63, 64]. The results are most likely to be compared with damaging techniques like the M-T firmness test. Firmness is one of the most significant mechanical feature of fruit and vegetable that correlates with ultrasonic characteristics [3, 60].

6. Advantages and disadvantages of instrumental measuring techniques and methods

For solid and semi-solid foods, a wide range of destructive and non-destructive methods of texture evaluation are employed. For an apple, for example, as a specific food product, many instrumental procedures are available. Any chosen method will rely on the measurements' intended use and any special requirements.

Limitations with some measurements, as puncture tests or compression, include a lack of clarity regarding what is being assessed, the test's arbitrary nature, and frequently the lack of an absolute benchmark [6]. Non-destructive techniques, such as ultrasonic and optical, have recently become important for evaluating and analyzing the texture of semi-solid foods, like fruit. These techniques are quick, easy to install and allowing continuous evaluation of textural attributes on multiple sections of the same probe without causing too much waste and consequent losses in comparison to basic and empirical measuring procedures [3, 59]. Non-destructive texture assessment tools, however, are prohibitively expensive to purchase and operate, which frequently prevents their broad use in food research.

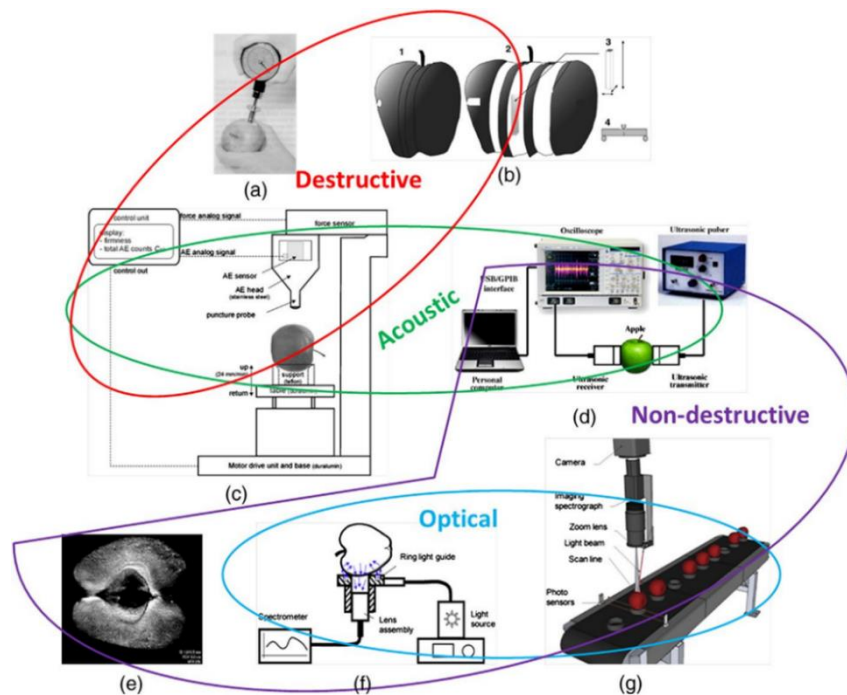


Fig. 9. Several methods of experimental measurement for apple texture characteristics.

7. Instrumental and sensory measurement relationships

Comparing sensory assessments to instrumental ones, we can quantify human perception more quickly [14]. Instrumental measurements, however, are impartial and, in certain cases, thought to be better than analysis by sensors [43]. Thus, among researchers and business, the significance of comprehending the relationship between subjective and objective metrics has grown. Generally speaking, phrases defined at initial touch (often by hands), first bite, after chewing, and after swallowing are used in the sensory evaluation of food texture [65]. According to oral processing considerations, the first two should be reasonably predicted by mechanical test since saliva contributes little to them. This is supported by numerous studies. It was discovered that the generalization “the closer the test speed to the mastication speed, the better” is not always accurate. The existing equipment restrictions and the texture analyzer's constrained force data sampling rate, which result in less accurate results at higher speeds, are particularly relevant here [61]. A significant improvement in the ability of instrumental variables to predict sensory qualities can be made, provided that the proper instrumental conditions are applied [66]. Food texture measurement may be made more effective and accurate by combining instrumental methods with sensory assessments.

8. Conclusions

One of the most often assessed food quality characteristics throughout postharvest handling, processing, and consumption is food texture. Since people's perceptions of food texture are subjective, measuring texture is still a challenging task for researchers and professionals in the industry. In order to: (a) evaluate a product's resistance to mechanical shocks, such as the mechanical harvesting of fruits and vegetables; (b) ascertain the resistance to deformation of products undergoing processing, transport, and storage; and (c) ascertain the mechanical behavior of a food product when consumed, it is crucial to study the texture of agri-food products. It depends largely on the situation how important texture is in determining whether a certain category of foods is liked or not. From the raw material stage through processing and up to the ultimate consumer, who is becoming more picky about the quality of the finished product, texture is a very significant aspect of the quality of agri-food products. To choose the best processing technologies, make the necessary modifications, select the working equipment, and choose the best operating schedule for both the individual pieces of equipment and the plants as a whole, it is essential to have a thorough understanding of the key characteristics of agri-food products. In the end, the assessment of texture is based on human sensory perception, but research and industry also frequently use destructive and non-destructive instrumental methods for measuring food texture. Recent technology advancements have enhanced the possibility for novel methods on non-destructive texture analysis that enable real-time or online texture evaluation for fresh and processed meals. Yet, even when using the same food product and apparatus, it is usually difficult to trace and compare research data because there are still no international standards for measuring food texture. Researchers should focus on the connections between the physical characteristics of food and the sensations that people experience because texture is a combination of subjective feel and objective measure. The sensory impression of food texture is also too complex to be characterized by just a few physical characteristics. For the management and creation of highly desired food products by consumers, multidisciplinary coordination between food engineers and technologists, consumer scientists, and other experts is required.

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