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food and drink innovation

Objective measurement of food textural properties

Texture analysis uses instruments to measure the physical properties of food products to complement the information from trained sensory panels. These are objective tests that measure the physical properties of foods and can thus provide information about their tactile properties such as hardness, springiness and fracturability. Tactile properties influence the consumer's sensory perception of foods and can be devised to determine the acceptability of a food when textural properties are of prime importance. These measurements can be made quickly and accurately and can quantify subtle aspects of texture. Application of texture analysis includes quality control to ensure that a product is consistent from one batch to the next, which is particularly important when an ingredient or process is changed and its impact on texture needs to be evaluated. Instrument based tests can also be valuable tools, both in product development, where a large number of samples need to be tested quickly, and in research, where product innovation is essential to create new products.

This white paper details the essentials of texture analysis as well as the typical applications to a range of foods systems. To find out more about this versatile technique or to discuss potential application contact:

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Introduction

Texture of foods includes a complex group of physical properties that result from the structural make up of the food. Texture is an important element of most food products that affects consumers' acceptance and repeat sales. Texture is a sensory attribute that can be perceived, described and quantified by human beings (Szczesniak, 1987) and can be determined either by sensory or instrumental methods. Instrumental methods of assessing texture can offer advantages over sensory analysis as they are economic, rapid and objective, offer a potential ease of standardisation, and can be carried out under strictly defined and controlled conditions. The food industry is making increasing use of instrument based measurements to assess final product quality before their release. However, it must be emphasised that any instrumental method used to determine physical texture must correlate closely with sensory evaluation for it to be appropriate. Sensory evaluations are equally important as objective measurements, particularly when developing new products where specific sensory parameters form a key element of the product quality.

Instrumentation

Textural properties are measured with instruments commonly known as texture analysers that can compress or stretch food materials. This is done by applying controlled forces to the product and recording the response in the form of force, deformation and time. A number of instruments are available that offer a range of force measuring capability. Basic requirements include equipment capable of driving a probe for a given distance into a sample at a fixed speed. The instrument must continuously log the force required to maintain this speed, respond to a trigger force (signal to start of test), detect initial height of the sample and compress it to a fixed portion of this height (% strain). A number of accessories are found for most instruments that provide consistent sample presentation, thus improving the accuracy obtained from the test method.

The choice of probe (platen, cone, cylinder, blade, ball, or wire) is important and depends on the nature of the food to be tested and the specific consumer action that is to be simulated. For example, a blade probe can imitate the first bite by the front teeth and a platen can give indication of firmness of bread as perceived by the consumer from a squeeze test. Other test parameters to consider include the speed at which the probe moves before it touches the sample, and the actual speed during the measurement. For accurate comparison of a set of samples all test conditions should be kept constant.

A number of different approaches and instruments are employed to study the texture of food products and they attempt to replicate some attributes of sensory methods. These can be summarised as follows:

Fundamental tests

Fundamental tests are based on measurement of physical properties such as stress and strain. Tests are performed under well-defined conditions using precise sample geometries. Fundamental tests usually require expensive equipment and can be slow to carry out. A major disadvantage is that that test results do not correlate well with sensory evaluation.

Empirical methods

This class of tests measures parameters that are not well defined, but are widely used in the food industry as they correlate well with textural quality. Foods are subjected to mechanical deformation applied in sequence or as a combination of stresses. Typical examples include the penetrometer, puncture, compression and Warner-Bratzler Shear Test. Each of these tests is only applicable to a limited number of food systems.

Imitative methods

These methods, as the name suggests, are designed to imitate the conditions to which a food is likely to be subjected in practice. Examples include the squeezometer, which has special attachments imitating finger tips and thumb tips on the Instron Universal Testing Machine, the Farinograph which imitates dough handling, Bostwick Consistometer and Adams Consistometer that measure the flow of foods such as ketchup and purees on a plate. These methods are carried out under poorly defined conditions, but like the empirical methods correlate well with sensory methods.

Terminology used in texture analysis

The terms for the textural properties of foods use a number of physical properties that correlate with sensory attributes. These include:

- **Firmness or hardness:** The maximum force required to compress a food between the teeth, which is an indicator of how firm the product is on initial bite.
- **Cohesiveness:** Measurement of the rate at which the material disintegrates under mechanical action, for example when a baked product is handled or sliced.
- **Springiness:** The ratio of the height to which the sample springs back after the first bite relative to total compression distance of the bite.
- **Chewiness:** This is a product of two properties and is the energy required to chew a solid food to the point required to swallow it.
- **Resilience:** How the sample recovers from compression relative to the distance it is compressed and the speed with which it was compressed.
- **Gumminess:** This is a product of two properties and is applicable to semi-solid products.

Although these terms are frequently used in texture analysis, some are poorly defined. Most of the instrument based tests measure a specific attribute of a food rather than the overall quality of the product. It is therefore vital that the correct test is used that will measure the critical attribute of the product being tested or developed.

Compression methods

Food compression tests are one of the most common tests carried out on food products, reflecting the action of the human jaw. Typically a sample is placed on the flat base of the instrument and an upper compression platen is lowered onto the sample. For a true compression test, the platen should be bigger than the sample being tested, otherwise it becomes a puncture test. Tests are performed by compression to a given force, a given position or a percentage of the original height of the sample. Texture Profile Analysis (TPA) is a widely used test based on double compression of a material between two flat plates. For bread it is widely used because it mimics the biting and chewing action of the jaw by compressing the sample, allowing it to recover briefly and then compressing again (see Figure 1). The force-time plot of the test appears as two peaks, representing the two compressions. The second peak is typically smaller than the first, since the crumb structure will be weakened by the first compression and will be less resistant to the second compression. The gap between the two peaks represents the time when the probe is stationary between the two compressions. The test is usually performed on a cylindrical core taken from the centre of a slice of bread or cake. The height of the first peak is the key feature of the trace and is related to the firmness or hardness of the bread. This parameter shows good correlation with the sensory evaluation of freshness for bread. Other attributes measured include resilience, cohesiveness, and springiness, as shown in Figure 2. This method is also suitable for measuring changes in firmness (staling) during storage by testing at different time points.

Figure 1. An example of instrumentation used for a compression test

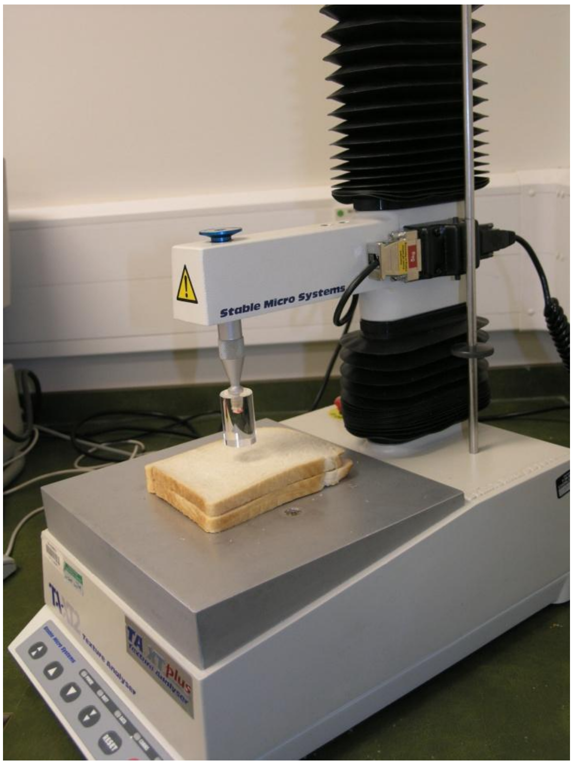
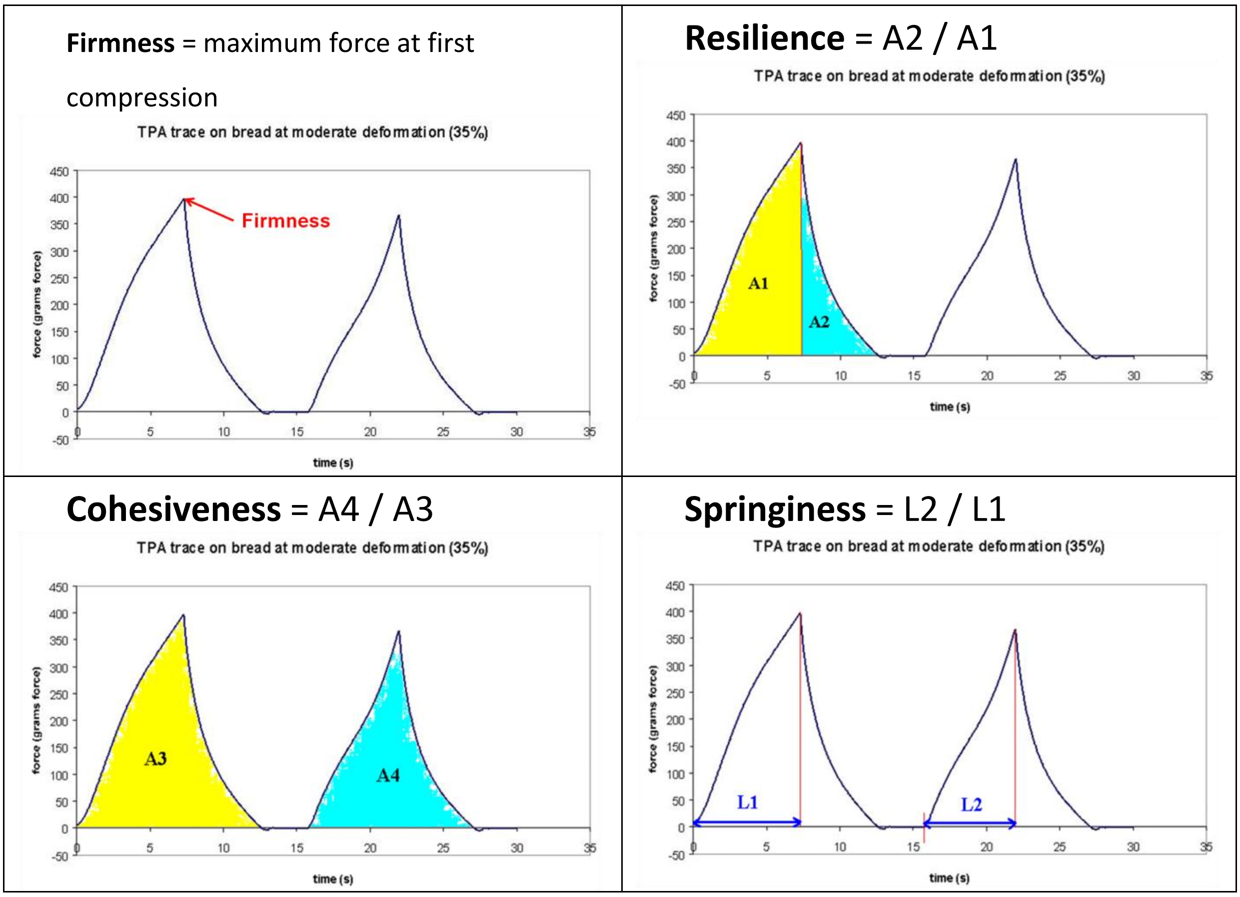


Figure 2. TPA traces and a selection of attributes obtained to characterise bread



Extrusion methods

Extrusion methods can be divided into two classes: back extrusion and forward extrusion. Forward extrusion is when the test sample is forced to flow through an orifice or a number of orifices in the base plate of the sample container and the flow is in the same direction as the plunger applying the extrusion force. The food's resistance to extrusion is recorded and is related to the viscosity of the sample. The size of the orifice selected depends on the consistency of the sample and the textural property of interest. Back extrusion is a more common method of food extrusion testing and is performed with the product in a container that is centrally located under a disc plunger, Figure 3, which has a smaller diameter than the sample container. The plunger performs a compression test which extrudes the product up and around the edge of the disc. The test measures the resulting resistive force and is suitable for products such as creams, yoghurt, sauces, and pureed fruits and vegetables. The gap between the plunger and sample pot governs the resistance to flow and this can be adjusted depending on the consistency of the food material. Figure 4 shows the clear difference in the back extrusion behaviour of full and low fat creams, with the latter extruding with significantly lower force.

Figure 3. Back extrusion test

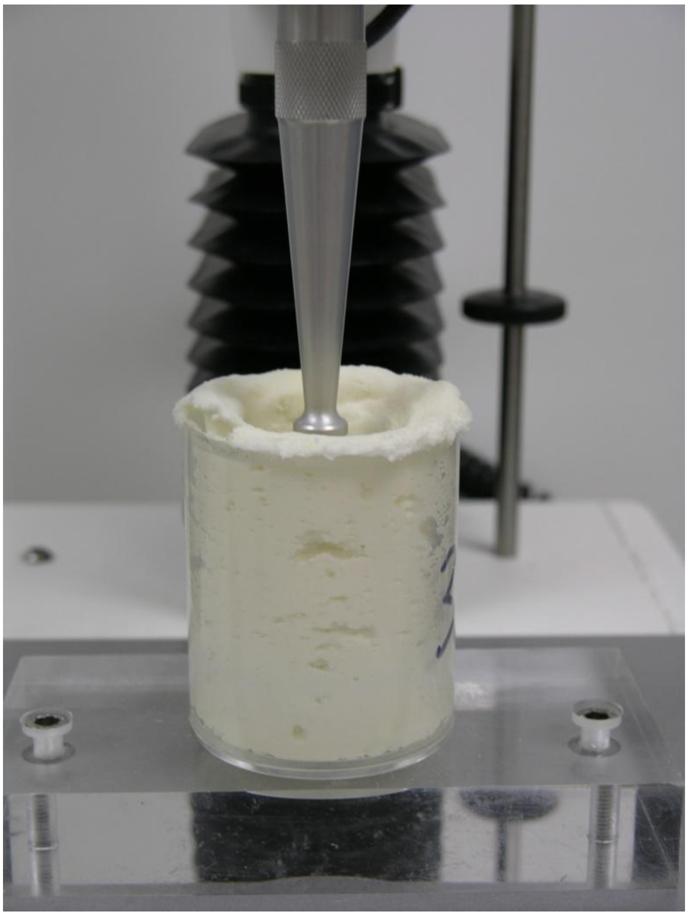
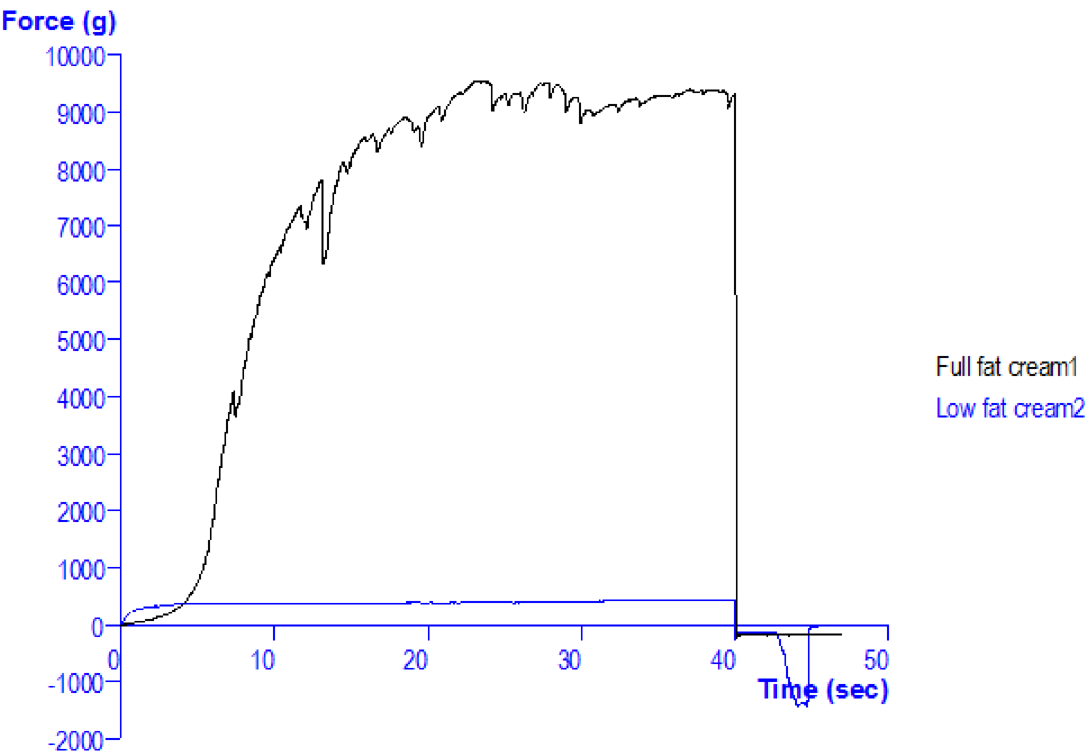


Figure 4. Back extrusion graph of low and full fat creams



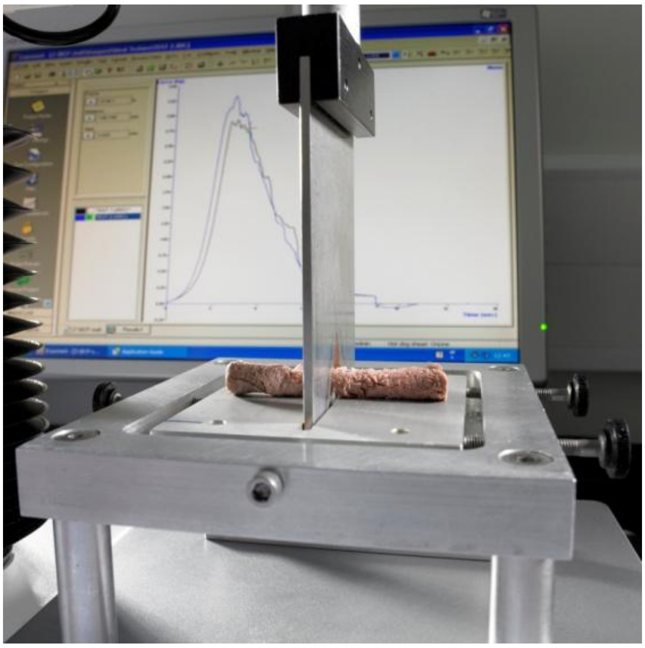
Penetration tests

Penetration or puncture testing is similar to compression testing, but with one key difference; the probe is typically much smaller than the dimensions of the sample under test. A wide range of probes can be used, including cones and cylinders, to measure products such as gels, pectins, yoghurts, margarine, and butter. A common application is puncturing the sample to a defined distance and recording the force required to do this, giving parameters such as hardness or gel break point. Ball probes can be used to measure the fracturability of snack products or the breaking strength of pasta sheets. Thin samples require the base plate to have a hole to avoid contribution from the base and in this case the test is referred to as a punch and die test. Penetrometry testing is also appropriate when assessing the hardness of crusty products such as French baguettes, where the maximum force is taken as an indicator for the crust hardness.

Food shearing testing

Shear testing is appropriate because many foods are first cut or “sheared” by the front incisors when introduced to the mouth. There are many different variations on the basic shear testing apparatus such as razor blades, V shaped blades, rounded blades and straight blades. A specific version called the Warner-Bratzler shear force test is widely used in the meat industry to measure tenderness of meat. An example is given in Figure 5; it consists of a stainless steel blade in which a hole consisting of an equilateral triangle is cut; the point of the triangle rounded off to specific radius. A cylindrical piece of meat is placed between the notch of the blade, which then moves down, forcing the meat into the V of the triangle until it is cut right through. The maximum force generated during the test is related to the tenderness of the meat, with a high value suggesting a tougher eating texture.

Figure 5. Warner-Bratzler method for meat texture



Bulk analysis methods

When the food material is small in size, such as with expanded rice grains or breakfast cereals, it is not practical to test a single piece at a time. In such cases it is more convenient to use bulk analysis, where a large amount of a product is tested at once, giving an average value of the textural properties. A good example of this type of test is the Kramer shear cell, which consists of a set of blades that move down through a containment box that holds the sample under test. The test combines compression, extrusion and shear and is applicable to a wide variety foods, such as ground meats, pasta, fruits and vegetables.

Breaking or bending tests

In these type of tests the product is stressed until it breaks and the peak or maximum force is measured. The amount of movement the sample absorbs before it finally breaks can also be of interest as it provides information about the strength of the internal structure of the food. The most common set up for this type of test is referred to as a "3 point bend". The product is supported by two parallel bars on either side and a probe, usually a plate with a rounded edge, comes down to apply the bending force. The distance between the two parallel bars can be adjusted to accommodate different sized samples. Biscuits and crackers are often tested using a 3 point bend test.

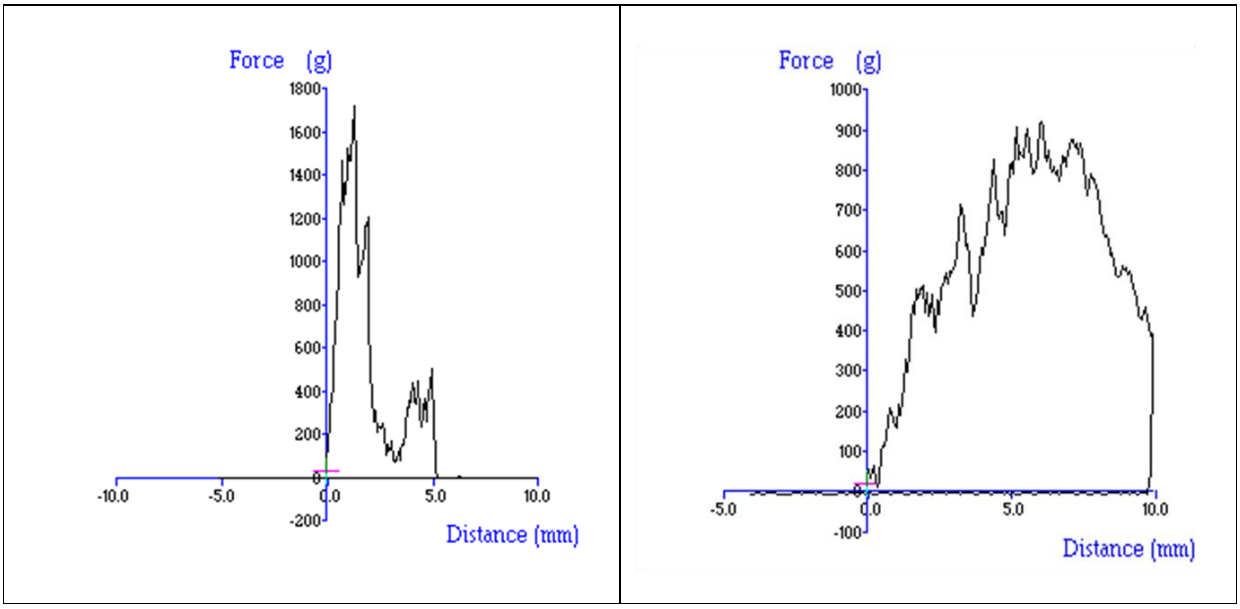
Hard Brittle Foods

Brittle foods have glassy structures, either due to low moisture or high level of sugar in the product. The glass state forms a hard material and the presence of foam cellular structures with thin cell walls reduce the hardness felt in the mouth. The brittleness is transformed into rubberiness by the addition of moisture above the glass transition, which changes the textural properties of the product. Hardness of these products is determined by the maximum force on the force-distance graph, Figure 6. This correlates with the force required to crush food between the teeth. The area under the graph is a measure of work done and correlates to the energy required to overcome the strength of the internal bonds within the product by the molars. The quantity of fractures can also be measured to give an indication of the crispiness or crunchiness of the sample, Figure 6. The fracturability values are the initial fractures and give an indication of the samples brittleness. By quantifying these textural attributes, the quality of brittle food products can be assessed to meet customer satisfaction. Examples of hard brittle foods include crisps, extruded snacks, biscuits, crackers, breadsticks (bread crusts), pastry, and chocolate couverture.

The problems with taking measurements with brittle foods are due to the shapes, breaking patterns and irregular cellular structures. These can be overcome by selection of methods and by averaging a large number of force-distance graphs.

In addition to physical measurements, the sound made by a hard brittle food is recorded at the same time that the physical test is carried out. The intensity of the sound is recorded over a restricted set of frequencies in order to quantify information relating to crispiness or crunchiness. It has been found that the combination of acoustic and mechanical techniques more adequately describes food sounds than either technique alone (Vickers 1987).

Figure 6. Penetration with tooth and needle showing products with different brittleness



Summary

Campden BRI uses a great number of these texture methods in assessing the texture properties of a wide range of food materials. It continues to research methods to measure textural properties of food products with the aim of supporting new product development as well as improving methods. In some instances new methods have to be developed for specific applications, for example to measure the breaking strength of lolly sticks with application of a twisting force and a method to measure the residual strength of croutons after exposure to hot liquid to mimic behaviour when added to a hot soup. In this respect it is important to mention the Cereals and Cereal Applications Testing Working Group (CCAT) at Campden BRI, the function of which is to validate and approve by collaborative testing standard methods to be used by the UK milling, baking and associated industries. It has recently approved a method for bread firmness and is working on a method to measure resilience.

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