TEXTURE ANALYSIS
APPLICATION OVERVIEW

Confectionery Products
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Confectionery Products

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INTRODUCTION

The sensory characteristics of foodstuffs – appearance, flavour and texture – are very important to the consumer. They are crucial to each individual’s preferences for specific products and attributes such as chewiness, crispness and mouthfeel have considerable impact on consumer brand loyalty.

This is more apparent in the confectionery market than in other food sectors because confectionery is not just a ‘hunger-satisfier’; it is frequently consumed just for its pleasant sensory characteristics.

The value to food manufacturers of accurate and consistent objective measurement of the texture of different foodstuffs has been established for a long time. Now, more than ever, manufacturers are searching for up to date techniques to quantify their products’ attributes accurately and very quickly. Texture analysis possibilities include the measurement of the crispness of sugar or chocolate coatings, the extensibility of chewing gum and fruit leathers, the stickiness of gums and the strength of edible films.

To be competitive manufacturers will have to respond by developing technically superior, more innovative products, and at a faster rate than their competitors. Unusual flavours, colours, and textures are what drive novelty in confectionery products. Whilst the use of texture analysis is commonplace in quality control, the product development laboratory is having to gather its pace in order to offer to consumers novel products that satisfy their curiosity in the search for new sensory experiences.
TESTING HOMOGENEOUS SEMI-SOLIDS
For example: syrups, caramel, fondants & fillings, chocolate spread, icings, glazes

Extensibility Issues
Syrups are the base of many confectionery products with a wide variety of flavours, rheological and textural properties which can be obtained or modified using different types and concentration of sugars, acids, flavours, colours, and polysaccharides.

Caramel is a versatile confection that can be enjoyed on its own or in combination with other components. The candy is produced primarily for the pleasurable taste but is also used for confectionery coating and adhesive applications, as are icings and glazes. By controlling formulation and processing, a wide range of physical properties can be produced.

Measuring Consistency and Cohesiveness
A back extrusion test (see Figure 1) can provide the means to contain a volume of semi-solid material to enable its testing. The vessel containing the sample is centrally located beneath a disc plunger which then moves down into the sample and extrudes it up and around the edge of the disc. On downward movement a measure of consistency is obtained, whilst upon withdrawal the sample’s cohesiveness is measured (see Figure 2).

Measuring Surface Stickiness, Deposit Tailing/Shortness and Stringiness
In some foods, adhesive properties greatly influence the performance of food before consumption, and the perception of texture in the mouth. Stickiness is commonly viewed as a negative food attribute, but in certain foods (like confectionery products), a level of stickiness is not only tolerable but desirable. In semisolids, the stickiness is caused by sugars, fats, gums, starches or mixes of these ingredients.

The most used test for measuring the range of adhesive properties in foods is the probe test. In this test, a probe applies a force over the sample for a chosen period of time to achieve a good bond between the two surfaces, before it is withdrawn until the sample completely separates (failure). A vessel and disc as used in a back extrusion test are also suitable; however, the disc would be employed to test the surface of the material rather than venture into the sample.

There are three types of failure identified: if the material remains on the surface of the probe, cohesive failure occurs. If separation is clean (no material remains on the probe), adhesive failure occurs. In adhesive failure, the clean separation occurs at the surface and there is no legging or little necking deformation of the sticking material, whereas cohesive failure occurs within the material and leaves residues in both surfaces. The cohesive-adhesive failure is the transition between the complete cohesive and complete adhesive failure.
For solid and semi-solid materials (such as gels, chewing gums, etc.) where the interfacial bonding balances against the internal mechanical strength of the material, either failure mechanism could be possible, but for many viscous (or viscoelastic) fluid foods, cohesive failure is most likely to be the dominant mechanism.

Using the software adhesive test, the adhesive force (or stickiness) is taken as the peak force; the work of adhesion is taken as the area under the curve and represents the total work during the withdrawal of the probe. The area from the start of separation to the maximum force is considered the best measure of work of adhesion. The cohesive force can be taken as the area between the maximum force and the point where force drops to near zero (the force will never return to zero if cohesive failure has occurred and residue remains on the probe at the end of the test). The stringiness is the distance between the sample surface and the point where force drops to near zero when the product finally separates from the probe.

A major difference between texture analysis profiles is the way the force decreases after the maximum peak. Products that possess a ‘short’ texture (e.g. jam, chocolate spread) have their forces drop to zero or a value of negligible very quickly. Products that are ‘stringy’, however, produce a tailing curve which extends for a considerable distance before returning to zero (or near zero if sample remains on the probe at the point of separation). The distance that this tailing occurs can usually be termed stringiness, and the area from the maximum force to this end point can be considered as the work of material stretching.

There is no doubt that the speed of probe separation has a great influence on the adhesive force and the work of separation, and once chosen should remain constant for comparison purposes.
Measuring Spreadability

Spreadability of confectionery spreads and icings are an important aspect of the consumer acceptability of these products.

Spreadability, in pragmatic terms, is the ease with which a spread can be applied in a thin, even layer to – for instance – a cake surface. Firmness or hardness may be measured by the force required to obtain a given deformation or by the amount of deformation under a given force. Although spreadability is also a deformation under an external load, it is a more dynamic property.

Measurements of firmness and spreadability are usually highly correlated, however the relationship is rarely perfect, and this is partly a function of worksoftening. Margarine, for instance, worksoftens (when spread on bread) more easily than butter, which allows it to be more spreadable even when hardness values are initially equal.

Whilst many people are interested in measuring the spreadability of these products, they are often very shear sensitive and are difficult to consistently prepare for testing. Penetration and compression style tests are simple methods that give results of sample hardness. Hardness measurements, however, even with cone probes, are not always good discriminators of spreadability.

The TTC Spreadability Fixture (see Figure 4) is an attachment which measures the ease with which a product can be applied in a thin, even layer. It comprises of a male 90° cone probe and five precisely matched female perspex cone shaped product holders. The material is either deposited and allowed to set up in the lower cone holders in advance of testing or is filled with a spatula and the surface then levelled. Excessive work is not introduced into the product and as long as the material has not been excessively worked, different styles of filling the material only affect the early part of the test.

The fixture comes with five replaceable female cone sample holders which can be filled in advance of testing and then easily locked into the base holder precisely centred under the matching upper cone probe. The sample holders can be stored in refrigerated or frozen environments, or they can be left ambient before testing (see later Temperature Controlled Testing).

The important action that the test is designed to measure, spreadability, occurs in the later stage of the test. The cone-shaped holders offer no locations into which the product can be packed or compressed, so the product is forced to flow outward at 45° between the male and female cone surfaces, the ease of which indicates the degree of spreadability. The probe withdrawal may also offer some insights into a product’s adhesive characteristics.

During the test the force is seen to increase up until the point of maximum penetration depth of the cone probe. This peak force value (maximum force to shear) can be taken as the “Firmness” at the specified depth. A firmer sample also shows a correspondingly larger area which represents the total amount of force (or otherwise referred to as ‘work of shear’) required to perform the shearing process. Both of these values have been shown to rank samples in the same order of spreadability (and firmness), but for some samples one many prove to be more suitable than the other. The probe then proceeds to withdraw from the sample and any adhesive characteristics are indicated by a negative force region on the curve (as shown in Figure 5).
The probe then proceeds to withdraw from the sample and any adhesive characteristics are indicated by a negative force region on the curve (as shown in Figure 5).

Knowledge of the rheological properties of a semisolid food is important in process design, quality control, and development of new products. These products may also need to be stored under refrigeration and should be spreadable when taken from the refrigerator. The spreadability out of the refrigerator and at room temperature should be even and smooth with no syneresis and separation. Figure 6 and Table 1 show the difference in spreadability properties of a chocolate spread tested at 5°C and 20°C.

**Figure 5:** Typical graph showing parameters measured during test

**Figure 6:** Comparison of spreadability/firmness of chocolate spread at storage temperatures of 5°C and 20°C

<table>
<thead>
<tr>
<th>Storage Temperature</th>
<th>Mean peak force (kg) (± S.D.)</th>
<th>Mean ‘Work of shear’ (kg s) (± S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5°C</td>
<td>23.5 ± 0.8</td>
<td>23.2 ± 1.6</td>
</tr>
<tr>
<td>20°C</td>
<td>4.4 ± 0.3</td>
<td>4.4 ± 0.5</td>
</tr>
</tbody>
</table>

**Table 1:** Test results obtained from 5 chocolate spread samples (at each storage temperature) give the following mean peak force and ‘work of shear’ values.
Measurement of Extrudability

Extrudability is the work required to push or force out (or expel) a product. For products in tubes, such as syrups and icings, removal of the contents relies upon the consumer squeezing the packaging to extrude the product.

The ability to squeeze the product out effectively is essential and the consistency of the contents of a tube or sachet is therefore fundamental to its ease of removal from the packaging when required. If the substance is too dense, consumers will experience difficulty extracting it; if it is too fluid, the product could leak. Assuming the orifice size remains constant, the force to squeeze the packaging depends largely on the consistency of the e.g. paste/cream.

To attempt to mimic this situation a forward extrusion test can be employed. A Forward Extrusion Cell (as shown in Figure 7) measures the compression force required for a piston disc to extrude a product through a standard size outlet in the base of the sample container. The base of the container accommodates a disc containing a central hole (termed the annulus) of varying diameter (3, 5, 7 or 10mm), depending upon the consistency of the sample. The tightly fitting plunger, which acts almost like a piston, compresses the sample and causes forward flow through the annulus of the disc.

Products suitable for this type of test include pastes and viscous liquids without the presence of particulates.

Figure 8 and Table 2 present typical results from the comparison of two types of icing tested using a Forward Extrusion Cell.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mean Extrusion force (kg) (± S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>19.5 +/- 3.2</td>
</tr>
<tr>
<td>B</td>
<td>28.6 +/- 3.8</td>
</tr>
</tbody>
</table>

Table 2: Test results obtained from 5 icing samples (of each type) give the following mean extrusion forces

![Figure 7: Forward Extrusion Cell](image1.png)

![Figure 8: Curves produced from 2 types of icing tested in 50% full forward extrusion containers at 5°C.](image2.png)
TESTING NON-HOMOGENEOUS SEMI-SOLIDS

The market for fruit preparations continues to grow, in large part due to their health and natural image. The addition of fruit is immediately seen to add value, as well as sophistication, to products and consumers commonly look for a high level of large fruit pieces, evenly suspended, with a natural texture.

Today fruit preparations are technologically advanced ingredients which can fit perfectly into the end user’s applications – sweet and viscous or low in fat, but very high in fruit content. The correct stabiliser system is also crucial for obtaining the desired texture from the fruit preparation. Modified starches, gums and gels are essential to control viscosity and texture and to guarantee the stability of the fruit preparation.

Measuring Consistency of Pastes & Pulps
(Purées, pulps, weak jellies and sauces)

Pulps and purées are very thick and viscous slurries made from processed fruit, often concentrated and include fibrous material or fruit pieces that add structure.

Commonly used for yoghurt, fromage frais or chilled dairy desserts, ice cream inclusion, fillings or toppings for pies, frozen desserts or fresh cakes.

A Back Extrusion test (as shown in Figure 9) has the benefit of allowing the means of assessment of sample body/consistency within the container in which the product is deposited (i.e. a jar). A suitable diameter disc is chosen to enter the vessel with good clearance between the vessel and the disc, so as not to produce erroneous increased force readings due to ‘side effects’. Testing within the sample container is often the only means of assessing the product reliably, where depositing the sample into an alternative vessel for testing may cause disruption of the structure of a ‘gelled’ product. The disc moves down into the product to a chosen distance (up to 75% of the depth of the product depending upon vessel height) and the area under the positive region of the resulting curve is taken as an indication of product consistency/overall firmness.

Measuring Consistency of Heterogeneous Contained Gels
(Jams, preserves, jellies)

In many regions, the season for fresh fruit, particularly berries, is short and as a result very few industrially processed jams are made from fresh berries during the harvesting season.

Instead, frozen berries are commonly used. Unfortunately, the freezing and the heating processes needed for jam making have a negative effect on fruit texture. In order to maintain the original shape of the fruit, it is sometimes necessary to pre-treat it to modify its structure.

Consumers demand high quality jams with more natural flavour, colour and whole fruit content. The changes in the texture of berries appear as tissue softening and loss of cohesiveness and the addition of calcium or crystallised sucrose is often necessary to fortify the fruit or act as a dehydrating agent in order to decrease the water content of the fruit, respectively.

Manufacturers of such products may then require a means of determining which pre-freezing and processing factors dominate in the modification of final jam texture to determine the most favourable ranges to obtain the highest quality jam.

For the measurement of jam or contained heterogenous product, a Multiple Puncture Probe is recommended (described later and shown in Figure 10).
TESTING HOMOGENEOUS PLASTIC SOLIDS

For example: Fudge, Toffee, Marzipan, Bubble Gum, Chocolate, Fondant

Hardness/firmness and stickiness are the most important properties of plastic solids.

Whilst the hardness can provide the means to assess affects of different formulation on the sample, the stickiness may provide a useful measurement such as the tooth pulling potential of a confectionery product.

Measurement of Firmness and Stickiness

Firmness and stickiness can be measured using a relatively small cylinder probe which performs a penetration test to a chosen distance into the sample. Firmness is commonly the force to penetrate to the chosen distance, whilst stickiness is the work/force necessary to overcome the attractive forces between the surface of the sample and the surface of the probe used for the measurement. In order to successfully measure the stickiness of a product, the sample needs to be held down to prevent it from being lifted on the end of the test probe upon its attempt to withdraw from the product. A Confectionery Holder (as shown in Figure 11) is an example of one such means of supporting a sticky sample.

Measurement of Bite Force

This property can be assessed with a Craft Knife if the sample is homogeneous (as shown in Figure 13) or a Kramer Shear Cell if non-homogenous (see Figure 19 later). A sample of fixed height and width is placed on the testing platform and the maximum force and area under the positive region of the curve obtained as measures of hardness or ‘bite characteristics’. For larger samples a standard Blade (as shown in Figure 14) may be used.
TESTING MULTIPARTICLE & NON-HOMOGENEOUS PRODUCTS
For example: Muesli bars, Nougat

Measuring Bulk Firmness
Empirical methods of assessing texture are often challenged by lack of homogeneity or uniformity in samples – such a challenge which is almost impossible to approach with fundamental methods.

Heterogeneous systems have structural elements that can vary considerably for the same overall chemical composition, depending upon how they were created.

Sometimes the sample to be analysed may be of variable configuration or structure from piece to piece – for example, bar samples with particulate structures consisting of large amounts of suspended particles, such as dried fruit, nuts, oats or multi-layered.

In the case of fruit testing, for example, whilst the preferred method of testing might be compression, the inherent variability of natural products and the range of sizes of fruit from piece to piece may preclude the option of testing the pieces one at a time. On the other hand, a manufactured sample such as a cereal bar may have uniformity in its sample shape and size, but consist of an entirely variable texture throughout.

This range of challenges calls for a set of tests which deal with the compromise of sample heterogeneity. In some instances the preferred method of testing (such as compression, penetration or shear) can be adapted to improve the chance of obtaining a repeatable result. What all of these methods have in common is the fact that by testing a larger number of pieces, or a wider surface area with more testing surfaces, an averaging effect is thereby created which is the result of a representative set of pieces or surfaces.

The primary issue of these types of samples is that they are usually of varying sizes or are of non-homogeneous nature and make comparisons difficult. They therefore have a high variability from piece to piece within the same batch and require a large sample set to be tested.

Puncture or compression tests to rupture are possible but usually produce results with poor repeatability. For the chance of obtaining repeatable results when testing by compression, testing demands that the dimensions of the test piece are constant. To do this, sample cylinders or cubes therefore need to be prepared which may be impractical in terms of time available or ease of testing.

In this instance, it is advised to take a certain number or certain weight of sample and perform a bulk compression or shearing test. This type of test creates an ‘averaging effect’ and gives the result of a representative number or weight of sample pieces.

The result is an average of the forces required to compress, shear, puncture or extrude the sample of variable geometry. The maximum force and area under the curve are usually recorded for all of these types of test and taken as an indication of bulk firmness. The area under the curve is usually termed the ‘work of shear/compression/penetration’ – a larger value indicating a firmer sample.

Bulk Compression
When compression is the preferred testing method, the repeatability relies heavily on the uniformity of the sample in terms of size, shape, configuration and homogeneity.

A small change in sample size has an immediate effect on surface area for testing, which will obviously affect the magnitude of the force to be measured, and thereby affect the repeatability.

A convenient physical test is to compress a population of pieces constrained within a container such as the Ottawa Cell (Figure 15), which attaches to a TA.XTplus Texture Analyser and is comprised of a square section test cell and loose fitting plunger. Test samples are typically compressed against an extrusion plate located in the base of the cell. Plates feature holes, wire, blades or bars, to suit the sample. A watertight base and liquid catchment tray expands the range of products which may be tested using this attachment, such as ‘bowl life’ assessment of breakfast cereals. It offers an averaging effect test of a more representative portion of the sample which is much more repeatable. Force can be reduced in this test by the employment of a Mini Ottawa/Kramer Shear Cell (as shown in Figure 16) which would be suitable for a product of this nature.

A standard compression test using a Cylinder Probe (see Figure 17) can be used for a certain number of sample pieces such as pellets where sample size is more uniform but where compression testing on single pieces has proven to be disappointingly unrepeatable.
filling volume or by weight, and the blades positioned at a constant position above the sample surface. The blades then move down into the sample compression, shearing and extruding the bulk to a point close to, or slightly through, the base of the cell. Because individual multi-particle products can be tested, the apparatus permits the determination of the distribution pattern, as well as of an average resistance for a lot of the test material. Both maximum force readings and areas under the peak (work function) can be determined.

For products with variable texture across their length, e.g. cereal bars, results from single blade tests may be highly variable. This is because for one blade test of a cereal bar, the blade may come into contact with e.g. a peanut and a chocolate chip, and the next blade test of the same bar may slice through a raisin and an apricot piece. Thus the blade is almost testing different samples. The Kramer Shear Cell method is made on a defined sample quantity. The multiple blades provide a measurement on several positions at the same time thus local texture deviations are compensated for with this method which provides an averaging effect and has shown to be more reproducible for highly variable samples. For self-supporting samples, such as cereal bars, testing can be simplified by the use of the multi-blade head of the Kramer Shear Cell without the need to contain the sample in the cell, and testing is performed directly on a flat testing platform.

Whilst the Kramer Shear Cell allows the testing of a larger sample size and therefore can have the advantage of testing using an averaging effect which is advantageous for the repeatable testing of highly non-uniform products, the drawback is often that this type of test commonly requires a high force load cell, e.g. 500kg, and therefore lends itself to a TA.HDplus application.

A standard Kramer Shear Cell or Ottawa Cell test would ordinarily produce test results of high force. Reducing the volume of small sample pieces to be tested (using a Miniature Kramer Shear/Ottawa Cell) subsequently reduces the magnitude of the forces produced during the test which makes the rig more suitable for use with the single column or low force Texture Analysers.
Multiple Penetration
A penetration test could well be considered the most simple of all tests. As the size of the probe surface area is constant, this often means that the sample size does not need to be carefully controlled unlike compression testing.

However, when faced with a non-homogeneous product penetration is highly compromised as a smaller surface area for measurement is also more sensitive to variations in sample structure and low reproducability and misleading data is obtained. Results may show a wide variance between maximum and minimum forces depending on whether the probe meets with, for example, an air pocket, hard particle or internal structure variation.

Multiple Puncture Probe
The use of a probe that penetrates the sample in several regions serves to create an averaging effect and is therefore usually more repeatable.

Using several testing pins, attached to the TA.XTplus texture analyser, the Multiple Puncture Probe (see Figure 20) allows manufacturers to test non-uniform products containing particulates of different size, shape, structure and levels of hardness, to provide repeatable results.

Such products have non-homogeneous textures due to the presence of, for example, dried fruits, vegetables or nuts, or consist of different layers to provide more interest to the consumer. By penetrating the product in several areas at the same time, the Multiple Puncture Probe produces an averaging effect and is therefore more representative.

This probe successfully quantifies the firmness and hardness of products such as jams and preserves containing fruit pieces or ice cream containing particulates. For example, these can be meringue pieces, chocolate chips or fruit chunks. These products can be difficult to measure as the number, size, shape and distribution of particulates is usually random within each container. The testing method also offers flexibility. When forces are created above the capacity of the load cell being used in the TA.XTplus texture analyser, the operator can adapt the test by removing pins and reducing the contact area, if necessary. However, the more probes that are used in the test, the more reproducible the results.

Multiple Pea Test Rig
This rig measures the force to simultaneously penetrate up to 18 samples.

The insert of the Multiple Pea Test Rig has 18 indentations surrounding a cone which allows the sample to easily locate into the test positions (see Figure 21). Puncture strength and penetration force are measured with 18 2mm cylinder probes and the penetration distance set so that the probes penetrate completely through the sample. Other applications using this rig include beans and confectionery samples.

Figure 20: Multiple Puncture Probe
Figure 21: Multiple Pea Test Rig
TESTING BRITTLE SOLIDS & PARTICULATES

For example: Tablets/Lozenges, High Boil Sweets, Chocolate Bars, Meringues, Biscuit Pieces, Inclusions, Malt Balls

This range of confectionery products covers very hard and brittle structures which fracture easily when deformed, e.g. cut, snapped, penetrated or compressed.

Or, small, irregular and non-uniform particulate pieces with a solid structure which are predominantly consumed or handled in bulk.

The Measurement of Crispness of Multi-Particle Products

Methods of penetration, compression (single piece and in bulk) and shearing have already been covered for the assessment of hardness and bite force of solid materials.

However there is an additional property, namely crispness/brittleness, which exists in a range of brittle solid and particulate confectionery products. This property is often affected by moisture migration within products during storage and, whilst it is the primary characteristic of many confectionery products, can therefore result in loss of a significant expectation by the consumer.

Fracture (of which effectively the property of crispness is as a result) itself represents a very difficult characteristic to measure, due to the fact that a fracture event never occurs identically a second time. A convenient physical test is to compress a population of multi-particulate products constrained within a container such as the Ottawa Cell (see Figure 22 as previously described). Figure 23 shows a typical graph produced by the bulk compression of a crispy multi-particulate product using an Ottawa Cell. In such a test, the multi-peak jagged curves obtained will result from the fracture of a number of flakes/pieces, each peak corresponding to the rupture of a single flake/piece. This is different from the situation where a single piece of sample is being compressed. However, it offers an averaging effect test of a more representative portion of the sample which is much more repeatable. The multi peak curves obtained may then be analysed using special calculations.

**Exponent software** is unique in its offering of many special calculations which are of interest in the analysis of multi-peak jagged curves, such as those produced from brittle confectionery products. Special calculations include the ability to measure parameters such as:

- **Drop Off**: This function calculates the average drop in force between consecutive peaks and troughs over the selected region.
- **Linear Distance**: This function calculates the length of an imaginary line joining all points in the selected region. A highly jagged line, i.e. lots of fluctuations (peaks) in force due to many fracture events, is often produced from those products that are perceived as crispy or crunchy. The length of this line is measured to be much longer if compared to perhaps a smooth line resulting from the testing of a similar soft product.
• **Curve Best Fit:** This function calculates the length of the line (linear distance) which joins the mid points between consecutive peaks and troughs (see Figure 24 for zoomed example).

• **Dispersion:** This function is determined by simply working out the sum of the absolute change in force between each consecutive data point, in the selected region.

• **Average Gradient:** This function calculates the average gradient of all positive slopes (trough to peak) using all peak and trough pairs in the selected region.

• **Smooth Line:** This function creates a smoothed version of the currently selected graph. It requires the user to specify a smoothing factor based on a rolling average calculation.

The above are all calculated from a single click movement and take less than a second to produce results which are automatically dropped into a spreadsheet.

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**The Measurement of Crispness of Single Product Pieces**

Many confectionery products exist in a solid bar form and as such their Snap Strength or force to break is of interest.

A **Three Point Bend** test (as shown in Figure 25) mimics the breaking of a bar in half by supporting a bar with guides positioned a suitable distance apart and pushing down centrally with a curved blade from the top. A low force is indicative of a product which requires little effort by the consumer to break whilst the distance at the break point indicates the degree of flexibility, or conversely brittleness, that the product possesses.

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Figure 24: Typical force-time curve displaying a zoomed section of curve to which the curve best fit function has been applied.

Figure 25: Three Point Bend Rig

Figure 26: Typical force-time curve displaying a zoomed section of curve to which the curve best fit function has been applied.

Figure 27: Three Point Bend Rig
Capturing Sound during a Test

In today’s ever-changing market climate, burdened with stringent retailer and consumer demands, new areas of texture analysis are being explored to further improve product quality, gain competitor advantage and increase market share.

Two recent developments in this field are the analysis of acoustic emissions from food products during deformation, and the video recording of the test during texture measurements to supplement traditional force-distance-time information. Analysing the sounds emitted from food can provide vital information on actual and perceived product quality.

When crispy or crunchy foods, such as breakfast cereals, crackers, hard fruit and vegetables, are crushed through mastication or mechanical testing, unique sounds are emitted by the brittle fracture of the product’s cell walls. These noises play a major role in determining the consumer’s perception of a product. A sharp, crisp sound emitted on biting into an apple, for example, implies freshness; without it, the apple could be less appealing to the consumer.

Every product has its own particular acoustic characteristics and the level or type of noise produced can determine the consumer’s acceptance or rejection of it. Acoustic analysis can therefore help manufacturers identify and analyse the sounds emitted from products and the results used to improve texture. For manufactured foods, for example, the ingredients, process or machinery employed could be altered, whereas for fresh produce, it may be necessary to make changes to the handling or packaging processes.

Emerging technology

Until recently, there have been few developments in instrumentation designed specifically to analyse acoustic emissions. Manufacturers have traditionally used mainly force-distance-time data, or relied on makeshift methods and tools that are inaccurate or incompatible with existing texture analysis equipment. Today, however, significant advances have been made to enable the measurement of acoustic emissions alongside traditional force-distance-time data – so providing accurate and realistic results. This acoustic analysis technology can be used in conjunction with existing texture analysis equipment and offers many advantages:

- Unwanted background noise can be omitted. Sophisticated equipment will discriminate between the sounds emitted from the product and mechanically-generated noise, so only the relevant acoustic emissions are recorded.
- Force and sound profiles from individual tests can be synchronised, so the resulting curves are analysed simultaneously. The relationship between acoustic and force events can then be easily identified.
- The tests themselves and sound acquisition can be handled automatically by software incorporated into sophisticated texture analysis machinery. This saves time, facilitates use and increases accuracy.
- Data can be saved in smaller files to aid the interpretation of test results – previous means of acoustic data collection, that have not used fully integrated or compatible equipment, have often produced large, unmanageable files, sometimes in the region of several megabytes.

One of the most recent developments in acoustic measurement is the Acoustic Envelope Detector from Stable Micro Systems (see Figure 28 overleaf). Attached to the TA.XTplus texture analyser, the new equipment enables manufacturers to record and analyse acoustic data simultaneously with other texture information. This is facilitated by the instrument’s advanced software, Exponent, which synchronises the collection of data during an experiment. The result is a more synergistic and detailed analysis of a product’s texture.

Visualising the benefits

Whilst the measurement of acoustic data is emerging as a test method in its own right, improvements are also being made to help manufacturers collect and interpret other test data. One of the most recent innovations in this field is instrumentation that synchronises video recordings with the corresponding force-distance-time data, so a more detailed and accurate sample analysis can be achieved.

Capturing texture tests on video offers genuine benefits to manufacturers. Crucial visual elements of an experiment can be easily missed by the human eye, due to the rapid speed of the test or to the complex breaking pattern of the sample; brittle, crispy or crunchy products, for example, break very quickly. Video recordings allow manufacturers to replay a test at their own speed at a later date if required.
Supplemented by force-distance-time data captured in the same test, a more in-depth product analysis could be achieved.

However, interpreting visual and graphical information after an experiment has taken place can prove difficult if the data is not synchronised. Correlating the peaks and troughs of a force-distance-time graph, for example, to specific moments in the test can be hard, even if the experiment has also been captured on video.

This is particularly true for products that have uneven textures or that break quickly, in a complicated manner. Certain bread varieties, for instance, consist of a range of textures, such as that of the crust, the main body of the bread and the crumb; each component produces its own event on a graph when broken during an experiment. With new technology, manufacturers can play back each frame of a video recording with the corresponding point on the force-distance-time graph, so a more accurate interpretation of the test can be achieved.

Synchronising visual and force-distance-time data can also help identify inconsistencies or irregularities in a test, as it may be difficult to recognise unusual or one-off factors by viewing force-distance-time or visual data alone. Testing the product at a later date, to iron out these inconsistencies, is often unfeasible due to the sample not being available or time limitations. Fruit and vegetables, for instance, remain fresh for only a short period of time, so their texture cannot be retained and subsequent tests would produce inaccurate data. Using synchronised visual and graphical data, irregularities in test results can be more easily identified without the need for re-evaluation, so misleading information could be eliminated from findings.

**Picture perfect**

Currently, Stable Micro Systems’ Video Playback Indicator (see Figure 28) is the only simple device on the market that enables manufacturers to replay visual recordings frame by frame, simultaneously with the corresponding force-distance-time graph. Data collected through the Video Playback Indicator is processed by the Exponent software supplied with the TA.XTplus texture analyser. As the TA.XTplus begins collecting data, a signal is relayed to the Video Playback Indicator that prompts an LED light source. The display of this light is captured on the video that is already recording the test. When replayed later, this light indicates the beginning of the data capture, enabling the frame at this point to be matched to the beginning of the force-time curve. Thus video frames can be synchronised with the matching points on the force-time graph, facilitating the interpretation of test data.

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*Figure 28: The Acoustic Envelope Detector helps manufacturers achieve an accurate and objective analysis of acoustic emissions from their products.*

*With the Video Playback Indicator, manufacturers can now synchronise visual recordings with other texture information, facilitating the interpretation of test data.*
TESTING MULTI-PHASE CONFECTIONERY

Food coatings and coextrusion methods result in a wide variety of dual- or multi-phase products in the confectionery sector.

Chewing gum tablets, wafers, and layered biscuits are typical examples of food products which may be comprised of a crispy/crunchy exterior shell enclosing a soft viscous filler material of a different texture. Inherent differences in the physical state and compositions of the phases offer interesting textural variation to the consumer.

In the case of dual-phase pockets (as featured in the paper by Samuel et al, 2007) the main focus of such an analysis is to differentiate between the textural properties of each phase. In order to monitor their textural quality, simple and rapid measurements are needed on the whole food. Differences in the mechanical properties of the shell and filler were used to deconvolute the textural differences between these two phases.

Using a 2mm Cylinder Probe (or Needle Probe) attached to the Texture Analyser, the multi textured products are often positioned on a holed base plate to provide the ability to penetrate through the entire structure of the sample (see Figures 32-34 overleaf). The diagram shown (Figure 30) depicts the working of the penetration probe and the corresponding force deformation curves for such products. The probe is effectively able to differentiate between the mechanical resistances offered by different phases.

The force deformation curves show an increasing force which is proportional to the length of the probe penetrating the firm material. Then, a sudden drop is observed consistent with the resistance offered by the softer material. The increase in the force during the penetration of the softer material is much less pronounced, consistent with the properties of the softer material. The final part of the curve shows again a sudden increase in the force during deformation as expected from the firm material. The parameters derived from the force deformation curve of a penetration test in commercial pockets are shown in Figure 31.

A Craft Knife (or Extended Craft Knife) have also proven suitable for the assessment of multi-layer products due to their sharp, small contact area blade, which allows the cutting of samples without the compressive action that a standard thickness blade would provide.

Figure 30: Different stages of a penetration test in a model pocket and the corresponding pocket deformation curves.

Figure 31: Textural parameters derived from the force information curve of the penetration on commercial dual-phase pocket.
Figure 32: 2mm Cylinder Probe

Figure 33: Small Cylinder Probe

Figure 34: Needle Probe

Figure 35: Graph produced from cutting of chewing gum dragee using a craft knife.

Figure 36: Graph highlighting different phases in a chocolate-filled caramel tested using a 2mm cylinder probe.
TESTING FILMS AND COATINGS

One relatively straightforward application for edible films is as a tack or adhesive coating in which the wet solution is used as an edible glue to adhere one food component to another.

In sugar-shelled or hard-panned candies, a moulded piece of chocolate, peanut butter or other confection, such as a chewing gum dragee, is placed in a rotating candy pan and coated with multiple applications of highly-concentrated sugar solution. The panning action ensures that solution is applied evenly and that a hard sugar shell results upon crystallisation. In some cases, a starch-based polymer is added to more conventional sugar shelling to alter the bite or strength of the coating.

Coatings should be fixed fast to the surface of the base product to prevent rub off during distribution. Powdered coatings may be weakly adhered to the food surface but for some confectionery applications grains, seeds or cereal flakes, for example, might necessitate an improvement to the adhesion to fix particulates to the product surfaces and be held in place until consumed. Glassy polymers, such as high molecular weight maltodextrins and starch hydrolysis products within the formulation will increase adhesion and tacking of the coating whilst being accompanied by a more resilient and flexible texture, which makes them less brittle in the mouth. Rough uneven coatings or less crystalline and brittle coatings are typically considered to be faults, if they were not intentional.

Measuring Coating Hardness and Brittleness

Penetration or cutting tests using small cylinders, needles or sharp blades (see TESTING MULTI-PHASE CONFECTIONERY) allow the detection of textural differences between coatings, crusts or harder exteriors and their internal texture.

Usually in such instances a harder exterior is indicated by a higher force to break through this coating or ‘region’ in order to enter the sample followed by a reduction in force due to the typically softer internal material.

Measuring Adhesion/Stickiness of Liquid Films/Coatings

An excessive stickiness is normally not desirable for a food product because of the inconvenience of handling and the unpleasant oral experience.

It is also the main cause of severe surface damage and quality loss of a food during packaging and transportation processes, resulting in possible packaging material damage, product loss and disfigurement of the product surface. It can be surmised that the extent to which this will generate adverse consumer reaction will depend on the extent of the sticking, on the type and cost of the product and on the availability of alternative product/packaging combinations. While excessive stickiness is undesirable in these cases, low stickiness could also be a problem in some other circumstances.

Stickiness depends on the physical properties of the surface of the product and the environmental conditions (RH, temperature) in which it is stored. However, the magnitude of stickiness also depends on the method used to test for stickiness. Adhesion can be measured under low frequency conditions, representing the stickiness encountered as one touches a material (tack), or under high frequency conditions, representing the stickiness encountered when one peels one material from another (peel).

Thin layers or films of coating material may need to be tested at various stages of drying. In this case a 1” Spherical Probe as shown in Figure 37 (overleaf) is recommended along with well controlled procedures for application and time between preparation and testing. During a simple adhesive test, a probe descends to begin the bonding process and maintains the pre-determined compression force for the dwell time. The probe then begins to withdraw and the sample elongates while stressing the just-created bonds. For improved sample mounting and testing efficiency, a Multiple Holed Plate can be used in conjunction with an Adhesive Indexing Rig. Information that can be obtained from the curves include area under the curve, peak force and distance to separation (see Figure 38 overleaf for typical graph).
Measuring Adhesion of Films to Product

Freestanding films, such as breath strips, are relatively new phenomena. Though these freestanding films are often formulated with the same kinds of ingredients as traditional edible coatings, there are additional demands on their performance.

They have to possess strength and integrity to be removed from backing material, and then undergo whatever processing is necessary to deliver the film to its intended use and remain dispensable throughout product shelf life. One of the biggest challenges to freestanding films is to have individual layers remain separate and not adhere to each other, or to curl once produced is cut into individual pieces or sheets. Usually, attention must be paid to the packaging material to ensure that the water-soluble polymers used in these products do not absorb moisture, which would result in the individual pieces sticking together.

These criteria must be accomplished without unacceptably extending the desired time of film dissolution and flavour delivery on the tongue or roof of the mouth. Dissolution in the mouth is largely a function of the nature of polymers used and thickness of the piece. Thicker pieces will have better strength, but might be unacceptable in the mouth or have an undesirably long dissolution time.

Where film samples are large and assessment of adhesion between two materials is required, manufacturers can employ a Flexible Substrate Clamp to assess potential difficulty created by the adhesion of films to the material they are covering when removed by the consumer. Wrapping material must be of a unique, non-stick quality to allow it to contain and protect the product, without being problematic to remove. Materials that adhere tightly to the product will split and tear on removal – leading to consumer frustration.

The Flexible Substrate Clamp incorporates a multi-slot plate and a clamping fixture, which work in conjunction with an Adhesive Indexing System (such as that shown in Figure 39) providing sample mounting and material securing prior to testing on the TA.XT plus texture analyser. The sample is placed on the underside of the multi-slot plate, while the flexible substrate material (i.e. the film) is attached to the upper fixture. During the test, the arm of the texture analyser brings the attached material/film down into each slot so that it repeatedly contacts and withdraws from the sample.

The maximum force required to withdraw from the sample is recorded, providing a measure of the adhesiveness of the film to the material. For optimum performance, as low a force as possible would be the target. The results obtained allow manufacturers to select or alter proposed packaging films to allow for an effortless consumer experience.
Measuring Peel Strength of Films and Packaging

The peel strength of a film type can be investigated by securing the material to which the film is to be removed to a sliding platform of a 90 Degree Peel Rig using a suitable adhesive or double sided tape.

The initial section of the film material is secured in the grips of the upper clamp (see Figure 41) such that a small length points vertically downwards.

The clamp then moves upwards at a chosen peel speed. Simultaneously, the sliding section is free to move horizontally, such that the angle formed at the interface between the film and skin is maintained at approximately 90 degrees. Peel strength is recorded as the maximal force per unit length of the separating interface.

Alternatively a 180 degree peel test can be carried out against a chosen rigid material (as shown in Figure 42).

Peel tests have been a popular test which have been traditionally performed. However, for accurate peel strength measurement, a constant force application before removal is required and can be difficult to regulate. This can be facilitated by either a manual or automatic roller.

Figure 41: 90 Degree Peel test

Figure 42: 180 degree Peel test
Measuring Tensile Strength and Elongation of Edible Films and Packaging

Tensile characterisation is a rapid, widely used method for determining the properties of solid materials.

Subjecting a solid material to a tensile stress allows the properties of the polymer in the solid state to be defined. Selection of types and amounts of different polymeric materials significantly alter the tensile properties of a material.

Tensile Grips allow the investigation of the tensile properties of candidate films and thus upon the performance of the final product. Tensile Grips (such as those shown in Figure 43) are attached to the base and cross head of the Texture Analyser. The upper grip is located above the lower grip so as to leave a gap of exposed test material. Where the gap between grips is set to 50mm the tensile strength of films can then be measured according to ASTM method D882. Strips of film (dimensions of which are advised by the ASTM standard) are cut from the dried film with a scalpel. The samples are placed between, and perpendicular to, the tensile grips which are tightened to ensure that the film does not slip out of the grips during the test. A tensile test is then performed at a speed of 0.5mm/s to failure. A load extension curve is produced from which the following parameters can be calculated:

- **Tensile Strength** = Force (N) at failure/Film thickness x Film width (mm²)
- **% Elongation at Break** = Distance to break/Initial length of the specimen x 100
- **Work of Failure** = Area under Curve x Cross-head Speed/Film Thickness x Film Width
- **Tensile Modulus** = Slope/Film Thickness x Film Width x Cross-head Speed

Peak force needed to break the film, as shown by a sudden drop in force, is recorded as a measure of the overall strength — the higher the value, the stronger is the film. By dividing by the cross sectional area of the film, this parameter can be normalised to represent Tensile Strength. The extent or distance that the film is stretched prior to the failure point is the extensibility or elongation, which is often expressed as a percentage of the length of the film piece tested. This percent extensibility is used as a measure of flexibility, pliability and resiliency of the film or coating.

In general, starch-based films are very strong when compared to those of other edible polymers, but usually score less favourably on the measurement of extensibility. The tensile energy to break (or work of failure) is the total energy absorbed per unit volume of the specimen up to the point of rupture. In some texts this property has been referred to as toughness. To determine tensile modulus data is required to be presented as Stress vs. Strain. Tensile strength and elongation at yield may also be recorded.

Tensile data is often used to specify or characterise a material, to design parts to withstand application force and as a quality control check of materials. Tensile properties can vary with specimen thickness, method of preparation, speed of testing, type of grips used, and manner of measuring extension. Consequently, where precise comparative results are desired, these factors must be carefully controlled. Since the physical properties of many materials can vary depending on ambient temperature, it is also sometimes appropriate to test materials at temperatures that simulate the intended end use environment.
Variations in Tensile Testing

Methods that are not according to an ASTM standard are also viable where sample dimensions cannot be prepared according to the standard, and where the operator may wish to modify test parameters such as the test speed to more closely mimic the situation under which the film is to be typically used. The operator should ensure that the length of the films exposed to the applied stress are constant. Ultimate tensile strength (or break strength as it may also be referred to), elongation at break and Young’s modulus are still typically calculated from such tensile tests, ensuring the change of test parameters are reported.

Whilst ASTM test methods recommend the length of specimens to be at least 50mm longer that the initial grip separation used, this is not always possible and sample preparation methods and testing parameters may need to be altered. Various adaptations in literature have been cited. For example, the ends of films may sometimes benefit from protection with metal supports glued with a cyanoacrylate adhesive.

It should be noted that several variations of Tensile Grips are available depending upon sample size, material strength and grip face requirements (see Figures 45 and 46).

Pneumatic Grips

Tensile strength can also be measured using Pneumatic Grips (see Figure 47) and a test procedure based on the ASTM D882-75d method. Extension speed is 5mm/min. The load (kg) and the displacement (mm) at film rupture refer to the cross section and starting length of the film specimens and are converted to the nominal tensile strength (MPa) at rupture and the nominal elongation (%) at rupture.

Pneumatic grips are often a preferred means of holding a sample for tensile testing, because the gripping pressure can be controlled precisely and because deformation of the specimen does not produce any change in the gripping pressure. This type of grip clamps the specimen by lever arms that are actuated by compressed air cylinders built into the grip bodies. A constant force maintained on the specimen compensates for decreases in force, resulting from creep of the specimen in the grip. Another advantage of this design is the ability to optimise gripping force by adjusting the air pressure, which makes it possible to minimise specimen breaks at the grip faces.

Pneumatic vice grips with rubber coated inserts are recommended to keep the film from prematurely breaking at the grip edge, and in combination with the constant pneumatic pressure the film is prevented from slipping out of the grips during the test. Foot pedals are also used to allow the operator to open and close the grips with their feet because thin films usually require both hands to line everything up properly.
**Film Support Rig**

Whilst tensile grips or pneumatic grips are the traditional choice for tensile testing, there are alternatives.

A Film Support Rig (shown in Figure 49) is designed to hold small amounts of film in a drum configuration in order to measure the biextensional properties of the films using a puncture test.

A 5mm diameter spherical probe is driven downwards to the centre of the film holder’s hole. The special raised perspex internal lip increases the tension without any operator error or variability. A top plate prevents the sample from slipping during testing. The test is then carried out as the arm of the texture analyser brings a 5mm stainless steel ball probe down into the aperture. During a test the maximum force to rupture the product is typically recorded and is referred to as burst strength or break point of the film.

For a more fundamental approach when using the Film Support Rig, load versus displacement curves (such as those shown in Figure 50) are recorded until rupture of the film and used to determine the % elongation at break as follows:

\[
\text{Elongation at break (\%)} = \frac{\sqrt{R^2 + D} - R}{R} \times 100\%
\]

where \( R \) denotes the radius of the film exposed in the cylindrical hole of the holder and \( D \) the displacement to puncture.

In addition, the load vs displacement curve (up to the rupture of the film) can determine the energy at break:

\[
\text{Energy at break} = \frac{\text{AUC}}{V}
\]

where AUC is the Area under the load vs. displacement curve and \( V \) is the Volume of the film located in the die cavity of the film holder (the energy at break is normalised to the film’s volume).

This rig also provides additional measurement of resilience and relaxation. Resilience can be assessed by depressing the film surface to a chosen distance before retracting the ball probe. The property is calculated using a ratio of the work of compression and work of withdrawal. Similarly, relaxation can be measured with the addition of a hold period within the test to allow the product’s recovery to be evaluated. The probe can be held at a certain point of displacement and maintained at that position for a period of time, e.g. 60 seconds. From force-time curves, the relaxation coefficient, dimensionless ratio used to represent decay of force, can be calculated as follows; where \( g_0 \) and \( g(60) \) are the force recorded initially and after 60 sec of relaxation, respectively.

\[
\text{Relaxation coefficient} = \frac{\frac{g_0}{g_0} - g(t)}{g_0}
\]

Both these properties broaden the application of the Film Support Rig. Burst strength, resilience and relaxation are important factors in determining the mechanical properties of the product when designing a product that must be able to withstand handling. These additional measures of physical properties provide more information to allow manufacturers to optimise product structure and formulation to ensure films are adequately robust.
ELASTIC SOLIDS
(For example: Marshmallows, Gums, Jellies, Leathers, Liquorice)
Gummy candies are part of the large category of confectionery products such as jellies, pastilles, and wine gums.

They are traditionally produced by using various water-holding hydrocolloids such as gelatine, starch, pectin, carrageenan, gum Arabic or a combination of these gelling agents. This category includes a diverse array of different sizes, flavours, shapes and textures depending upon the gelling agent which is chosen. Desired textures – brittle or flexible, soft or firm – will determine the type of gelling agent used for a specific application.

Measuring Gel Strength, Rupture Force & Elasticity
The measurement of gel strength is of widespread interest in the manufacture of confectionery products.

Gel properties such as elasticity and rupture force of, for example, pectin, gelatine, agar etc. are important in the development of novel products with diverse textural differences. Whilst many confectionery products are predominantly considered as gels or ‘jellies’, the strength of gels can also be utilised in products where gelling agents are added to modify the consistency of the required end product.

Using a Cylinder Probe (typically 1” radiused for pectin and 0.5” for other gel types), the probe is lowered into the gelled system at a fixed rate to a distance which does not lead to fracture of the gel surface. The strength of the gel is assessed as the peak force (i.e. the force to reach the chosen distance) or the force to penetrate to a smaller chosen depth.

Standard probes such as that required for gelatine testing (according to the ISO Standard), as shown in Figure 49, are also available for the assessment of Bloom strength or rupture characteristics of gels, where the force at 4mm penetration is taken as its Bloom value (typical graph as shown in Figure 50).

Should it be necessary to measure rupture force, gel brittleness/elasticity, this test (for the determination of Bloom Strength) can be adapted to continue penetration after 4mm to e.g. 15mm into the bloom jar. So long as the sample is prepared according to the standard and the Bloom value is taken from the curve at Distance = 4mm, the Force (Rupture Force) and Distance (Brittleness/Flexibility) at Rupture can also be obtained.
Measuring Springiness/Elasticity
A measurement of both firmness and springiness (elastic recovery) can be made using a cylinder probe larger than the sample being tested.

By using a ‘Hold Until Time’ test (see Figure 54 for typical curves) a chosen compression distance is held for a chosen period of time, over which the product’s recovery is recorded. A simple calculation can be made to analyse the data. A major change during the ageing of elastic confectionery products is an increased resistance to compression (firming) and a loss of recovery when compressed, i.e. decreased springiness. Studies of this rheological change may prove beneficial in obtaining a better understanding of the shelf life process and how to control it.

For self-supporting gels and a more fundamental test approach, the elastic moduli can be determined by compressing cylindrical shape hydrogel samples (fixed on sandpaper to avoid slip as shown in Figure 55) with a larger surface area cylinder probe at a test speed of 0.1mm/sec. Elastic moduli are determined from the initial parts of the stress-strain curves.

Using Texture Profile Analysis (TPA)
A rapid, straightforward analytical technique, texture profile analysis (TPA) has been found useful to apply to the mechanical characterisation of freestanding confectionery gels and jellies.

In this type of test, a cylinder probe compresses the sample twice (as shown in Figure 56) to a defined distance and at a defined rate, allowing a delay period between successive compressions. From the resultant force-time plot, the sensory parameters of Hardness, Chewiness, Gumminess, Fracturability, Resilience, Stickiness and Springiness are automatically obtained.

Whilst this test is universally accepted and found useful in quickly generating multiple textural parameters, it must be remembered that in several cases not all products possess the properties that are calculated from such a test. Also, this test should be performed at high deformation with cylinder probes. It is the misunderstanding of these principles that often lead to the abuse of the TPA test and the misrepresentation of results obtained from the test.
Measuring Tensile Properties

Many sugar confectionery products are manufactured by the cut-and-wrap process.

In this process, a “rope” of the product is drawn down to the required size by repeatedly passing it through pairs of grooved wheels, with each succeeding pair being smaller and rotating faster. By this means the rope becomes longer and thinner, i.e. it is drawn out in tension. Once reduced to the final size, the rope is cut into pieces by a rotating knife. Therefore, it seems appropriate to use a tension test.

As with all tensile tests, the art of a valid and useful test comes in the successful holding of the sample in order to perform the test and avoid breakage of the sample at the grip face. Researchers have previously prepared samples by depositing into oval moulds coated with a release agent in order to prepare nougat oval samples. These samples were then placed over two lubricated metal pins (1.4cm diameter) and held in place by screw-on knobs. The ovals were then stretched in tension, at varying test speeds. The gradient of the linear portion (at low strain) was determined and termed the force-deformation modulus.

See ‘Measuring Tensile Strength and Elongation of Edible Films and Packaging’ for all Tensile testing options.

Viscoelastic properties may also be determined in tension by stress relaxation tests with a texture analyser. The film can be held at a certain point of tensile displacement and maintained at that position for a period of time, e.g. 60 seconds. The force required to maintain this deformation is measured, as well as the force during the unloading phase and viscoelastic properties calculated.
TEMPERATURE CONTROL
for temperature sensitive confectionery products

Temperature affects adhesion properties and so testing the adhesive strength of film samples, for example, at a constant temperature provides a constant controlled testing platform to equilibrate the sample.

Carrying out such a controlled test on a Peltier Plate (as shown in Figure 58) results in a more accurate measurement at temperatures suited to the environments in which the films are to be employed.

With such a rise in demand for chocolate comes the increasing need to produce it more efficiently. Today, the skill of the early chocolatiers has largely been replaced by bulk production methods using automated equipment. This brings its own challenges, including the adhesive properties of chocolate during demoulding.

In a study undertaken by Leeds University (Keijbets et al), texture analysis was used to explore the effects of processing conditions on chocolate demoulding. Researchers investigated the influences of time, temperature, moisture content and relative humidity to determine the optimum processing conditions to ease chocolate demoulding. The TA.XTplus Texture Analyser, was used to measure chocolate adhesion to the mould surface under varying controlled conditions, using a specially developed fixture (see Figure 60). The surface adhesion force, an indicator of stickiness, was measured by bringing a flat polycarbonate probe into contact with liquid chocolate. Once the chocolate solidified, the probe was pulled upwards, imitating the forces involved in the demoulding process of commercial chocolate bars. The force of adhesion is recorded, which is a measure of the ease of demoulding.

A Peltier Cabinet (see Figure 59) provided a controlled environment. The contact between chocolate and polycarbonate surface, i.e. the chocolate-mould interface, was created at a temperature of approximately 30°C, after which the temperature was normally adjusted to 15°C using a standardised temperature profile. The set-up was left without disturbance for 60min, ensuring complete solidification of the chocolate sample.

In the enjoyment of chocolate, the bite or hardness is a key qualitative parameter which is affected by varying the processing conditions and can also be successfully measured using texture analysis. Solidified chocolate samples were analysed for hardness using a 2mm cylindrical stainless steel probe driven 5mm into the samples at a constant speed. The maximum penetration force obtained was recorded as the measure of hardness, enabling the effect of different processing conditions on the end product to be determined.

The results demonstrated that processing parameters, including temperature, contact time, and the relative humidity of the surrounding environment, have a significant impact on chocolate crystallisation and solidification processes and on the adhesion of chocolate to a mould surface. Warmer temperatures and moisture have detrimental effects on chocolate viscosity, making it stickier and more problematic to demould. There are significant benefits in refining the demoulding process including waste reduction and production losses, as well as line efficiency in terms of both speed and output quality. Plus, less equipment cleaning helps keep processing downtime and costs down.

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**Figure 58:** Testing performed at constant temperature (controlled by a Peltier Plate attached to a texture analyser)

**Figure 59:** Peltier Cabinet

**Figure 60:** Principle of chocolate demoulding test
MEASURING POWDERED/
GRANULATED INGREDIENTS

Measuring Powder Flow

In the confectionery industry, various types of particulate materials are mixed to improve the product qualities.

However the addition of these materials to confectionery can affect the bulk powder behaviour and flowability.

Dry powder flow characteristics have traditionally been subjectively measured by hand or by simple pouring methods. Such characteristics are dependent on many features, including: particle or granule size/shape and distribution; humidity or moisture content; surface properties including sorption; electrostatic charge; mixing kinetics; rest/flow transition; interparticulate and particle to contact surface frictions.

The Stable Micro Systems Powder Flow Analyser with Controlled Flow Measurement rapidly derives an objective value for the sample that characterises and ranks its performance when subjected to a specific test programme. Samples’ characteristics are measured, ranked and compared under different test modes. Measurements can be used in product and process development, optimisation and quality control.

The Powder Flow Analyser (as shown in Figure 59) offers:

- Application with many types of powder capable of flow, not just free flowing powders
- Rapid, automated, test and analysis routines for Go – No Go quality control applications
- Sample pre-conditioning at the start of the test, giving independence from variable sample loading
- Exact repetition of the test sequence best suited to your need, time after time
- User programmable tests cause flow in the sample by slicing, shearing, compressing, compacting, mixing and lifting in any combinations and in any sequence
- Flow behaviour measurements that define the sample’s behaviour during the programmed test
- Objective, numeric, real time display and automated analysis of the flow measurements, to uniquely characterise and rank the sample.

Rotating Stable Micro Systems’ patented blade (as shown in Figure 60) down and up through the sample achieves Controlled Flow. The design of the blade is the single most important factor in achieving repeatable powder flow measurements. The Stable Micro Systems patented blade is a true helix and can be mathematically described, unlike the blades fitted to other powder measuring devices on the market. The helical blade naturally cuts through the column of powder being tested and negates the need for complex torque measuring systems. This innovative test method enables a wide range of sample flow modes to be achieved as the enhanced blade form provides optimum repeatability and sensitivity in controlling flow, from extremely gentle lifting through to aggressive compaction.

Measurement is achieved by a sensitive transducer, protected from overload, that monitors the axial force created by the test conditions. Almost any sample capable of flow can be tested, provided the resultant force is within the range of the instrument. Controlled Flow offers you the ability to test in a manner that is complimentary to a process or need.
Exponent software can control the action of the test to be performed and subsequently analyse the data to determine, for example: Particle cohesion and flow after compaction, Resistance to compression, Batch and source variation, from a range of standard tests such as Powder Flow Speed Dependence, Cohesion and Caking.

The Powder Flow Analyser is installed and calibrated in minutes by simple force verification on the TA.XTplus/TA.HDplus Texture Analyser ready for use.

**Powder Flow Analyser Test Types**

**Cohesion Test** (see Figures 63/64)

The Problem: Changes in powder specification (formulation, particle size distribution, particle shape etc.), storage conditions and test environment can all influence the tendency of a powder to agglomerate. A change in the cohesive properties of a powder may have an important effect on production processes such as die filling that could impair production efficiency and product quality.

The Test: This quick analysis allows rapid and repeatable quantification of the cohesiveness of a bulk powder. Test results can be used to compare the sample being tested with previously analysed products, to assess if it is more cohesive or more free flowing.

Analysis: A Cohesion Index is determined that characterises the flow behaviour of the product from extremely cohesive to free flowing.

**Caking Test** (see Figure 65)

The Problem: Caking is the tendency of a powder to agglomerate (or form lumps) or ‘cakes’ during storage or transportation.

The Test: This test compacts the powder column to a user-defined force, then slices back to the top of the column with minimum disturbance, before re-compacting. This is repeated for the programmed number of cycles and the blade then slices the compacted cake.

Analysis: The mean force and work done when slicing through the cake, cake height and strength of the cake are calculated.
Powder Flow Speed Dependence

**The Problem:** Process changes to meet increased output demand can be problematic when powders are flow speed sensitive.

**The Test:** This test measures detailed characteristics of a powder sample, as controlled flow is imposed at different speeds. Powders that show an increasing compaction coefficient trend (such as that shown in *Figure 68*) become less free flowing with increasing tip speed and so may lead to under-filling in a production environment. Conversely, in *Figure 67*, the sample becomes more free flowing with increasing tip speed and so may lead to over-filling in a production environment.

**Analysis:** A comparison of compaction at 4 different speeds, a measurement of cohesion at one speed, and a measurement of flow stability are calculated. Flow stability is an indication of the susceptibility of the product to attrition (breakdown) or some other change, such as the melting of a polymeric binder.
CHEWING GUM – FROM RAW INGREDIENT TO FINISHED PRODUCT
When you look at a stick of gum, it seems to be a very simple product, yet making the finished product takes skill and care and requires special equipment.

Chewing gum is a particularly interesting product to manufacture and it is a challenge to the confectioner to make a product which has both the right texture and flavour whilst retaining a long shelf life. The individual ingredient types and amounts play an important role in determining the product structure and hence texture. Also storage, packaging and production conditions have a major effect on the product where temperature, turn-around time and production procedures are important parameters.

Product development teams are continually seeking ingredients and processes that can improve product quality. In recent years, new synthetic gum base materials have been developed which overcome limitations found with previously used natural ingredients. These new materials offer a variety of benefits, such as allowing for longer-lasting flavour, improving the texture of chewing gum and reducing tackiness.

Sugar-free chewing gum
There has been a huge growth in the so called sugar-free chewing gums (which is in fact the fastest growing sector in the international market for sugar free confectionery) because the product is so adaptable to the use of new sweeteners. Today, sugar-free chewing gum production is a well-established technology. The specifications for the raw materials used are quite different because of the absence of sugar and glucose syrup. It is based principally on a solid phase, sorbitol powder and a liquid phase, usually a non-crystallizing sorbitol syrup, which gives body to the gum necessary for processing and to control the plasticity and chewability. Higher glycerin levels are also used to give softness and flexibility.

Chewing gum types
Chewing gum is customarily offered in the form of sticks or candy-coated tablets. Stick chewing gums represent the largest segment of chewing gum sold in the world. This presentation form is difficult, costly, and complicated to manufacture. The quality of the finished product should be high and consistency maintained since the target consumer group are usually very discriminating. Gum base is of prime importance for high quality sticks. It should impart a good softness and flexibility yet have quick set up character to give efficient processing. On chewing, the gum should be smooth and uniform with good flavour impact and duration. The gum base should not have a taste which would interfere with any notes of the flavour, and during long chewing, the gum should remain soft, smooth and even slightly slippery, to give a pleasant mouth feel.

Textural Properties and Suitable Measurement Methods
A thorough knowledge of the raw materials used in gum production is not required but an understanding of each material is necessary. The function of each material in the formula and how the specifications of these materials influence the final chewing gum are helpful to find and understand solutions to formulation or process problems that may be encountered.

A wide range of test methods are available for use on the Texture Analyser for the assessment of various chewing gum properties.

A: Assessment of sorbitol powder hardness by a compression/deformation test
This is a compression test which measures the distance to compress the powder (using a 1cm2 cylinder probe) to 35kg/cm2 for well defined times (2- and 30 seconds) to study the crystal morphology. This tests the suitability of some sorbitol powders for chewing gum manufacturing.

Both crystal morphology and hardness influence not only the rate of dispersibility of the sorbitol powder in the gum mass but also the texture of the end product. The use of a slightly coarser powder results in a softer product with a slight increase in flexibility. A shift in the particle size distribution to larger particles would give a further softening effect but with increased risk of undesirable grainy texture depending on the formulation.
B. Assessment of chewing gum mass hardness by a penetration test

To select the correct firmness level, one needs to look at the form and processing that will be needed for the chewing gum product. Often development of a new product will fail because the wrong gum base was used. Gum bases come in a variety of chewing characteristics. These differences are sometimes for character preferences in the chewing gum product or sometimes for processing reasons.

For example, pan-coated items such as hollow bubble gum ball or pillow shaped chewing gum dragees, need a firmer gum base so shapes will not deform during the coating procedure. Round, smooth to slightly waxy chewing gum characteristics are wanted to give different chewing gum individuality over other products in the market.

Firmer or softer characteristics may be required or desired for different flavour types. Flavour has an effect on gum base and, if a high flavour level is needed, a firmer gum base should be selected to obtain satisfactory chewing characteristics. Some flavours do not soften or plasticise gum base well. In these cases, a softer gum base is needed to give better chewing or bubbling character.

C. Assessment of chewing gum rope flexibility by a cycle test (held by tensile grips)

The extruded rope is fixed between the two jaws of the tensile grips (see Fig. 2). After cooling the rope to 44°C, the crosshead of the texture analyser is moved down (9%) to obtain a bended rope, and the texture analyser is set on a ‘cycle’ mode. During the test a temperature of 12°C is used. The number of cycles before breakage of the rope and the increasing forces are notified on a graph. This test checks for processibility and texture of the chewing gum rope.

Using the same set-up of sample support the gum rope can also be extended to assess its tensile properties. Such properties can be affected by the amount of glucose syrup added to the formulation. Up to six per cent glycerine can be added to the glucose syrup to maintain softness and inhibit moisture movement in the sample. A good indicator on whether too little glucose syrup has been used is whether the batch tends to break on extrusion. By measuring the force and the distance to extend the gum rope an indication of the tensile strength and the brittleness of the batch can be provided.

D. Assessment of chewing gum stick flexibility after storage

This can be done in the same way as for the measurement of chewing gum rope flexibility. Storage stability (shelf life) is measured by monitoring the changes in flexibility of chewing gum stick samples stored at 35°C and 70% relative humidity for 3 months (wrapped). Stability is a function of the number of flex cycles before sample breakage and the force required to bend the chewing gum rope (see Table 3 for example results).

E. Assessment of chewing gum tablet hardness/shelf life changes by a cutting test

Chewing gum and bubble gum will pick up or lose moisture to the atmosphere. The resulting changes may make the product unsaleable. With the moisture increase, the chewing gum will become soft and, in severe case, very dark in colour and too soft to chew. If the chewing gum dries after the surface is wet, it may stick to the wrapping material making it difficult or impossible to unwrap the chewing gum piece. The usual poor shelf life problem is the loss of moisture and hardening of the chewing gum product. A simple penetration or cutting test (using a craft knife blade as shown in Figure 13 earlier), performed over time, through the tablet will assess the hardness changes (if any) of the product or assess differences in hardness of perhaps different formulas or brands. Figure 71 shows three different dragee products which clearly possess different coating textural characteristics.

F. Assessment of stickiness of gum and sticks

Using a 50mm diameter cylinder probe and setting up an Adhesive test is a good way of assessing the stickiness of the chewing gum. A force of 10kg is applied to the sample (held in a plastic cup at 60°C) and this force is held for 0.1 seconds after which time the probe is withdrawn at a speed of 10mm/s. The maximum force to separate the surface of the probe from the sample is taken as the measure of stickiness. As surface stickiness of wrapped stick samples is a
potential problem, during prolonged storage at high humidity, a similar
method can be applied to assess the degree of stickiness on the
unwrapped stick.

6. Assessment of hardness and stickiness after periods of
chewing (‘chew-life’)

The properties of the sample during chewing are very important for
consumer acceptability. An assessment of hardness and stickiness
after certain periods of chewing are important to indicate changes in
‘chew-life’. Ideally the consumer does not wish the chewing gum to
become harder, more sticky or lose its flavour and this is the challenge
which product development teams strive to improve.

The chewing gum can be tested at certain stages.

The initial bite of the stick rates the resistance of the chewing gum to
the first penetration of the teeth. This type of test can be mimicked by
measuring the force required for a knife blade to cut through a stick. For
dragees or other small forms a penetration test will give an indication of
the hardness (as explained above), although it may be necessary to test
more than one piece before arriving at a good evaluation.

The intermediate chew period (15-45 seconds – 5 minutes) is the
time period during which the sweeteners and flavours are extracted
and is the point of most change. When chewing any gum you will see a
change in the size and structure of the cud as the saliva is absorbed
into it and the sweeteners are dissolving. The objective of base and
gum formulations is to have as little texture change as possible during
the entire chew. However, most gums do change, some more than
others. A measure therefore of firmness (or softness) is an important
textural parameter.

The final chew stage is the time after all the sweeteners have been
extracted and all that remains in the mouth is the gum base with some
flavour still present. This time usually occurs after five minutes of
chewing and can last for hours if you keep the gum in the mouth. At
this stage important textural parameters are firmness, tack to teeth
(stickiness), and stringiness. To measure these the sample can be held
down with a holed plate and a penetration test performed. This can be
done in solution within a thermal cabinet at 37°C.

As most gums may change if chewed for long periods of time, it is
better to set a standard elapsed time before testing. The firmness
(maximum force to penetrate) is a measure of the resistance of the
teeth to penetrate through the gum. One important part of this is that
the firmness should be constant for a long time period, 30 minutes or
more. If the gum hardens after 15 minutes of chewing, then this is a
fault and must be noted.

The stickiness is the force to withdraw the probe from the gum,
ideally this value should not be high, especially if dentures are present
in the mouth. Stringiness is the distance the chewing gum can be
stretched before it separates from the probe. The greater the distance,
the higher is the degree of stringiness. This type of assessment may be
better performed in a tensile test where the sample can be gripped at
both ends and stretched. This measures more imitatively the ability of
the chewing gum to be stretched from the mouth to arms length
without breaking.

What we look for with this test is how compatible the chewing gum
base is compounded. The objective is a broad flat ribbon, not a round
filament like string. Also, the ribbon should be uniform and not fatter in
some parts than in others.
Table 3: Flexibility improvement of Chewing Gum - Standard Formulation with 20% Substitution of Sorbitol Powder

<table>
<thead>
<tr>
<th></th>
<th>Flexibility (Number of cycles)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>After production</td>
</tr>
<tr>
<td>Maltitol</td>
<td>15</td>
</tr>
<tr>
<td>Xylitol</td>
<td>13</td>
</tr>
<tr>
<td>Mannitol</td>
<td>11</td>
</tr>
<tr>
<td>Sorbitol</td>
<td>6-7</td>
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</tbody>
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For more detailed information of texture analyser settings, special calculations, specific sample preparation procedures and data analysis techniques on this and any of the above mentioned tests, please contact Stable Micro Systems: app.support@stablemicrosystems.com.

Figure 70: Curves obtained from flexibility measurement on Chewing Gum

Figure 71: Graphs showing the testing of dragees using a craft knife blade

visit www.stablemicrosystems.com
REFERENCES

Burfi

Candy

Caramel

Chhana Podo

Chikki (Sunflower sesame kernel confection)

Chocolate

Chewing Gum
Chocolate Spread

Fruit Leather

Gelled Confectionery

Melt (Indian milk sweet balls)

Honey

Nougat

Sucrose Solution

Sugar Coating

Syrup


Xixona Turron
For more detailed information of texture analyser settings, special calculations, specific sample preparation procedures and data analysis techniques on any of the above mentioned tests, please contact Stable Micro Systems:
app.support@stablemicrosystems.com

MORE INFORMATION:
- Company Profile
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