Fruits & Vegetables

Some simple guidelines for texture testing...
What does Texture Analysis mean to the Fruits & Vegetables Industry?

Fruit & vegetable texture properties and requirements are dependant upon the product itself, as well as, subsequent use or consumption. The same fruit or vegetable may be consumed raw or cooked, while different varieties and stages of maturity will result in different physical properties and ultimately, expectations from the consumer or processor.

The generic category of fruits and vegetables contains a wide and varying range of tissue types from complex leafy structures to inhomogeneous berries and fleshy fruits to homogeneous tubers and root vegetables. The texture test and ultimately the test fixture used depends upon these considerations.

Texture measurements provide the fresh produce sector with objective means to put numbers to very subjective characteristics.

- From a manufacturer’s perspective, this could be a canned or frozen pea producer measuring the tenderness of peas at harvest and paying the farmer accordingly.
- From a customer’s perspective, this could be the consistency of a mashed potato or firmness of a fruit compote.

Some Texture Analysis Experiences with the Total Quality Loop

**QUALITY DEPARTMENT**

“...we measured the texture of chopped tomatoes at goods-in to make sure they had the right texture for our process”

“...texture testing gave us a quick and simple way to measure the ripeness and maturity of our strawberries”

**PROCESS DEVELOPMENT**

“...texture testing helped us to understand the effect of downtime on starch gelation in our vegetable puree”

“...we used the Kramer Shear Cell to improve product consistency of our roasted vegetables”

**PRODUCT DEVELOPMENT**

“...texture analysis helped us to optimize the mouthfeel of our mashed potato to maximize customer satisfaction”

“...we used it to measure shelf-life changes to texture of our prepared fruit slices”

**RESEARCH & DEVELOPMENT**

“...texture analysis measured the effect of potato variety on French fry texture during plant breeding trials”

“...we used it to investigate the effect of processing aids in the prevention of structural damage of canned potatoes”

**Total Approach to Quality**
How do I know that I need to measure the texture of my fruit or vegetable product?

Food texture analysis is primarily concerned with how food material feels, behaves and performs. There are two approaches that can be taken to measure food texture:

**Sensory based**
Texture treated as a perception or human experience, which is correlated to what we feel.

**Engineering based**
Texture treated as a condition, which can be monitored and manipulated during manufacture.

Whatever approach is taken, the methods followed should be simple, practical and, most importantly, generate information of “real” value on the product being tested.

Do I have a texture related problem?

Are you getting...?
- Lots of complaints
- Process down-time
- Inconsistent production

Yes → Identified Problem

No → Do you get...?
- High levels of rework
- High levels of rejects
- High levels of concession

Yes → Texture Testing will...
- Improve product consistency
- Reduce process down-time
- Improve customer satisfaction
- Accelerate and reduce development costs
- Minimize quality costs:
  - Loss in reputation
  - Cost of production
  - Devalue brand
- Reduce internal and external commercial pressure for improved product quality

No → Unidentified Problem

Do you have...?
- Always correcting processes
- Guessing what to change

Yes → Plus

No → Are you...?
- Poor process and product knowledge
- Lots of new product launches

Yes → Even if it looks ok...
- Prevent failure
- Proactive when it needs to be
- Aid continuous improvement
- Understand process and product variation (due diligence)

No → No Immediate Requirement
## Food Technology Corporation

### Pastes & Pulps
- **Purées**
- **Pulps**
- **Mashed Potato**

Very thick and viscous slurries made from processed vegetables to produce a semi-solid state. Additional ingredients are added to manipulate consistency and processing properties.

### Legumes & Kernels
- **Peas**
- **Beans**
- **Pulses**
- **Sweet Corn**

Starchy beans, kernels, peas, grains and pulses either tested succulent in hydrated state or in dried form. Generally consist of a tough outer skin with succulent pasty inner structure that softens on hydration or during cooking. Can become pasty when chewed.

### Florets
- **Broccoli**
- **Cauliflower**

Irregular shaped floret type vegetables with tough stalks and tender flower heads. Floret head will often soften prior to stalk that has more fibrous consistency. Stalk is used as batch quality predictor.

### Leaf & Stems
- **Cabbage**
- **Sprouts**
- **Celery**
- **Fennel**
- **Rhubarb**

Thin layer(s) of tissue incorporating venial structures to aid photosynthesis. May be singular as in the case of spinach and salad leaves or tightly bound together to form clusters or balls as with Dutch cabbage and Brussel sprouts.

### Pods & Modified Stems
- **Asparagus**
- **Green Beans**
- **Runner Beans**
- **Mange Tout**

Cylindrical or flattened samples with varying texture across the length of sample. Encased by tough outer skin, while pods contain seeds. Texture can vary along cross-section of shoot.

### Core Characteristics
- **Stringiness (tailing) when deposited**
- **Flow characteristics on pumping**
- **Mouthfeel during consumption**
- **Hydration/drying properties**
- **Skin toughness**
- **Maturity, tenderness and ripeness**
- **Cooking time optimization**
- **Functionality in fermentation, blending & cooking**
- **Resilience to processing and handling**
- **Stalk toughness from shearing**
- **Resilience to compression of whole floret**
- **Blanched texture & degradation**
- **Break strength & flexibility of celery sticks & batons**
- **Bite strength & eating quality**
- **Blanch hardness & firmness post cooking**
- **Crispness over shelf-life in modified atmosphere packaging**
- **Tensile strength & toughness of vertical fibers**
- **Pod/stem tenderness**
- **Chewiness of fibrousness**
- **Crispness or freshness**
- **Toughness of skin & fibers**
### Product Description Core Characteristics

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Core Characteristics</th>
</tr>
</thead>
</table>
| Prepared                  | Small, irregular and non-uniform pieces of vegetables with fleshy or starchy structure. High degree of variation between individual pieces and even within individual pieces themselves. May include skin where appropriate, which can influence textural properties | • Flesh firmness  
• Cook quality and heat degradation on blanching  
• Process stability and consistency  
• French fry crispness  
• Processing stability  
• Shelf-life and pH degradation |
| Grains & Seeds            | Small, tough and regularly sized seeds with tough outer shell and mealy inner consistency. Irregular surface properties and brittle texture makes individual analysis highly variable.                                      | • Roasting profile  
• Bite force  
• Resilience & strength  
• Consistency & fracture properties |
| Bulbs                     | Small bulbs made up from layers of leaf like material. Penetration through layers provides indication of structure at each layer.                                                                               | • Flesh firmness/harness  
• Resilience to cooking process  
• Crispness in prepared salads  
• Softening during storage (pickling) |
| Multiple Textured & Fleshy| Variable anatomical tissue, which supports and protects internal seeds. Skin or peel surrounds fleshy pericarp material. Samples are anisotropic where orientation directly influences results (if you squash a tomato in different directions you will get different results) | • Flesh firmness  
• Skin toughness & Bio-yield  
• Resilience to cooking & processing  
• Variety differentiation  
• Softening on storage  
• Crunchiness as an indicator of freshness |
| Roots & Tubers            | Homogeneous large and starchy roots and tubers with predominantly uniform structures. Taproots may incorporate central woody core, which will influence texture results and sample isotropy - if sample is presented to analyzer in different directions different results will be obtained. | • Bite strength & resilience  
• Softening on cooking  
• Toughness through season and changes pre/post harvest  
• Cooked texture for mashing & purées  
• Performance in size reduction unit operations |

**Semi-solid**
Flows if unsupported, poured, pumped, extruded or spread during handling or consumption

**Solid**
Self-supporting structure, deformed, squashed, sheared or snapped during handling or consumption
## Choosing The Right Fixture

### Extrusion
- Make a thick liquid flow, just like squeezing tomato purée from a tube or shaking sauce from a bottle

### Bulk Analysis
- Measure individual pieces in bulk like eating a spoonful of peas or scooping out some salsa

### Multiple Point Analysis
- Multiple site tests are used to measure products with variable textures like pushing a fork into a tomato

<table>
<thead>
<tr>
<th>Group</th>
<th>Examples</th>
<th>Fixture Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pastes &amp; Pulps</td>
<td>Purées, Pulps, Mashed Potato</td>
<td>• TMS Extrusion Cell (432-026)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• TMS Extrusion Cone (432-027)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• TMS Extrusion Platen Set (432-029)</td>
</tr>
<tr>
<td>Prepared</td>
<td>Chopped Tomato, Chopped Green Beans, Chopped Onions, Diced Vegetables</td>
<td>Extrude tomato purée to measure flow and consistency properties</td>
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<td></td>
<td>Salsa</td>
<td></td>
</tr>
<tr>
<td>Legumes &amp; Kernels</td>
<td>Peas, Beans, Pulses, Sweet Corn</td>
<td>• FTC Standard Shear Compression Cell (432-240)</td>
</tr>
<tr>
<td>Grains &amp; Seeds</td>
<td>Pumpkin Seeds, Poppy Seeds, Animal Feeds, Cooked Rice</td>
<td></td>
</tr>
<tr>
<td>Florets</td>
<td>Broccoli, Cauliflower</td>
<td>• FTC Standard Shear Compression Cell (432-240)</td>
</tr>
<tr>
<td>Bulbs</td>
<td>Onion, Shallot, Garlic</td>
<td></td>
</tr>
<tr>
<td>Leafs &amp; Stems</td>
<td>Cabbage, Sprouts, Celery, Fennel, Rhubarb</td>
<td>• FTC Standard Shear Compression Cell (432-240)</td>
</tr>
<tr>
<td>Multiple Textured &amp; Fleshy</td>
<td>Tomato, Peppers, Zucchini (Courgette), Cucumber, Egg Plant (Aubergine)</td>
<td>Measure the effect of cooking conditions on rice texture</td>
</tr>
<tr>
<td></td>
<td>Squash</td>
<td></td>
</tr>
<tr>
<td>Pods &amp; Modified Stems</td>
<td>Asparagus, Green Beans, Runner Beans, Mange Tout</td>
<td>Penetrate into cooked sprouts to assess hardness</td>
</tr>
<tr>
<td>Roots &amp; Tubers</td>
<td>Carrots, Parsnip, Swede, Turnip, Celeriac, Potato, Yam</td>
<td>Penetrate into the pericarp tissue of the tomato to measure ripeness</td>
</tr>
<tr>
<td>Penetration</td>
<td>Shearing</td>
<td>Compression</td>
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<tr>
<td>-------------</td>
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</tr>
<tr>
<td>Use small cylinders, balls, needles and cones to push into a sample like pushing your finger into a piece of potato</td>
<td>Cut across a section of the sample just like biting into a carrot or cutting through broccoli stalks</td>
<td>Squash a small sample with a flat or rounded probe like squeezing a piece of cooked carrot in your hand</td>
</tr>
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</table>

- 1" Perspex Hemispherical (432-096)
- 1" Ball Probe (432-088)
- 2mm ø Needle Probe (432-087)
- 2mm ø Needle Probe (432-087)
- 2mm ø Needle Probe (432-087)
- 2mm ø Needle Probe (432-087)
- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Lightweight Three Point Bend (432-248)
- FTC Succulometer (432-266)
- TMS Large Craft Knife (432-295)
- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS 50mm ø Compression Platen (432-009)
- TMS 75mm ø Compression Platen (432-010)
- 1" Ball Probe (432-088)

Please Note: Accessories listed in each category are examples of those most suited to the application. Only one accessory is normally required per application to perform the majority of tests.
## Food Technology Corporation

### Paste & Pulps

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Core Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purées</td>
<td>Very thick and viscous slurries made from processed fruit. Purés and purées are often concentrated and include fibrous material that adds structure.</td>
<td>• Stringiness (tailing) when deposited</td>
</tr>
<tr>
<td>Pulps</td>
<td></td>
<td>• Flow characteristics on pumping</td>
</tr>
<tr>
<td>Weak Jellies &amp; Sauces</td>
<td></td>
<td>• Structural recovery</td>
</tr>
</tbody>
</table>

### Dried & Chopped

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Core Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currants</td>
<td>Sticky, dried preserved fruits with tough and fibrous consistency. Very irregular in shape and highly adhesive. Can have extremely brittle, almost crisp, consistency depending on method of drying.</td>
<td>• Skin toughness</td>
</tr>
<tr>
<td>Raisins</td>
<td></td>
<td>• Storage hardening</td>
</tr>
<tr>
<td>Dates</td>
<td></td>
<td>• Moisture content</td>
</tr>
<tr>
<td>Candied Fruit (Peels etc)</td>
<td></td>
<td>• Resilience in baking and handling</td>
</tr>
<tr>
<td>Freeze Dried Fruits</td>
<td></td>
<td>• Toughness or chewiness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tooth packing and pulling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Crispness &amp; crunchiness of brittle pieces</td>
</tr>
</tbody>
</table>

### Fleshy Fruits (including pomaceous)

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Core Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>Fleshy fruits with high pectin content consisting of outer skin, firm and juicy inner flesh and central core containing seeds. Homogeneous texture to outer flesh, which gives good reproducibility</td>
<td>• Bruising potential</td>
</tr>
<tr>
<td>Pears</td>
<td></td>
<td>• Ripeness - Flesh firmness</td>
</tr>
<tr>
<td>Quinces</td>
<td></td>
<td>• Skin toughness &amp; Bio-yield</td>
</tr>
<tr>
<td>Melons</td>
<td></td>
<td>• Juicing potential (pressing)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hardness to touch/squeeze</td>
</tr>
</tbody>
</table>

### Soft Fruits (Drupelets & Berries)

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Core Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackberries</td>
<td>Small berries with large content of seeds and irregular geometries. High variability between individual fruit sizes make comparisons difficult. Standardization in fruit size and treatment should be maintained where possible.</td>
<td>• Ripeness and softening</td>
</tr>
<tr>
<td>Raspberries</td>
<td></td>
<td>• Process resilience</td>
</tr>
<tr>
<td>Strawberries</td>
<td></td>
<td>• Breakdown of structure</td>
</tr>
</tbody>
</table>

### Citrus Fruit

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Core Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oranges</td>
<td>Cellular and particulate high moisture content cell sacks bound together to form individual segments. Encased in tough peel, which protect the fruit.</td>
<td>• Physical strength &amp; resilience</td>
</tr>
<tr>
<td>Lemons</td>
<td></td>
<td>• Internal pith &amp; skin tensile strength</td>
</tr>
<tr>
<td>Limes</td>
<td></td>
<td>• Flesh firmness</td>
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<tr>
<td>Grapefruit</td>
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</tbody>
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| Product               | Description                                                                                                                                                                                                                                                                                                                                 | Core Characteristics                                                                                                                                                                                                 |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Small Berries        | Berries of varying sizes predominantly with tough outer skins and soft succulent centres. High variability within same sample batch large sample set.                                                                                                                                                                                                 | • Maturity & ripeness  
• Resilience to processing & handling  
• Harvest resistance  
• Bio-yield point or skin toughness  
• Whole fruit firmness                                                                                                                                                                                                 |
| Elastic Gels         | Pectin set gels with either homogeneous smooth consistencies or containing fruit pieces. Often supplied in jars unless highly gelled with pectin to form jellies.                                                                                                                                                                                                 | • Gel strength  
• Elasticity & consistency comparisons  
• Relaxation & failure properties over time  
• Spreading consistency                                                                                                                                                                                                 |
| Stoned Fruit (Drupes)| Fruits that have an outer skin encasing a soft flesh centre surrounding a hard stone. The skin will yield once penetrated and the flesh may be analyzed using a squeezing action.                                                                                                                                                                                                 | • Skin strength & toughness  
• Yield point & resilience  
• Ripeness & softening profile  
• Pitting properties for processing                                                                                                                                                                                                 |
| Starchy Fruit        | Pasty homogeneous starchy fruits with very soft texture. Easily mashed to pulp or follow viscous behavior when squashed.                                                                                                                                                                                                                     | • Ripening process changes & effect of modified environments  
• Firmness & rigidity                                                                                                                                                                                                                                    |
### Choosing The Right Fixture

<table>
<thead>
<tr>
<th>Pastes &amp; Pulps</th>
<th>Extrusion</th>
<th>Bulk Analysis</th>
</tr>
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<tbody>
<tr>
<td>Purées</td>
<td>Make a thick liquid flow, as if spooning a strawberry purée</td>
<td>Test small irregular berries and fruit pieces in bulk, like eating a handful of raisins</td>
</tr>
<tr>
<td>Pulps</td>
<td>• TMS Extrusion Cell (432-026)</td>
<td>• FTC Standard Shear Compression Cell (432-240)</td>
</tr>
<tr>
<td>Weak Jellies &amp; Sauces</td>
<td>• TMS Extrusion Cone (432-027)</td>
<td>• FTC Universal Cell (432-032)</td>
</tr>
<tr>
<td>Whole Particulates</td>
<td>• TMS Extrusion Platen Set (432-029)</td>
<td>• FTC Standard Shear Compression Cell (432-240)</td>
</tr>
<tr>
<td>Redcurrants</td>
<td>Extrude thick purées and fruit pulps to measure flow characteristics</td>
<td></td>
</tr>
<tr>
<td>Blackcurrants</td>
<td></td>
<td>• FTC Standard Shear Compression Cell (432-240)</td>
</tr>
<tr>
<td>Blueberries</td>
<td></td>
<td>• FTC Universal Cell (432-032)</td>
</tr>
<tr>
<td>Cranberries</td>
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<tr>
<td>Grapes</td>
<td></td>
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<tr>
<td>Dried &amp; Chopped</td>
<td>Use the multiple needle probe to measure set firmness of fruited jams and jellies</td>
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</tr>
<tr>
<td>Currants</td>
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<td>• FTC Standard Shear Compression Cell (432-240)</td>
</tr>
<tr>
<td>Raisins</td>
<td></td>
<td>• FTC Standard Shear Compression Cell (432-240)</td>
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<tr>
<td>Dates</td>
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<td>Candied Fruit (Peels etc)</td>
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<td>Elastic Gels</td>
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<tr>
<td>Jams</td>
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<tr>
<td>Preserves</td>
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<tr>
<td>Jellies</td>
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<td>Fleshy Fruit (including Pomaceous)</td>
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<tr>
<td>Apples</td>
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<td>Pears</td>
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<td>Quinces</td>
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<td>Melons</td>
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<tr>
<td>Stoned Fruit (Drupelets &amp; Berries)</td>
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<tr>
<td>Peaches</td>
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<tr>
<td>Apricots</td>
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<td>Plums</td>
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<td>Avocados</td>
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<tr>
<td>Cherries &amp; Olives</td>
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<tr>
<td>Soft Fruits (Drupelets &amp; Berries)</td>
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<tr>
<td>Blackberries</td>
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<tr>
<td>Raspberries</td>
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<tr>
<td>Strawberries</td>
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<tr>
<td>Starchy Fruit</td>
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<tr>
<td>Bananas</td>
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<tr>
<td>Plantain</td>
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<tr>
<td>Citrus Fruit</td>
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<tr>
<td>Oranges</td>
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<tr>
<td>Lemons</td>
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<tr>
<td>Limes</td>
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<tr>
<td>Grapefruit</td>
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</tbody>
</table>

Bulk compression of comparably sized soft fruits acts as a predictor to final integrity.
## Multiple Point Analysis

Multiple site tests are used to measure products with variable textures like pushing a fork into a tomato.

### Penetration

Use small cylinders, balls, needles and cones to punch into fruits and measure their firmness.

- 1" Perspex Hemispherical (432-096)
- 1" Ball Probe (432-088)
- 2mm ø Needle Probe (432-087)
- 1mm ø Needle Probe (432-086)
- TMS Magness Taylor Probe Set (432-241)

### Shearing

Cut across a section of the sample just like biting into an apple or cutting through a strawberry.

- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Multiple Needle Probe Fixture (432-249)
- 5mm ø and Smaller S.S. Cylinders (432-071 to 432-074)
- TMS Magness Taylor Probe Set (432-241)

### Compression

Squash a small sample with a flat or rounded probe like squeezing a fruit in your hand.

- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Wire Shear Probe And Plate (432-242)
- TMS 75mm ø Compression Platen (432-010)

#### Penetration Shearing Compression

- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS 50mm ø Compression Platen (432-009)
- TMS Multiple Needle Probe Fixture (432-249)
- 5mm ø and Smaller S.S. Cylinders (432-071 to 432-074)
- TMS Magness Taylor Probe Set (432-241)

#### Measure bulk structure of chopped vegetables to predict process integrity

- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Multiple Needle Probe Fixture (432-249)
- 5mm ø and Smaller S.S. Cylinders (432-071 to 432-074)
- TMS Magness Taylor Probe Set (432-241)

#### Measure ripeness and storage changes in apples using penetration testing

- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Multiple Needle Probe Fixture (432-249)
- 5mm ø and Smaller S.S. Cylinders (432-071 to 432-074)
- TMS Magness Taylor Probe Set (432-241)

#### Simply penetrate into fruit flesh to assess skin strength and flesh texture for ripeness

- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Multiple Needle Probe Fixture (432-249)
- 5mm ø and Smaller S.S. Cylinders (432-071 to 432-074)
- TMS Magness Taylor Probe Set (432-241)

#### Penetrate citrus fruit to measure peel characteristics

- TMS Lightweight Blade Set (432-245)
- TMS Large Craft Knife (432-295)
- TMS Multiple Needle Probe Fixture (432-249)
- 5mm ø and Smaller S.S. Cylinders (432-071 to 432-074)
- TMS Magness Taylor Probe Set (432-241)

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**Please Note:** Accessories listed in each category are examples of those most suited to the application. Only one accessory is normally required per application to perform the majority of tests.
Who is Food Technology Corporation?

Founded in 1966, Food Technology Corporation is the industry's longest standing provider of quality texture measurement systems. With over 40 years experience evolving from the groundbreaking Kramer Shear Press, our company is able to provide systems for the field, factory and laboratory test environments. Our extensive experience in practical food texture measurements, combined with our cost-effective solutions makes us the ideal partner for your texture instrumentation needs.

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