The Revolution In Texture Testing

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Texture analysis is an established technique originating from the 1950s when manufacturers in the food industry began to require a more objective assessment of their products. Textural (or rheological) properties of foods, such as hardness, chewiness, gumminess, tenderness, ripeness, elasticity, and adhesiveness, had been characterised by laboratories using humans to do the qualitative evaluation. Today these same properties are largely measured in a consistently quantifiable manner using a Texture Analyser.

Figure 1. Brookfield CT3 Texture Analyser Performs Snap Test on Cracker

A Texture Analyser works by applying a controlled deformation in either compression or tension to a sample under defined test conditions. *(See Figure 1)* The user chooses the type of probe that will cause the deformation, then selects the distance that the probe travels to deform the sample, as well as the rate of deformation. The measured parameter is the force load that causes the mechanical deformation; this is continuously recorded during the test. Using different probe geometries, the kinetic forces generated within a sample can be manipulated. For example, the same cracker shown in *Figure 1* could also be tested with the punch probe shown in *Figure 2*.

A compression test begins when the probe travels to the sample surface and detects an initial resistance of a given value (trigger force) as it begins to make contact. At this point the instrument records the response of the sample as the probe shears, penetrates or compresses the sample over a specified distance or force value. Then the probe withdraws from the sample and returns to its starting position at the sample surface. The bend test on the cracker in *Figure 1* is an indicator of its crispiness, while the penetration test in *Figure 2* is a measure of its hardness.

In a tension test, the sample is held fixed between two clamps which then pull apart from each other while the item is stretched as shown in *Figure 3*. For example, this type of test is used to assess the force required to open sealed pouches of snack foods, such as peanuts, or the extensibility of candy, such as taffy.

Figure 2. Junior Punch Assembly for Measuring Hardness

Texture analysis is used to facilitate consistency in production and quality control, optimise the textural attributes of a product, and predict consumer perception of a product. It is a cost effective technique that delivers quick results and provides a scientific means of quantifying physical properties of foods that correlate to sensory perception.

With consumers now better informed, there are expectations that the food industry will produce products that deliver healthier choices (while maintaining similar texture and flavour) and greater economic value. In the heart of research and development, texture analysis now plays a key part in producing these new products.

Figure 3. Dual Grip Assembly for Tension Test

Texture Analysis of Full-Fat and Low-Fat Products

Over the years, the number of consumers interested in healthy eating by reducing calorie and fat intake has significantly increased. There is now growing demand for low fat and low calorie products due to health concerns such as obesity, cancer and heart disease. Consumer preference for alternative low fat products that do not compromise taste, texture, and nutrition has necessitated research within food industries for artificial sweeteners and fat replacers. To the food technologist, textural quality, mouth feel and taste are key factors to consider in gaining acceptance for the reduced fat/calorie food market. However, replacing fats in food is not an easy process. Fats contribute significantly to food texture, taste, consistency, and stability. The aim of the current natural and synthetic fat replacers introduced in the food industry is therefore to mimic the complex properties of natural fats such as flavour, palatability, and creaminess, as well as reducing fat/calorie content.

For a product developer an objective and accurate means of quantifying the textural properties of food products is necessary, not only to predict consumer response to the product (or to a new formulation of a product during development), but also to ensure consistency in production at the Q/C level. With a large number of techniques and fixtures available to assess physical properties of products, texture analysis can be applied to a wide range of products. The most popular reduced-fat products are found in dairy, meat, bakery, confectionary, and snack foods.

Mayonnaise is a typical example of a dairy product for which there are low fat alternatives. Full fat mayonnaise contains approximately 75% oil, along with a mix of egg yolks, water, vinegar, and spices. Oil in mayonnaise is crucial to giving the product a creamy texture resulting from the formation of a densely packed network of oil droplets emulsified by the egg yolk protein to form a gel structure. It is the gel structure that gives mayonnaise its typical semi-solid and plastic behaviour. The higher the oil content, the smaller the size of the oil droplets and the firmer the emulsion.

Creating sensory textural perceptions of high fat levels in the low fat variants requires a consideration of the properties and function the fat replacer needs to mimic. A food processor therefore needs to identify fat replacers and ingredients that produce the desired texture, mouth feel and flavour for a given product. Lighter variants of mayonnaise typically have reduced oil content of 15-25%. This means that the densely packed network of oil droplets in the full fat counterpart is destroyed and the creamy texture is lost. To produce a similar texture to the full fat counterpart, water along with starches and gum thickeners replace the oil, enabling the emulsion to set. The choice of fat replacer may, however, compromise the texture by giving the product a sticky mouth feeling or a slimy feel. The challenge to a food processor is therefore to reduce the oil content whilst maintaining the desired structure and texture. Achieving a product similar in texture to its full fat counterpart requires good sample thickness that produces the desired consistency. Using the texture analyser with a special mayonnaise mesh probe, the textural attributes of different types of mayonnaise formulations can be quantified for product matching, new product development, shelf life studies and quality control.

Figure 4 shows the mesh probe at its starting position above the sample. surface.

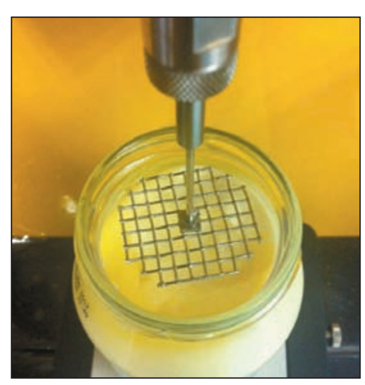

Figure 4. Mesh Probe Performs Extrusion Test on Mayonnaise

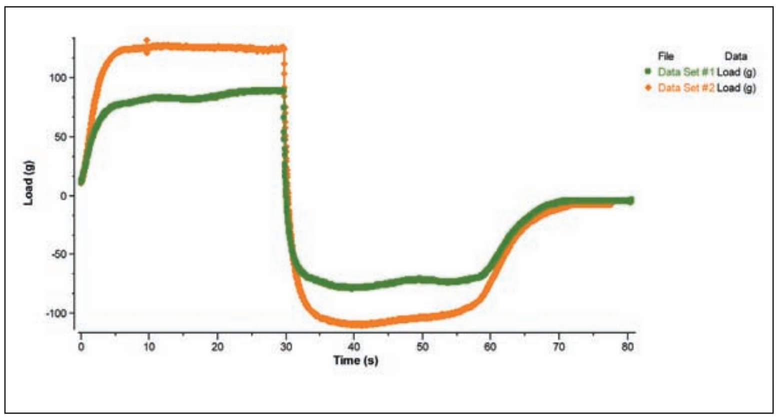

Figure 5. Texture Analysis Test on Mayonnaise

Figure 5 is a typical example of graphical data obtained during an extrusion test of full fat and low fat mayonnaise using a mesh probe. The firmness and adhesiveness of full fat and low fat mayonnaise samples are tested directly after removal from storage (6°C). When a given trigger force has been attained at the sample surface, the mesh probe proceeds to compress the sample to a depth of 30 mm (or other specified distance). During this time, the sample is deformed and compressed to pack more tightly into the remaining space available (under the descending mesh probe). When the sample becomes more compact with limited air pockets, the force increases and the extrusion commences. When the force increases to a maximum point, a plateau is observed indicating the steady-state force required to continue extrusion. This maximum force is a measure of sample firmness. The higher the force value, the more viscous the sample. The maximum negative load value occurs when the probe reverses direction and is pulled back up out of the sample. This is a measure of adhesive force and the area above the negative peak a measure of adhesiveness both of which correlate with the stickiness of the mayonnaise.

Data Set #1: Full Fat Mayonnaise

Data Set #2: Low Fat Mayonnaise

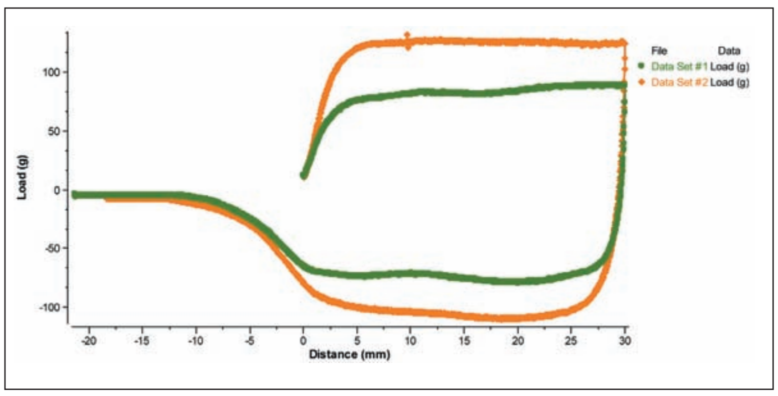

Figure 6. Load vs. Distance Graph for Full Fat and Low Fat Mayonnaise

Figure 6 shows an additional way of displaying the results. The maximum force is a measure of sample firmness. The Work Done (consistency) is the area under the starting point of the test to the target distance point; the higher the value the thicker the sample. The maximum negative load value is a measure of adhesive force and the area above the negative peak a measure of adhesiveness. The negative distance values at a zero load are the points when the probe has fully separated from the sample as it returns to its starting position above the sample surface.

Measurable mechanical properties obtained from the texture analyser can be correlated to the products sensory attributes as follows using mayonnaise as an example:

• Hardness/Firmness

This is the set strength of the mayonnaise and is an indication of the force required to shear the mayonnaise with a spoon or knife.

• Work done

Energy required spooning the mayonnaise from the bottle or container.

• Adhesive Force

Force required overcoming the attractive forces between the mayonnaise and the surface of other materials which the mayonnaise comes into contact with (for example, tongue, teeth, palate, or spoon)

• Adhesiveness

Energy required separating the mayonnaise from the spoon or knife.

Table 1 below is a typical example of the texture analysis results of full fat and low fat mayonnaise using the mesh probe:

Mayonnaise	Hardness (g)	Work Done (mJ)	Adhesive Force (g)	Adhesiveness (mJ)
Full Fat	89.4	23.13	79.4	24.29
Low Fat	131.6	34.62	110.4	32.9

The table shows that the low fat mayonnaise is firmer and more adhesive (sticky) than its full fat counterpart.

Texture Analysis of Gluten-free Products

Consumer acceptance of gluten-free products is still limited by the texture, taste and mouth-feel. Gluten is a special type of protein containing gliadin and glutenin proteins that make up 75-86% of the gluten (the remaining fraction being carbohydrate and lipids). The protein components in gluten, when hydrated, give the gluten its cohesive, elastic and viscous properties. The gluten therefore determines the textural properties of dough in terms of extensibility, resistance to stretch, mixing tolerance, and ability to trap gas. In baked products, gluten is responsible for the light and fluffy, elastic, springy and cohesive structure of bread, cakes and bread rolls. It is not surprising then that current gluten-free products available on the market are of a lower quality in terms of mouth-feel and flavour. Gluten-free bakery products lack the cohesive and fluffy crumb textures found in gluten-based baked products and are comparatively dry with a significantly reduced shelf-life.

Food developers, who optimise ingredients and raw materials to produce products of high textural quality that replace gluten and gluten-containing ingredients, might gain acceptance not only from consumers who are gluten intolerant, but also from healthy consumers. In the production of gluten-free products, texture analysis is key in correlating the desired sensory perception to the physical properties of the product.

Figure 7 shows a typical example of a Texture Analyser in compression mode for two slices of bread using a cylinder probe attached to the instrument arm and a fixture base table to the base of the instrument. In the test, the cylinder probe compresses the bread rolls to provide instrumental measurements of the bread's textural parameters, which include firmness, resilience, cohesiveness, springiness, and chewiness. Since the bread rolls vary in thickness, a percentage deformation test has been performed in order to obtain comparable results. The bread rolls have been compressed by 50 % of their sample length.

Figure 7. CT3 Texture Analyser Tests Bread

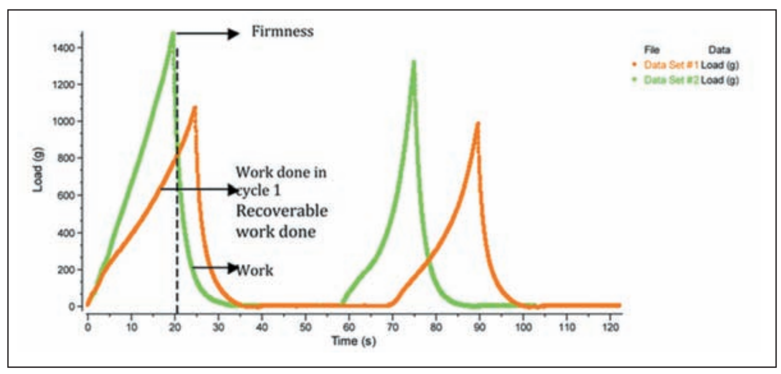

Figure 8a. Two-Cycle Texture Profile Analysis (TPA Graph)

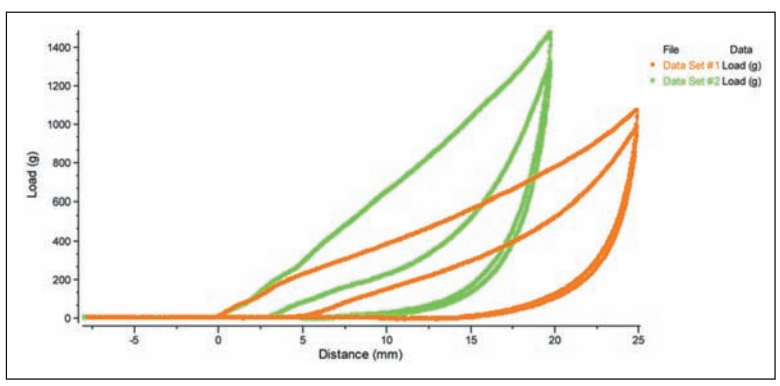

Figure 8b. Load vs. Distance Graph for a Two-Cycle Texture Profile Analysis (TPA Graph)

Figure 8a and b and Table 2 are typical examples of test results obtained from a wholemeal bread roll and a gluten-free brown bread roll of similar size, using a Texture Analyser with a 36mm aluminium cylinder probe (TA-AACC36).

Two force peaks resulting from the first and second compression cycles are shown in *Figure 8a*. The peak values are a measure of sample firmness.

The graph in *Figure 8b* displays the responses of the samples to the application and removal of a compressive strain. The maximum peak on the graph is a measure of sample firmness and the area under the graph from the start of the cycle to the target distance point a measure of work done. The recoverable work done is the area under the target distance point down to zero load as the compressive force is removed from the bread rolls.

Data set #1: Wholemeal bread roll, Data Set #2: Gluten-free bread roll

Sample	Hardness (g)	Work (mJ)	Resilience	Cohesiveness	Springiness Index	Chewiness Index
Wholemeal roll	1074	119.81	0.17	0.63	0.82	502.4
Gluten-free roll	1475	128.53	0.23	0.53	0.85	634.1

The measurable mechanical properties obtained from the texture analyser can be correlated to the products' sensory attributes as follows:

• Firmness/Hardness

This is the force required to compress/deform the bread with the fingers or with the molar teeth during chewing.

• Work done

This is the Energy required to deform the bread when biting or chewing.

• Resilience

This is how the bread recovers from compression. This is calculated as the ratio of the recoverable work done with respect to the energy required for deformation (hardness work done) and gives a value between 0 and 1.

• Cohesiveness

This is the strength of the internal bonds within the bread crumb.

• Springiness Index

This shows how springy the product feels and is an indication of the freshness of the bread to touch.

• Chewiness Index

This is the energy required to chew the food until it is ready for swallowing.

Results show that the gluten-free bread roll is a lot firmer than the wholemeal bread roll with a higher chewiness index value, meaning that the gluten-free bread roll requires more energy to chew until it is ready for swallowing. However the two bread rolls have similar resilience and springiness index values, indicating that their recoverable properties after a compressive load has been removed are similar. The springiness index values show that both the wholemeal and gluten-free bread rolls recover 82% and 85% respectively of their original length after deformation. The wholemeal bread roll is, however, more cohesive than the gluten-free bread roll. This indicates that the whole meal roll is less likely to crumble compared to the gluten-free bread roll.

The increasing demand for gluten-free products in the bakery industry has necessitated the adaptation of texture analysis for the objective assessment of the textures of raw materials and final products. Texture analysis is becoming a common technique for predicting consumer response to a new formulation of a product during development. Subsequently, texture analysis is used to ensure consistency in production at the Q/C level. The Texture Analyser can assess all types of gluten-free products in the bakery industry, including raw material, such as dough, to finished products like cakes and cookies. The fixtures and probes shown in *Figures 9a, b,* and *c* are typically used in tests performed on dough.

To summarise, Texture Analysis plays an integral part in product development for new formulations, ingredient changes, scale-up approval, shelf-life trials, and product matching. In quality control, texture analysis can assess critical quality points that relate to raw materials and supplier conformance. In process

Figure 9a. Dough Stickiness Fixture is Standard Test for Measuring Dough Stickiness which is an Important Parameter for Processing Raw Dough.

Figure 9b. Standard Dough Post Set for Preparing Dough Samples and Measuring Dough Firmness.

Figure 9c. Dough Extensibility Fixture for Holding Sheet of Raw Dough or Flat Bread such as Tortilla. Biaxial Test Force is Applied by Spherical Probe. Test Measures Force and Distance as Sample is Stretched to Breaking Point.

development, texture analysis can be used for at-line process control, process optimisation, and pipeline and pump design. In research and development, texture analysis can be used for long-term investigation into product characteristics, such as shelf-life, and for sensory correlations. Thankfully, the investment cost for this versatile instrument is sufficiently low that units can easily be placed throughout the plant for all the purposes identified above.

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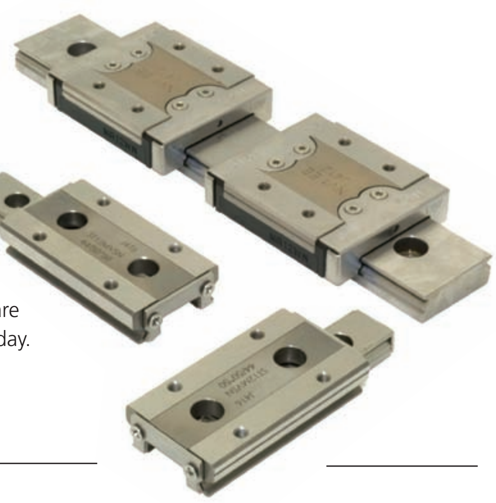

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