**Stable Micro Systems**
innovation • education • application

## TEXTURE ANALYSIS APPLICATION OVERVIEW

# fruit and fruit product testing

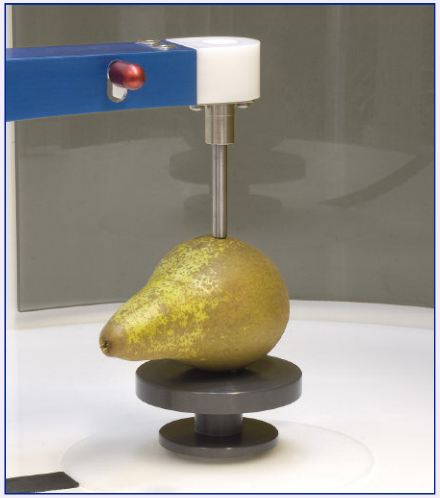
**TA.XTplusC**
**Texture Analyser**

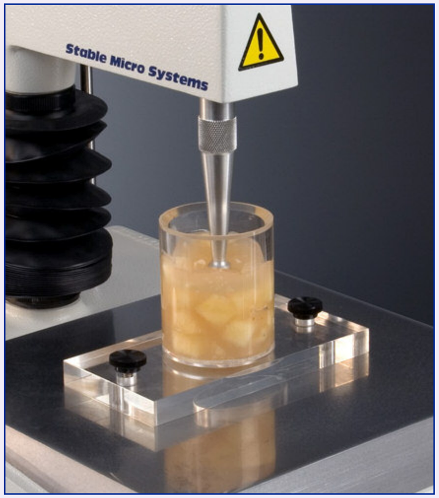
NEXT ▶

Stable Micro Systems™

*TEXTURE ANALYSIS*
*APPLICATION OVERVIEW*

# Fruit and Fruit Products








*Click on a topic to jump directly to it*

Stable Micro Systems™

# INTRODUCTION

**Fruit in various forms, as a whole, dehydrated, in pieces, as juice, extracts, pastes and purées – is used in a myriad of food and drink products including smoothies, salsas and other condiments, cereal bars, dessert toppings, bakery fillings, dairy products such as ice creams and yoghurts, and even fruit leathers.**

In addition to its traditional function as a sweetener and colourant, fruit is now also recognised as a natural preservative providing smooth mouthfeel and texture, a natural humectant to extend shelf-life and as a provider of phytochemicals important to human health. Fruit-based snacks can be modest in bulk as well as rapidly edible; sustaining without providing excessive residues; simple yet glamorous and satisfying to eye, mouthfeel and memory. Their consumption can be a positive cultural move towards a more healthy existence.

The multi-functional nature of fruit and its almost infinite variety contribute to its rising demand in applications and especially in convenience products.

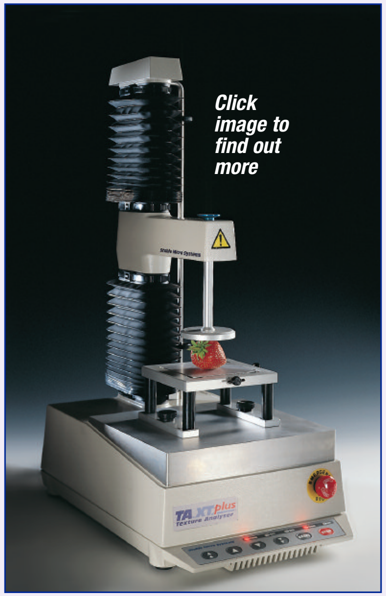
## MEASURING FIRMNESS/RIPENESS

## Fresh Fruit Ripeness

**New fruit crops and varieties appear each year. Fruit growers and processors, faced with the challenge of gaining and maintaining a healthy position in the competitive fruit sector are using increasingly sophisticated methods to investigate quality.**

Coupled with consumer appetite for new products, the fierce competition to supply quality fruit has stimulated these advances in assessment techniques. These include texture analysis methods using sophisticated software and equipment systems (the **TA.XT*plus* Texture Analyser** and ***Exponent***), which can accurately assess the texture of food during maturation, ripening, storage and marketing and identify whether a fruit is capable of withstanding the stresses and strains of packaging, transportation and processing. At each stage a method for measuring the firmness of the skin, flesh, and core of the fruit is necessary to ensure the maximum return from a crop.

*more...*




*The **TA.XTplus** Texture Analyser*


*The **TA.HDplus** Texture Analyser – required for high force texture analysis*

Fruit quality is a concept based on several criteria which depend on the objective. When do you harvest fruit from a plant, to arrive into the supermarket in a 'fresh picked' condition? Every day, consumers perform a simple subjective test in an attempt to measure the quality of fruit they wish to purchase by pressing the surface with the thumb or by squeezing the fruit in the hand, thus utilising the principle of deformation in either a penetration or compression manner. Firmness is an important factor to take into account since most, if not all, fruits exhibit a substantial change in firmness during the process of ripening. This change may considerably influence the consumer acceptance of the product as it is related to the 'eating maturity' and the fruit texture. Generally, it if is firm the fruit will be purchased, and if it is soft then the question will be, when to consume it by, or whether to purchase it at all.

The term 'firmness of fruit' is commonly used to describe a parameter assessed by means of empirical mechanical tests and understood as an attribute that ought to be maintained during storage and processing. Firmness, interpreted as a mechanical response intrinsic to the fruit structure, is influenced by the stage of physiological development, degree of ripeness, damage, fibrosity and turgidity.

From the producer's point of view, firmness can be an indication of the shelf life of the product. Also of major consideration is the mechanical harvesting of fruits which can cause damage from branches and other fruits as fruit falls from the tree and drops on the ground. These damages are in the form of splits, punctures and bruises. Further damage is caused when it is raked, picked up, loaded and transported to distant places by trucks. Generally, it takes several days in transportation from one place to another that causes various changes in physico-mechanical properties of fruits. The post-harvest mechanical properties data of fruits and vegetables are important in adoption and design of various handling, packaging, storage and transportation systems.

The fruit compression test simulates the condition of static loading that fruit can withstand in mechanical handling and storage. Force deformation characteristics of fruits beyond the elastic limit are important to simulate the destruction that occurs in bruising. The most common practice to determine the fruit ripeness in a field situation is pressing with the ball of the thumb. Puncture tests are an imitative means of measuring the firmness of fruits and vegetables to estimate harvest maturity or post-harvest evaluation of firmness.

Finally, for the fruit processor, being able to measure different stages in the ripening process objectively and compare the texture of fruits from different sources can be of vital importance. Such information gives the processor more control over the supplier and allows the monitoring of specific textural characteristics. Many food companies search for the proper combination of crispness, crunchiness, toughness etc., to make their products successful. The importance of such texture analysis testing regimes increases as new packaging methods promote longer shelf life. Food technologists need to carefully measure the effect of such advancements and ensure that produce quality does not suffer.

# ASSESSING SKIN STRENGTH AND FLESH FIRMNESS OF WHOLE FRUITS

**The measurement of firmness is of paramount importance to know the proper maturity and ripening stage during growth and storage of fruit.**

Firmness can be an indicator of immaturity or overmaturity. Excessive peach firmness, for example, can indicate an immature peach with little free juice. Conversely, an overmature, soft peach can be excessively juicy and prone to bruises.

Where individual fruits are to be tested **penetration testing** (using a cylinder or ball probe smaller than the fruit as shown in *Figures 1* and *2*) provides a constant surface area for testing which often reduces the variability of results when compared to compression testing data.

A penetration test destructively measures firmness by registering the force required for a cylinder probe (generally from 2mm-8mm in diameter), Magness-Taylor puncture probe, or ball probe, to penetrate the fruit's flesh to a chosen distance and is frequently used for testing firmness of a wide variety of fruits. Magness-Taylor probes are commonly used and widely accepted in the field of fruit testing of whole fruit and have historically been the reference measure for firmness in many fruits as this method has shown good correlation with consumer acceptability for firmness. With probes of this size and shape the skin will yield once penetrated and the underlying flesh can also be measured.

Penetration testing has the benefit of not requiring samples to be of the same size and does not require sample preparation. However, orientation of the penetration is important as samples of this nature are anisotropic. The depth of penetration varies according to the fruit size and proximity to e.g. pits or cores and it is sometimes possible to perform tests on both sides of each fruit tested e.g. peaches. Some larger berries are commonly penetrated using a small (e.g. 2-3mm cylinder probe) and the maximum force taken as the flesh firmness value. For ease of testing the fruit is often cut in half and the fruit laid down onto the sample platform, cut surface down, in order to stabilise the sample for penetration testing of its side. This method may be the only testing option if there is limited availability of sample to test but repeatability may be compromised. To obtain reliable results and reduced variation in this way, special attention should be paid to aspects of size, ripening stage and growing conditions.

This type of test primarily assesses skin strength/toughness and elasticity, yield point and resilience, the ripening and softening profile and the firmness of the underlying flesh. Some researchers prefer to remove a small section of the skin/peel with a razor blade so that penetration can be performed on the flesh only and the test is isolated to the measurement of flesh firmness.


***Figure 1:*** *Penetration test of whole fruit*

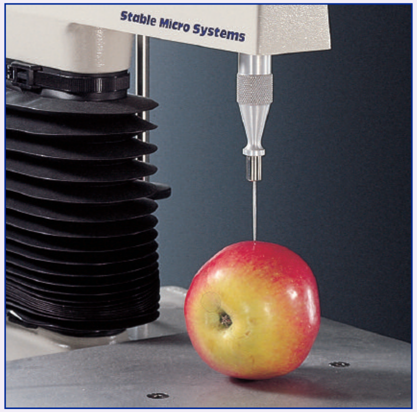



***Figure 2:*** *Penetration test of whole fruit*

**A penetration test of whole fruit can be applied to:**

- **A: Fruit with pits** – where the outer skin covers a soft, fleshy fruit and the fruit surrounds a single, hard stone, or pit, which contains the seed – cherries, apricots, nectarines, peaches, plums, avocado, olives.
- **B: Fruit with cores** – where there is a central seed-containing core surrounded by a thick layer of flesh – apples, pears
- **C: Large fruits without cores** – melons – Large, juicy fruits with thick skins and many seeds
- **D: Citrus fruits where a measure of the peel characteristics are required** – These possess a thick outer rind and a thin membrane separates the flesh into segments – e.g. oranges, tangerines, grapefruits, kumquats, lemons, limes
- **E: Starchy fruits** – banana – pasty homogeneous starchy fruits with very soft texture. Easily mashed to pulp or follow viscous behaviour when squashed
- **F: Large Berries**
- **G: Tropical Fruits** – papaya, figs, dates, guavas, mangoes, kiwis

## Interpretation of Whole Fruit Penetration Curve

**The firmness of ripe and unripe samples can be tested by penetrating a small diameter cylinder probe into the whole fruit (around the equatorial region) and measuring the subsequent force to rupture the skin and further penetrate through the underlying tissue to a chosen distance of e.g. 5mm.**

The probe proceeds to move down onto the fruit and an initial rapid rise in force is observed. During this stage the sample is deforming under the applied force but there is no puncturing of the tissues.

This stage ends abruptly when the probe punctures through the skin and begins to penetrate into the sample flesh, which event is represented by the sudden change in slope called the “yield point” (or “bioyield point”). The yield point (maximum force) occurs when the probe begins to penetrate into the food, causing irreversible damage.

The third phase of the puncture test, namely, the plateau of the force after the yield point is an indication of the underlying flesh firmness of the fruit.

Six texture parameters can be calculated from the force-displacement curve (as illustrated in *Figure 4*). The maximum force (*Fmax*) represents the force required to puncture the fruit skin. *Fmax* represents the skin strength and is often termed the bioyield point. The probe displacement *Dp*, expressed in mm, is the value of the probe position at *Fmax* and indicates the elasticity of the skin. Stiffness, is the slope of the first part of the curve measured from the beginning of the curve to *Fmax*. Work of penetration (*W1*) is the mechanical work needed to reach the rupture point, and is taken as the area under the curve to *Fmax*. Flesh firmness (*Ff*) is the average value of the forces measured after skin rupture. *W2* is the work measured (area under the curve) after the skin rupture. These calculations can be automatically calculated with the use of a simple macro within *Exponent* software making collection of parameters quick and intelligent.

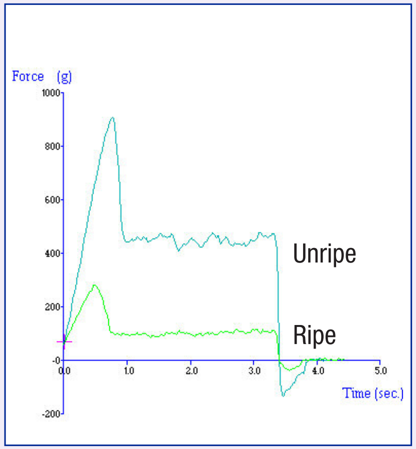



***Figure 3:*** *Curves of ripe vs. unripe pears tested using a 2mm cylinder probe*

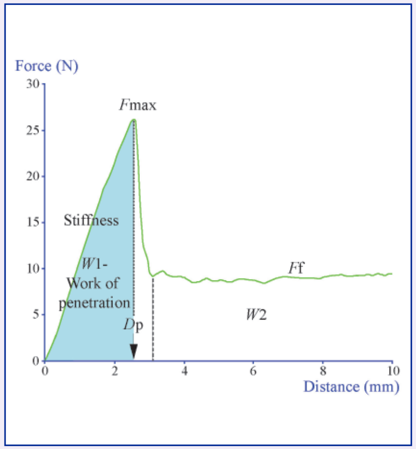



***Figure 4:*** *Penetration force/distance curve and parameters extracted*

| Sample | Maximum Force (‘Yield of Skin’) (g) (± S.D.) | Average Plateau Force (‘Flesh Firmness’) (g) (± S.D.) |
|---|---|---|
| Pear - unripe | 914.2 ± 64.8 | 456.2 ± 18.4 |
| Pear - ripe | 284.4 ± 14.3 | 101.2 ± 10.8 |

***Table 1:*** *Typical results of penetration of ripe and unripe pears using 2mm cylinder probe*

# MEASUREMENT OF FIRMNESS OF WHOLE FRUIT BY COMPRESSION

**Fruit can alternatively undergo a mild non-destructive test where the deformation response of a large cylinder probe or platen (as shown in *Figure 5*) is measured to effectively mimic the compression between one's fingers.**

However this has the problem of measurement variability due to differing contact area with the fruit surface which varies because of irregularities in fruit shape and size and results may then be compromised for the convenience of using such a test.

One way to address this is by firstly measuring the diameter of the fruit and then measuring the force to achieve, for example, 2% deformation on the equatorial zone (fruit diameter). Results are then expressed as the force-deformation ratio – the ratio between the force that achieved the 2% deformation of the fruit and the fruit diameter (N/mm) multiplied by 100. When testing the fruit in this way, a bevelled holder is often located under the fruit to prevent bruising of the opposite side. For large fruits, three measurements around the equatorial zone may be possible without overlap of test regions.

Alternatively when compressing large fruit, such as whole pineapples, on their equatorial region the compression could be stopped at a force, for example, of 50N and the gradient of the force/deformation curve used to indicate the firmness.

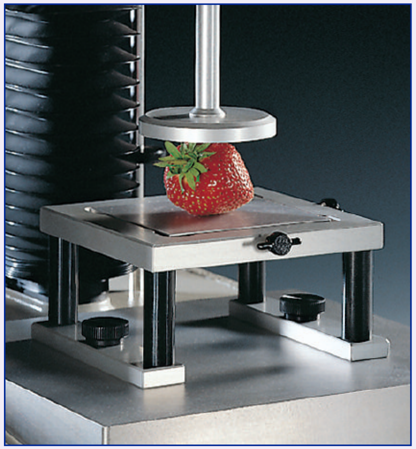


***Figure 5:*** *Compression test*

## MEASURING THE BRUISING POTENTIAL

**Apples are abundant in Europe with hundreds of varieties available for snacks and in processed desserts and jams.**

Gaining and maintaining market share for apples in their perishable state depends heavily on the quality/maturity of crop at harvest. Factors influencing this include cultivar, climate, soil quality, chemicals and water. However, growers generally lack reliable crop maturity indices to gauge the possible effects of damage suffered by the crop during harvesting and handling.

Measuring the textural properties of apples to determine the likelihood of bruising and/or splitting is a necessary assessment. Resistance to bruising depends on the magnitude and nature of damage and on the stiffness, strength and toughness of the variety. These mechanical properties have far-reaching implications – affecting not only the oral perception of texture, and hence its eating quality, but also storage and cooking properties.

Damage is a major cause of quality loss for fresh fruit markets. For that reason, the strength properties of fruits and vegetables must be known for proper handling, storage and transportation. Knowledge of these properties can help to reduce fruit damage during these operations. These properties depend on the maturity, degree of ripeness and tissue composition and they are useful in predicting shelf life.

During and after harvesting many fruit and vegetables are subject to vibration and compressive loads. Apples, for instance, stored in boxes or bags are under continual static (slow) compression but, when moved, they may also experience faster compressive forces due to impact such as dropping which can be uneconomical if splitting or bruising is extensive. Apples are normally stored with their central axes lying horizontally to prevent the stalks from piercing the apples above. In boxes containing several layers of apples, this means that most of the apples bruise on the cheeks. It is important therefore, that the mechanical properties of the apple are able to withstand as great a deformation as possible, under stacking layers, without damage.

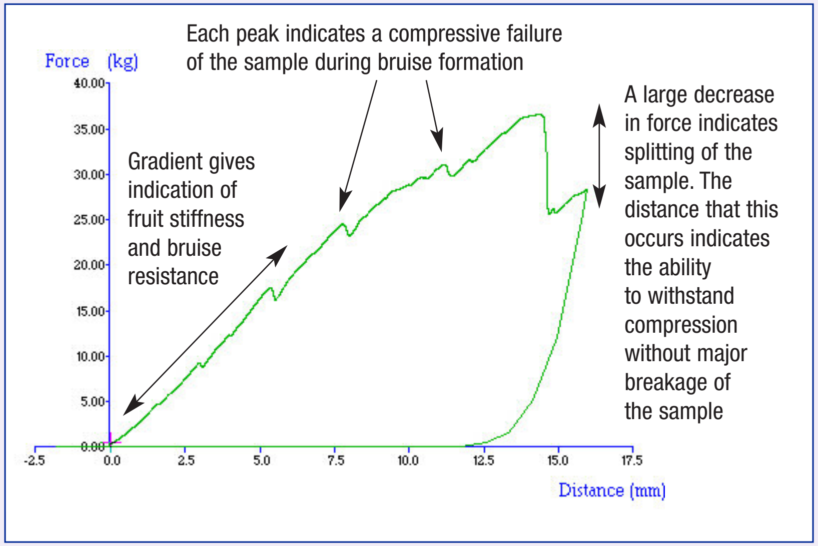



***Figure 6:*** *Annotated curves of compression test of whole apple*

Using a 75mm compression platen the force deformation characteristics of the fruit beyond the elastic limit is important to simulate the destruction that occurs in bruising. The curve in *Figure 6* highlights the effect of compressing a whole apple to assess its mechanical strength. The gradient of the curve (Elastic modulus or Young's modulus) indicates the fruit stiffness and bruise resistance. Peaks are displayed upon bruising and as the apple splits a large decrease in force is experienced. The main indication is that the higher the deformation distance before compressive failure of the sample (leading to bruise formation) the better the fruit is able to withstand stacking weight.

## MEASURING THE OVERALL FIRMNESS OF A WEIGHT OR QUANTITY OF FRUITS

**This type of test commonly applies to:**

**A: Soft Fruits – Drupelets and Berries – e.g. cranberries, blueberries, blackberries, raspberries, strawberries, pomegranate arils, grapes.**

**B: Fibrous samples such as pomegranates, citrus fruits, pineapples which have been prepared into pieces.**

**C: Pieces of fruit that have been prepared into smaller pieces e.g. apple cubes.**

The primary issue of these types of samples is that they are usually of varying sizes or are of non-homogeneous nature and therefore 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 pieces are constant. To do this, fruit 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 fruit pieces. Bulk testing of comparably sized soft fruits acts as a predictor to final integrity.

Bulk testing can be performed either with a Kramer Shear cell or Ottawa cell (as shown in *Figures 7 and 8*). When using an Ottawa cell, a chosen number or weight of samples may be placed into an Ottawa cell containing a holed extrusion plate. Starting at a height of 50mm from the base of the cell the firmness of the samples are measured by the ease of extrusion of the fruit through the holed plate (held at the bottom of the cell) when force is applied by a plunger to a final position of 10mm above the holed plate.

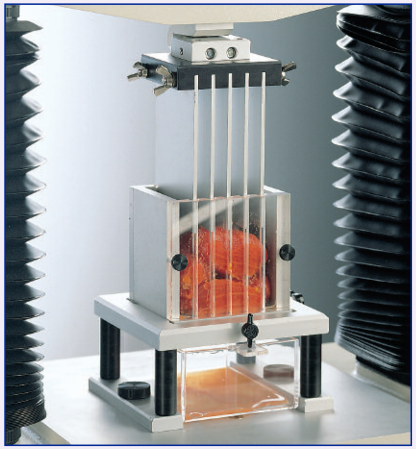


***Figure 7:*** *Kramer Shear Cell*


***Figure 8:*** *Ottawa Cell*

The plunger compresses the fruit until the structure of the sample is disrupted and it extrudes through the holed outlets. The maximum force and total area under the extrusion curve ("Work of Extrusion") is obtained and used as an index of textural quality.

Similarly when using a Kramer Shear Cell, pieces are placed into the cell to the same filling volume, and the blades positioned at a constant position above the fruit surface. The blades then move down into the sample shearing the bulk to a point close to, or slightly through, the base of the cell.

The maximum force and area under the curve are usually recorded for both of these types of test and taken as an indication of bulk fruit firmness which can be a measure of maturity and ripeness, resilience to processing and handling or conversely, breakdown of structure due to, for example, processing conditions such as canning, or freezing. Examples of such processing techniques are shown over in *Figures 9 and 10.*

# EXAMPLES OF MEASURING BULK FIRMNESS/ TEXTURAL INTEGRITY

## Canned vs. Fresh Fruit

**Canned fruits and vegetables retain a great deal of their nutritive value but such products often come under criticism for their texture.**

Texture is the most severely affected sensory property during canning and the wholesomeness of the fruit is often rated by the degree to which the fruit maintains its integrity. Texture may be assisted by the addition of firming agents (e.g. calcium chloride) to maintain the physical integrity of vegetable and fruit pieces characteristic of many salsas, chutneys, etc.

To enable control of the textural characteristics of a fruit it is necessary to monitor the condition of the fruit – timing and degree of the breakdown of structure – during processing. Texture analysis tests such as the following could be used to differentiate between the success of alternative processing methods in maintaining the integrity of firmness of fruits.

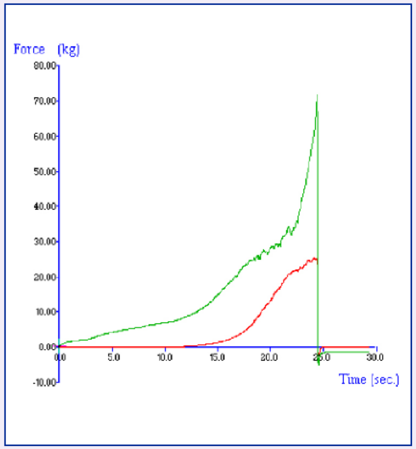



***Figure 9:*** *Curves of fresh vs. tinned strawberries tested with an Ottawa cell*

| Sample | Maximum Force (kg) (± S.D.) | 'Work of Extrusion' (kg s) (± S.D.) |
|---|---|---|
| Strawberries - tinned | 33.9 ± 3.8 | 172.2 ± 16.3 |
| Strawberries - fresh | 54.7 ± 5.5 | 322.3 ± 24.3 |

***Table 2:*** *Typical Ottawa Cell results of fresh vs. tinned strawberries*

## Frozen vs. Fresh Fruit

**Freezing is one of the main techniques for the long-term preservation of foods. It is a sublethal method of preservation based primarily on retardation of microbial growth and chemical and enzymatic deteriorative reactions during storage at low temperatures.**

Despite being a method of storage to pause deterioration of fruit and vegetables, freezing leads to alterations in textural characteristics which, in certain cases such as fresh tomatoes and lettuce, are so drastic as to make the method unsuitable. Major textural damage results from physical distortion of the cells and the rupturing of cell membranes by ice crystals with consequent loss of turgor and crispness on thawing.

It is generally accepted that fast freezing gives rise to products with better textural properties than slow freezing. While slow freezing promotes formation of large extracellular ice crystals, rapid freezing leads to less cell dehydration and to formation of smaller ice crystals intra- and extra-cellularly, thereby resulting in much less structural damage and higher quality products. The aim of fruit and vegetable processors is to find an optimum method of freezing which maintains the integrity of the food which upon thawing is as close to the original fresh produce as possible. Such fruits as blackberries, blackcurrants, cranberries, raspberries, and strawberries even, are now individually quick frozen (IQF) to optimise the retention of textural integrity. This subsequently improves the quality of the product in which these fruits are incorporated, e.g. pavlovas, cheesecakes etc.

The curve (*Figure 10*) shows the comparison of firmness of fresh and frozen raspberries (IQF) by a bulk compression test to assess retention of textural integrity. The term ‘firmness of fruit’ is commonly used to describe a parameter assessed by means of empirical mechanical tests and understood as an attribute that ought to be maintained during storage and processing. In this test, which again involves the use of an Ottawa cell with a holed extrusion plate, the higher the maximum force and total force to extrude, the higher is the firmness of the fruit which subsequently indicates the overall bite of the sample.

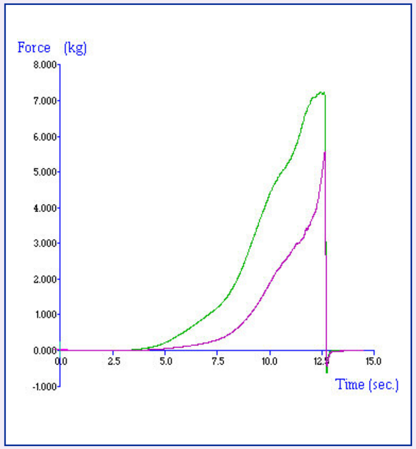



***Figure 10:*** *Curves of fresh vs. frozen raspberries tested with an Ottawa cell*

| Sample | Maximum Force (kg) (± S.D.) | Total Force to Extrude (kg s) (± S.D.) |
|---|---|---|
| Raspberries - fresh | 7.4 ± 0.2 | 23.9 ± 0.2 |
| Raspberries - frozen | 5.3 ± 0.5 | 11.2 ± 0.8 |

***Table 3:*** *Typical Ottawa Cell results of fresh vs. frozen raspberries*

Stable Micro Systems™

## MEASUREMENT OF FLESH FIRMNESS OF PREPARED HOMOGENEOUS FRUIT SAMPLES

**A compression test may be the preferred test method** but where fruit samples vary in size this will immediately reflect in the magnitude of force measured as it is subject to surface area differences and consequently the reproducibility of results will be poor. In this instance, the fruit will be required to be prepared into pieces of accurate dimensions – usually cubes or cylinders. Cubes are often obtained with the aid of dual razor blades mounted a set distance apart then used to trim the cylinder after the first 3mm (including skin) are discarded whilst cylinders are usually prepared with the aid of a core borer. Because specimen orientation significantly affects resultant mechanical textural properties it may be preferable to test the pieces with the original skin or rind-side down taken from the same region of the fruit to avoid differences due to anisotropy.

A compression test to, for example, 75% of the original height using a cylinder probe or platen larger than the sample, is typical. Force versus distance values are recorded and used to calculate: the rupture or breaking force (bioyield point) – a measure of the fruit firmness or resistance to rupture, toughness or the area under the force-distance curve up to the point of rupture of the fruits (bioyield area), and slope of the force deformation curve until the 1st inflection point (modulus of elasticity or Young's modulus) – a measure of stiffness in the region of linear elasticity (~3% strain).

Cutting tests of cubed or cylindrical samples (with or without skin) using a Blade set, Craft Knife, Light Knife Blade or Fracture Wedges (as shown in *Figure 12*) to a depth of 0.5mm above the base of the test platform, are also valid methods and testing tools but again have the disadvantage of requiring careful sample preparation to make sure that samples are the same in every dimension and tissue orientation. Peak fruit cutting force and energy (area under the curve) are typically recorded. The use of a blade when testing is a useful way to measure 'bite' characteristics.

## MEASUREMENT OF FLESH FIRMNESS OF NON-HOMOGENEOUS FRUITS

**Testing fruits of non-homogenous nature or variable texture,** such as water melons where there is a high seed content, is not only tricky by any puncture, shearing or compression method, but often results in low reproducibility and misleading data. In any of these tests the data may show wide variances between maximum and minimum force resistance, depending upon whether the probe or fixture meets with less or more seeds or variable texture when tested. By penetrating the product in several areas at the same time, the Multiple Puncture Probe produces an averaging effect and is therefore more representative. Using several testing pins, attached to the TA.XT*plus* Texture Analyser (as shown in *Figure 11*), melons, for example, of different varieties, root stocks and post-harvest storage times can be compared. The testing method also offers flexibility. When forces are created above the capacity of the load cell being used in the TA.XT*plus* 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. The central pins may, in the case of water melons, be removed so as to avoid the hard core which would otherwise give mis-representative results. The outer ring of pins are then ideally located as they can puncture the heart of the melon yet avoid the majority of the seeds. Preparation would involve cutting the melon in half and removing the blossom end with a sharp knife to provide extra stability. The melon is then presented to the Texture Analyser and levelled if necessary to ensure a flat testing surface. The multi-penetration test is commenced and the area under the curve taken as average flesh firmness.

***Figure 11:*** *Multiple Puncture Probe for assessment of watermelon*

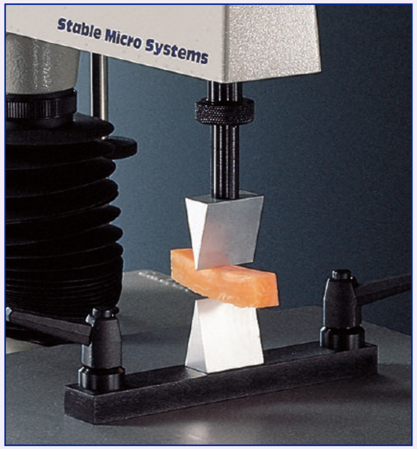



***Figure 12:*** *Fracture wedges*

## MEASURING DETACHMENT FORCE

**Table grapes are highly perishable, non-climacteric fruits.** Their shelf life is shortened by loss of firmness, berry drop, discoloration of the stem, desiccation and fungal rots. The berry drop is due basically to dry-drop (or abscission) – ethylene in conjunction with falling auxin levels, induces the formation of an abscission zone at the pedicel-berry junction, thus stimulating their drop. Grape varieties susceptible to berry drop present a huge problem for successful storage and marketing. For this reason it is required to predict and control the harvested abscission of grape berries, which is not only of inherent scientific interest but it also has considerable commercial significance.

The fruit detachment force, an index of berry adherence strength which controls berry drop, consists of the linking force (between berry brush and berry flesh) and tensile strength of the abscission zone. Deng et al. (2007) have found there to be a high negative correlation between fruit detachment force and harvested berry abscission. Therefore, the progress of abscission can be determined by the changes in fruit detachment force. A quantitative prediction of berry drop and optimisation of storage conditions for grapes would therefore be of high value.

To measure detachment force, an individual grape stem is put through a hole of a plate and firmly clamped with a spring clamp. The spring clamp is then fastened to the load cell fixture. The texture analyser moves upwards until they are pulled apart. The maximum force encountered during this tensile test is termed the fruit detachment force.

## MEASURING DESEEDING FORCE

**Researchers Paull et al (1997), have also documented a method for the measurement of deseeding force of papaya.** Deseeding force is measured by cutting the fruit into halves horizontally at the top and bottom of the half, leaving approximately 4cm section at the equator, which is placed on a plate with a hollow centre. A triangle blade-like tool (i.e. Fracture Wedges) is used to remove the seeds and the force required to push the fruit placenta and seeds out from the top to the bottom of the section determined.

# MEASURING TOUGHNESS AND STICKINESS OF DRIED FRUIT

**Fresh fruits are in many ways ideal snacks but suffer from difficulties in distribution and lack of universal seasonal availability.** Convenience, therefore, dictates that frequently some preparation and preservation needs to be carried out to ensure their availability throughout the year, ensure consistency of quality and even enhancement of particular attributes. Whilst dried fruits retain a great deal of their nutritive value they often come under criticism for texture as drying can cause considerable loss of textural integrity.

Degradation of product colour and texture is usually attributed to the long product drying times at high temperatures. Drying with microwave assistance, for instance, has potential for producing better quality dried products while considerably reducing the duration of drying. However, the quality of dried products depends not only on the drying process itself but also on the various steps preceding the drying process, such as blanching.

When controlling the textural characteristics of fruit during processing, it is necessary to monitor the condition of the fruit-timing and degree of the breakdown of structure.

Dried fruits such as currants, raisins, dates, candied fruit (peels etc.), freeze dried fruits, firm fruit pastes often have a tough and fibrous consistency. They are normally very irregular in shape and highly adhesive although some more recent variations can have an extremely brittle, almost crisp, consistency depending on the method of drying.

Drying of fruit normally needs to be carried out where it is produced and while it is very fresh. There is a great variation in the needs in processing different fruits to achieve the wide variety of purchaser requirements so that practically every fruit that is dried requires different processing cycles. For example, a readily reconstitutable fruit salad may require quite different dried fruits than perhaps the more general specifications of fruit destined for use in a composite fruit snack bar.

Subjectively, important characteristics expected of a dried fruit are that it is not too tough and chewy and that the fruit does not stick to the teeth when chewed which, if excessive, may be regarded as unacceptable. The avoidance of case-hardening, which contributes to dried fruit toughness, is important as is the osmotic dehydration process which can contribute to stickiness because of the sugar that adheres to the product surface.

***Figure 13:** Cylinder probe for firmness and surface stickiness measurement. A Confectionery Holder avoids sample lifting upon probe withdrawal*

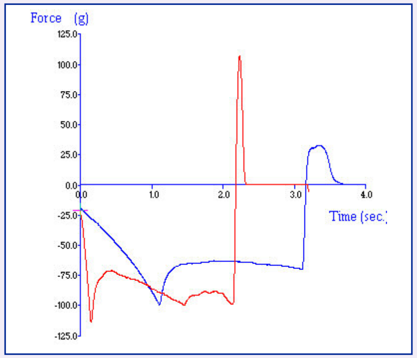



***Figure 14:** Curve showing comparison of firmness and stickiness of two brands of dried apricots*

| Apricot sample | Maximum +ve Force ('Stickiness') (g) (± S.D.) | Distance to 100g (mm) (± S.D.) |
|---|---|---|
| Brand A | 33.8 ± 3.0 | 2.1 ± 0.3 |
| Brand B | 102.6 ± 7.1 | 0.28 ± 0.01 |

***Table 4:** Typical Results of penetration testing of two brands of dried apricots*

Texture analysis tests such as the penetration (using a small cylinder probe as shown in *Figure 13*) or cutting (using a Craft Knife as shown in *Figure 15*) can differentiate between the success of alternative processing methods and ascertain the relative integrity or firmness of fruits following drying.

The curve in *Figure 14* shows the comparison of the firmness and stickiness of two brands of dried apricots. Samples are compressed with a 6mm cylinder probe until 100g of resistance is achieved. The time this takes (or the distance moved) to reach 100g indicates the softness/firmness of the sample; a shorter compression distance indicates a firmer sample. The cylinder probe is then withdrawn at maximum speed and the force to withdraw from the product is subsequently measured; the higher the force the greater is the measurement of stickiness. It is important to hold the sample down during testing to avoid lifting of the sample when the probe withdraws (see *Figure 13*).

## FIRM PASTES

**Texture is a very important property of fruit pastes since they are often used as fillings for energy bars and other products containing fruits.** Among all textural properties hardness and stickiness are the most important ones since they can dictate the possibility of application onto a product. Usually fruit pastes are applied by lightly heated rollers. If the paste is too hard or sticky it may be not properly applied.

This kind of product can be tested with a Craft Knife if the paste is homogeneous (as shown in *Figure 15*) or a Kramer shear cell if non-homogenous. A rectangular piece of fruit paste of fixed dimensions are placed across the bottom of a Kramer shear cell and the maximum force and area under the positive region of the curve obtained as measures of hardness or 'bite characteristics'.

Stickiness and hardness can be measured using a cylinder probe which performs a penetration test to a chosen distance into the bar. Stickiness is the work/force necessary to overcome the attractive forces between the surface of the food and the surface of the material (the probe) with which the food comes into contact.

## DRIED FRUIT FLAKES

**Dehydrated pieces of fruit are available in various sizes and moisture levels making them suitable for applications such as cereal bars, muesli, breakfast cereals, muffins and biscuits.** The fruit pieces can be preserved (with sulphur dioxide), rice flour rolled or candied.

Dried fruit flakes can be similar to berries or small fresh fruits in that they can often represent a remarkably non-uniform configuration from piece to piece (flake to flake) and therefore the testing of one flake at a time is often meaningless. As previously mentioned, a convenient physical test is to compress a population of flakes constrained within a container such as the Ottawa cell which attaches to a TA.XT*plus*/TA.HD*plus* Texture Analyser. 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.


***Figure 15:*** *Craft Knife*


***Figure 16:*** *Mini Ottawa/Kramer Shear cell*

# ASSESSING PROPERTIES OF FRUIT PEEL, FRUIT FILMS AND FRUIT LEATHER

## Fruit Leather

**A fruit leather is made by drying a very thin layer of fruit puree or a mixture of fruit juice concentrate and other ingredients on a flat surface in an oven, desiccators or in direct sunlight, to obtain a product with a chewy** texture similar to soft leather. Almost any type of fruit is suitable for making fruit leathers. Fruit leather is easy to eat, convenient to pack, and makes an ideal snack almost anywhere. When dried, the product is pulled from the surface, rolled and consumed as a snack. The control of the drying temperature is very important, as very high temperatures may cause case hardening, hindering the outflow of water. Too thin a layer of puree, on the other hand, can make the product brittle and difficult to be pulled from the surface.

A blade test would be a suitable fixture for the assessment of 'bite characteristics'. Alternatively the assessment of surface stickiness would be performed as previously mentioned for dried fruits whereby a cylinder probe contacts the sample surface with a chosen force (to achieve a good bond between two surfaces) and the force to separate the probe from the sample surface is measured as stickiness.

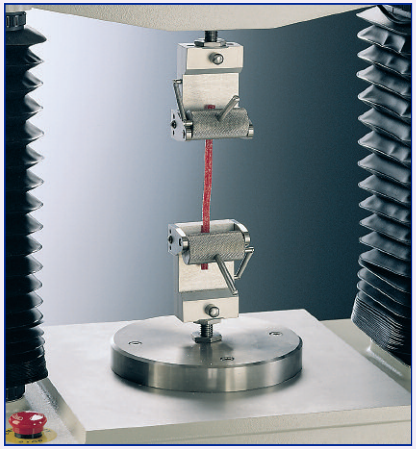


***Figure 17:*** *Self-Tightening Roller Grips*

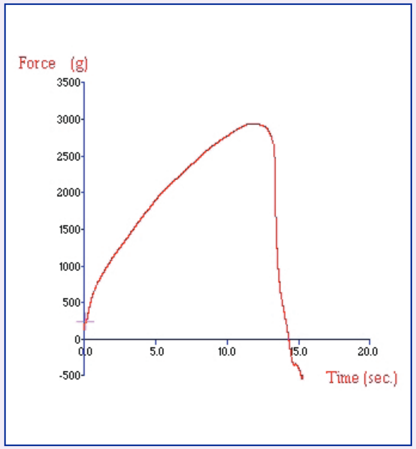



***Figure 18:*** *Test of tensile strength of fruit leather using Self-Tightening Roller Grips*

## Edible Films

**Fruit pomace extracts, which contain pectin, celluloses, pigments, and other functional compounds, may also be used as a novel film-forming material for making edible films and coatings.** Such edible films and coatings would provide additional benefits to traditional edible film-forming materials by providing unique fruit flavour and colour, thus attracting more potential applications.

Mechanical properties of such films can be measured using ASTM D882 method for the measurement of tensile strength and percent elongation at break. Each film (of specified dimensions) is mounted between Tensile Grips (as shown in *Figure 17*) with an initial grip separation of 50mm and a tensile test performed at 0.5mm/s. The maximum force (N) is divided by the film cross-sectional area ($mm^2$) to calculate the tensile strength and elongation at break is divided by the initial length of the specimen and multiplied by 100 to calculate the percent elongation at break.

*more...*

Alternatively, biextensional properties can be measure with the use of a Film Support Rig (as shown in *Figure 19*). The Film Support Rig allows the measurement of the resilience of fine films. Prior to performing the test, the sample is placed over a hole in a raised perspex platform. 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. The maximum force to rupture the film is recorded and is referred to as the burst strength of the film.

The resilience and relaxation properties of the film can also be measured. 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. 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, allowing manufacturers to optimise product structure and formulation.

***Figure 19:*** *Film Support Rig*

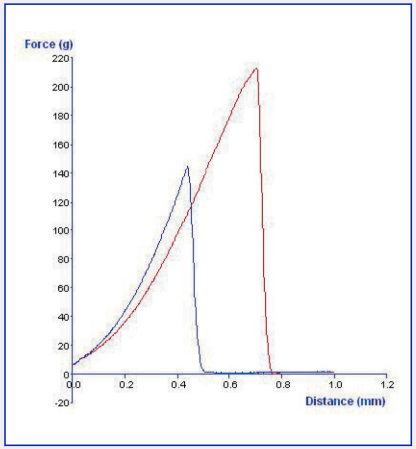



***Figure 20:*** *Comparison of burst strength of 2 types of edible films*

## Fruit Peel

**There is little information on post-harvest physico-mechanical property changes of orange peel and fruit under ambient and refrigerated storage conditions** which are helpful to decide handling, packaging, storage, and transportation systems to be adopted and their designs. However, researchers (Singh *et al*, 2006) have reported the use of a peel tensile strength test to evaluate the behaviour of orange peel under applied tensile loads. Clamps were made to hold a section of orange peel for determining peel strength. Peel pieces were carefully dissected from the equator of five randomly selected fruits. Immediately after peel removal, peel thickness was measured using vernier callipers and peel strips of 15mm (polar) and 60mm (equatorial) were attached via clamps. Strips were subjected to axial tensile loading in an equatorial direction with a crosshead speed of 10mm/min until rupture. Rupture force was taken as the maximum peak force required to rupture the peel. Tensile strength was calculated by dividing the peak rupture force by the cross-sectional area (thickness x width) of the initial specimen. Modulus of elasticity was calculated as the slope of the initial linear portion of a stress-strain curve.

## MEASURING CONSISTENCY OF FRUIT PREPARATIONS

**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, from yoghurt to fresh cheese and ice cream. Consumers 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.

### Measurement of Soft Pastes and Pulps

**(Purees, pulps, weak jellies and sauces)**

**Very thick and viscous slurries made from processed fruit.** Pulps and purees are 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 21*) 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.

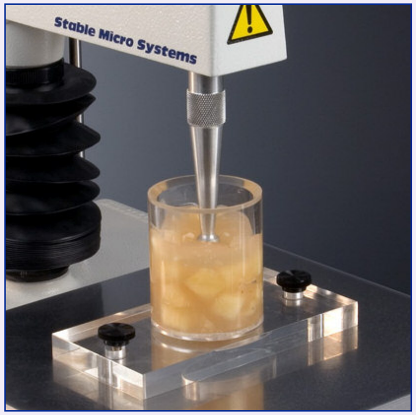



***Figure 21:*** *Back Extrusion Rig*


***Figure 22:*** *Multiple Puncture Probe*

### Measurement of Fruit Gels

**(Jams, preserves, jellies)**

**Pectin set gels with either homogeneous smooth consistencies or containing fruit pieces.** Often supplied in jars unless highly gelled with pectin to form 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 pretreat 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, a Multiple Puncture Probe is recommended (as previously described and shown in *Figure 22*).

## MEASURING WHOLE FRUIT VOLUME

**Quality components of fruits and vegetables are classified into the external such as size (weight, volume and dimensions), colour, shape (diameter/depth ratio), external defects etc. and the internal such as sugar content, acid content, firmness, maturity etc and internal characteristics.**

Volume is an important physical property of agricultural materials. The method most commonly used to determine volume is water displacement. However simple, the water displacement method produces one figure which is manually recorded.

Agricultural products have the characteristics of being ‘low value added’ as compared with other industrial commodities. Because of this, application of start-of-the-art technology to agricultural sectors has been relatively recently activated and various up to date techniques have now reached the point of practical implementation.

One such example is the use of a *VolScan Profiler* (as shown in *Figure 23*), a benchtop laser-based scanner that measures the volume of products. This measurement system offers considerable advantages over displacement techniques which purely measure volume.

The rapid 3-dimensional digitisation of products enables an automatic calculation of several detailed dimension related parameters the results of which may be mathematically manipulated for immediate use or future retrieval in a variety of different data formats. The product is mounted at each end (as shown in *Figure 24*) and the test started. The sample is automatically weighed and a laser measures the contours of the sample at given intervals while it rotates.

Once the *VolScan Profiler* has completed a test, data (as shown in *Figures 25-28*) may be viewed in 2D or 3D, to allow visual comparisons with previous archived measurements. Controlled, repeatable analysis not only provides unambiguous quality assessment standards but also offers precision in physical characterisation.


***Figure 23:*** *VolScan Profiler*

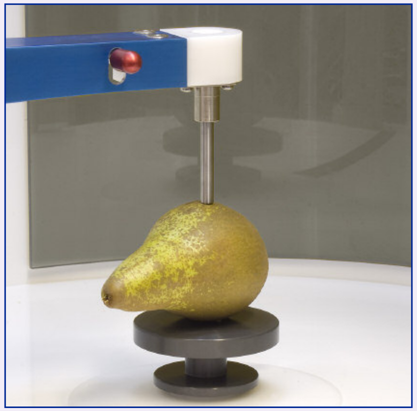


***Figure 24:*** *Fruit mounted on VolScan*

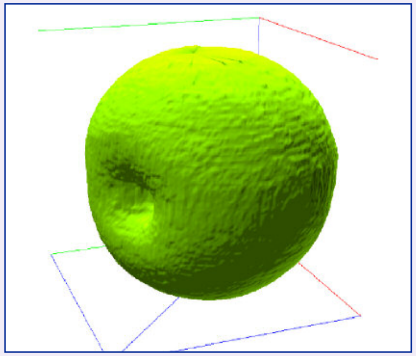


***Figure 25:*** *3D scan of apple*

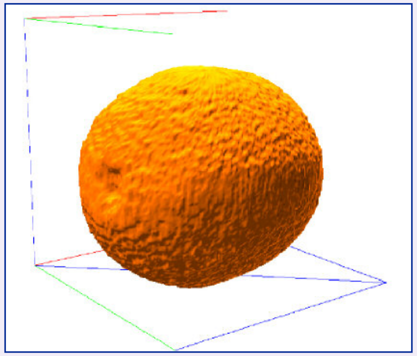


***Figure 26:*** *3D scan of orange*

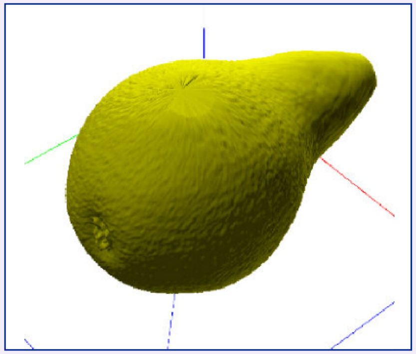


***Figure 27:*** *3D scan of pear*

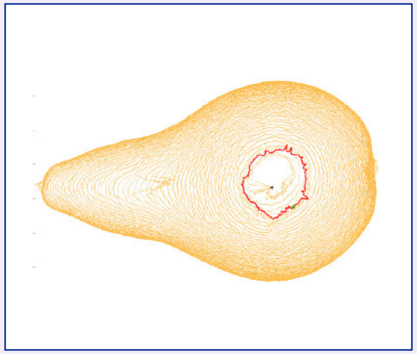


***Figure 28:*** *2D scan of pear*

**Whatever type of fruit product is being produced – thick and chunky, smooth with tiny fruit pieces – its texture must match consumer sensory preferences.**

The ability to produce accurate and repeatable data on different food textures is central to achieving the optimum texture quality for the end-product. The TA.XT*plus* Texture Analyser and its attachments is currently the most advanced of its type and facilitates such efficient and cost-effective testing, helping food processors to develop technically superior products.

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

## REFERENCES


### APPLE

**Camps, C., Guillermin, P., Mauget, J. C. & Bertrand, D.** (2005). *Data analysis of penetrometric force-displacement curves for the characterisation of whole apple* ***Fruits.*** **Journal Of Texture Studies, 36, 387-401.**

**Eswaranandam, S., Hettiarachchy, N.S. & Meullenet, J. F.** (2006). *Effect of malic and lactic acid incorporated soy protein coatings on the sensory attributes of whole apple and fresh-cut cantaloupe.* Journal of Food Science, 71 (3), 307-313.

### CHERRIES

**Marquina, P. L., Burgos, J. & Oria, R.** (2001). *Application of a compression-relaxation test for the characterisation of burlat sweet cherry.* Journal of Texture Studies, 32, 15-30.

### FRUIT LEATHER

**Azeredo, H. M. C., Brito, E. S, Moreira, G. E. G., Farias, V. L. & Bruno, L. M.** (2006). *Effect of drying and storage time on the physico-chemical properties of mango leathers.* International Journal of Food Science and Technology, 41, 635-638.

### FRUIT FILMS

**Park, S. I. & Zhao, Y.** (2006). *Development and characterization of edible films from cranberry pomace extracts.* Journal of Food Science, 71 (2), 95-101.

### FRUIT PASTE

**Kopjar, M., Pilizota, V., Hribar, J., Tiban, N. N., Subaric, D., Babic, J. & Pozrl, T.** (2008). *Influence of trehalose addition on instrumental textural properties of strawberry pastes.* International Journal of Food Properties, 11, 646-655.

### GRAPES

**Deng, Y., Wu, Y. & Li, Y.** (2007). *Effects of high $CO_2$ and low $O_2$ atmospheres on the berry drop of 'Kyoho' grapes.* Food Chemistry, 100, 768-773.

### JAM

**Suutarinen, J., Honkapaa, K., Heinio, R.-L., Mustranta, A., Liukkonen-Lilja, H. & Mokkila, M.** (2002). *Modeling of calcium chloride and pectin methylesterase prefreezing treatments of strawberries and jams.* Journal of Food Science, 67 (3), 1240-1248.

### MANGO

**Rajkumar, P., Kailappan, R., Viswanathan, R. & Raghaven, G. S. V.** (2006). *Drying characteristics of foamed alphonso mango pulp in a continuous type foam mat dryer.* Journal of Food Engineering, In Press.

**Moreno, M., Castell-Perez, M. E., Gomes, C., Da Silva, P. F. & Moreira, R. G.** (2006). *Effects of electron beam irradiation on physical, textural and microstructural properties of 'Tommy Atkins' mangoes (Mangifera indica L.).* Journal of Food Science, 71 (2), 80-86.

### MELON

**Beaulieu, J. C., Ingram, D. A., Lea, J. M. & Bett-Garber, K. L.** (2004). *Effect of harvest maturity on the sensory characteristics of fresh-cut cantaloupe.* Journal of Food Science, 69 (7), 250-258.

### ORANGES

**Singh, K. K. & Reddy, B. S.** (2006). *Post-harvest physic-mechanical properties of orange peel and fruit.* Journal of Food Engineering, 73, 112-120.

### PAPAYA

***Paull, R. E. & Chen, W.*** *(1997). Minimal processing of papaya (Carica papaya L.) and the physiology of halved fruit.* Postharvest Biology and Technology, 12, 93-99.

### PEACHES

**Diezma-Inglesias, B., Valero, C., Garcia-Ramos, F. J. & Ruiz-Altisent, M.** (2006). *Monitoring of firmness evolution of peaches during storage by combining acoustic and impact methods.* Journal of Food Engineering, 77, 926-935.

### PEPINO

**Martinez-Romero, D., Serrano, M. & Valero, D.** (2003). *Physiological changes in pepino (Solanum muricatum Ait) fruit stored at chilling and non-chilling temperatures.* Postharvest Biology and Technology, 30, 177-186.

### PINEAPPLE

**Boonmung, S., Chomtee, B. & Kanlayasiri, K.** (2006). *Evaluation of artificial neural networks for pineapple grading.* Journal of Texture Studies, 37, 568-579.

**Lopez-Malo, A. & Palou, E.** (2008). *Storage stability of pineapple slices preserved by combined methods.* International Journal of Food Science & Technology, 43, 289-295.

**Martinez-Ferrer, M., Harper, C., Perez-Munoz, F., & Chaparro, M.** (2002). *Modified atmosphere packaging of minimally processed mango and pineapple fruits.* Journal of Food Science, 67 (9), 3365-3371.

### STRAWBERRIES

**Suutarinen, J., Heiska, K., Moss, P. & Autio, K.** (2000). *The effects of calcium chloride and sucrose prefreezing treatments on the structure of strawberry tissues.* Lebensm.-Wiss. und.-Technologie, 33 (2), 89-102.

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
- Pharmaceutical Applications
- Powder Flow Analyser
- Distributors
- Temperature products

**Stable Micro Systems**
Vienna Court, Lammas Road, Godalming, Surrey GU7 1YL, UK
**Telephone: *44 1483 427345**
Facsimile: *44 1483 427600