1 Evaluation of Food Quality

Introduction

Food quality is an important concept because the food people choose depends largely on quality. Consumer preference is important to the food manufacturer, who wants to gain as wide a share of the market for the product as possible. Quality is difficult to define precisely, though it refers to the degree of excellence of a food and includes all the characteristics of a food that are significant and that make the food acceptable.

Whereas certain attributes of a food, such as nutritional quality, can be measured by chemical analysis, food acceptability is not easy to measure as it is very subjective. In fact, consumers make subjective judgments using one or more of the five senses every time they select or eat any food. For example, potato chips, celery, and some cereals have a crunchy sound when they are eaten; the taste and smell of foods can be highly appealing or unacceptable; and the appearance and feel of a food are also important in determining its acceptability.

Food quality must be monitored on a regular day-to-day basis to ensure that a uniform product is produced and that it meets the required quality control standards. Companies must also monitor the quality of their products during storage while changing ingredients and developing new lines. Objective tests using laboratory equipment are useful for routine quality control, yet they cannot measure consumer preference. The only sure way to determine what a population thinks about any food is to ask them! This is done using sensory testing and asking panelists to taste a food and give their opinion on it. Both sensory and objective tests are important in evaluating food quality, and ideally, they should correlate with or complement each other.

However, some consumer attributes can be correlated to laboratory measurements. For instance, LAB color charts can serve to produce foods within the range of acceptability for consumers. The same is true for texture, which can be correlated to viscosity for flowable products or breaking strength for hard products (more details in the "Texture" section). Flavor is the hardest attribute to predict via analytical measurements.

Aspects of Food Quality

Food quality has both subjective and nonsubjective aspects. Appearance, texture, and flavor are largely subjective attributes, whereas nutritional and bacterial quality are not. The last two qualities can be measured objectively, either by chemical analysis, by measuring bacterial counts, or using other specific tests (Sahin and Sumnu 2006). They will only be mentioned briefly in this chapter, and the subjective qualities will be discussed in detail.

Appearance

The appearance of a food includes its size, shape, color, structure, transparency or turbidity,

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dullness or gloss, and degree of wholeness or damage. While selecting a food and judging its quality, a consumer takes these factors into account, as they are indeed an index of quality. For instance, the *color* of a fruit indicates how ripe it is, and color is also an indication of strength (as in tea or coffee), degree of cooking, freshness, or spoilage. Consumers expect foods to be of a certain color, and if they are not, it is judged to be a quality defect. The same is true for *size*, and one may choose large eggs over small ones, or large peaches over small ones, for example.

Structure is important in baked goods. For example, bread should have many small holes uniformly spread throughout, and not one large hole close to the top. *Turbidity* is important in beverages; for example, orange juice is supposed to be cloudy because it contains pulp, while white grape juice should be clear and without any sediment, which would indicate a quality defect.

Texture

Texture refers to those qualities of a food that can be felt with the fingers, tongue, palate, or teeth. Foods have different textures, such as crisp crackers or potato chips, crunchy celery, hard candy, tender steaks, chewy chocolate chip cookies, and creamy ice cream, to name but a few.

Texture is also an index of quality. The texture of a food can change as it is stored, for various reasons. If fruits or vegetables lose water during storage, they wilt or lose their turgor pressure, and a crisp apple becomes unacceptable and leathery on the outside. Bread can become hard and stale on storage. Products like ice cream can become gritty due to precipitation of lactose and growth of ice crystals if the freezer temperature is allowed to fluctuate, allowing thawing and refreezing.

Evaluation of texture involves measuring the response of a food when it is subjected to forces such as cutting, shearing, chewing, compressing, or stretching. Food texture depends on the rheological properties of the food (Bourne 1982). ***Rheology*** is defined as the science of deformation and flow of matter or, in other words, reaction of a food when a force is applied to it. Does it flow, bend, stretch, or break? From a sensory perspective, the texture of a food is evaluated when it is chewed. The teeth, tongue, and jaw exert a force on the food, and how easily it breaks or flows in the mouth determines whether it is perceived as hard, brittle, thick, runny, and so on. The term ***mouthfeel*** is a general term used to describe the textural properties of a food as perceived in the mouth.

Subjective measurement of texture gives an indirect evaluation of the *rheological* properties of a food. For example, a sensory panel might evaluate *viscosity* as the consistency or mouthfeel of a food. However, viscosity can be measured directly using a viscometer. Rheological properties are therefore discussed in more detail in section "Objective Evaluation" of this chapter.

> "Formulators typically turn to hydrocolloids first when trying to manipulate texture. It is important to remember that hydrocolloids vary significantly in their performance, price, ease of use and even impact on clean labeling" (Berry 2012)

Collectively known as *texturants*, some carbohydrate and proteins can impact the texture and mouthfeel of foods, while most likely contributing in a minor manner in terms of calories or flavor.

Research and Development (R&D) scientists now may use a blend of texturants in order to achieve the texture and mouthfeel desired in a specific food. "Our approach is to get ample information on the ideal end product. In many cases it is important to retain information on other stabilizing systems in the product, as well as any ingredients that may have a synergistic reaction with the texturant." (Berry 2012)

Flavor

Flavor is a combination of taste and smell and is largely subjective. If a person has a cold, food usually seems to be tasteless. Though it is not the taste buds that are affected, rather it is the sense of smell. Taste is detected by the taste buds at the tip, sides, and back of the tongue, whereas aromas are detected by the olfactory epithelium in the upper part of the nasal cavity. For any food to have an aroma, it must be volatile. These volatile substances can be detected in very small amounts (vanillin can be detected at a concentration of 2×10^{-10} mg/l of air).

Aroma is a valuable index of quality. A food will often smell bad before it looks bad, and old meat can be easily detected by its smell. (However, foods that are contaminated with pathogens may have no off-odor, so the absence of bad smell is not a guarantee that the food, such as meat, is safe to eat.)

The taste of a food is a combination of five major tastes—salt, sweet, sour, bitter, and ***umami***. It is complex and hard to describe completely. *Sweet* and *salt* tastes are detected primarily on the tip of the tongue, and so they are detected quickly, whereas *bitter* tastes are detected mainly by taste buds at the back of the tongue. It takes longer to perceive a bitter taste, and it lingers in the mouth; thus bitter foods are often described as having an aftertaste. *Sour* tastes are mainly detected by the taste buds along the side of the tongue.

Sugars, alcohols, aldehydes, and certain amino acids taste sweet to varying degrees. Acids (such as vinegar, lemon juice, and the many organic acids present in fruits) contribute the sour taste, saltiness is due to salts, including sodium chloride, and bitter tastes are due to alkaloids such as caffeine, theobromine, quinine, and other bitter compounds.

Umami is a taste that in recent times been added to the other four. It is a savory taste given by ingredients such as monosodium glutamate (MSG) and other flavor enhancers. The umami taste is significant in Japanese foods and in snack foods such as taco-flavored chips. "In the early 1900's . . . merges the Japanese words for 'delicious and 'taste'." (Koetke 2013)

Taste Sensitivity

People vary in their sensitivity to different tastes. Sensitivity depends on the length of time allowed to taste a substance. Taste sensitivity varies greatly from person to person and sometimes even day to day for the same person, which makes it very difficult to measure flavor objectively. Sweet and salt tastes are detected quickly (in less than a second), because they are detected by taste buds on the tip of the tongue; in addition, they are usually very soluble compounds. Bitter compounds, on the other hand, may take a full second to be detected because they are detected at the back of the tongue. The taste may linger, producing a bitter aftertaste.

Sensitivity to a particular taste also depends on the concentration of the substance responsible for the taste. The ***threshold*** concentration is defined as the concentration required for identification of a particular substance. The threshold concentration may vary from person to person; some people are more sensitive to a particular taste than others and are, therefore, able to detect it at a lower concentration. Below the threshold concentration, a substance would not be identified yet may affect the perception of another taste. For example, *subthreshold* salt levels *increase* perceived sweetness and *decrease* perceived acidity, whereas subthreshold sugar concentrations make a food taste *less* salty than it actually is. Although it is not clear why, flavor enhancers such as MSG also affect taste sensitivity by intensifying a particular taste in a food.

Temperature of a food also affects its flavor. Warm foods generally taste stronger and sweeter than cold foods. For example, melted ice cream tastes much sweeter than frozen ice cream. There are two reasons for the effects of temperature on flavor. The volatility of substances is increased at higher temperatures, and so they smell stronger. Taste bud receptivity is also an important factor. Taste buds are most receptive in the region between 68 and 86 °F (20 and 30 °C), and so tastes will be more intense in this temperature range. For example, coffee that has cooled to room temperature tends to taste stronger and more bitter than very hot coffee.

CULINARY ALERT! Food tastes best when served at its optimum temperature. If chilled or frozen food is warmed to room temperature, or inversely, if hot food is cooled to room temperature, the flavor may be negatively impacted.

Psychological factors also affect taste sensitivity and perception. Judgments about flavor are often influenced by preconceived ideas based on the appearance of the food or on previous experience with a similar food. For example, strawberry-flavored foods would be expected to be red. However, if colored green, because of the association of green foods with flavors such as lime, it would be difficult to identify the flavor as strawberry unless it was very strong. Color intensity also affects flavor perception. A stronger color may cause perception of a stronger flavor in a product, even if the stronger color is simply due to the addition of more food coloring!

Texture can also be misleading. A thicker product may be perceived as tasting richer or stronger simply because it is thicker, and not because the thickening agent affects the flavor of the food. Other psychological factors that may come into play when making judgments about the flavor of foods include time of day (for example, certain tastes are preferred at breakfast time), general sense of well-being, health, and previous reactions to a particular food or taste.

Sensory Evaluation

Sensory evaluation has been defined as a scientific method used to evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing (Stone et al. 2012). This definition has been accepted and endorsed by sensory evaluation committees within both the Institute of Food Technologists and the American Society for Testing and Materials. For more detailed information on sensory evaluation, the reader is referred to the books by Lawless and Heymann (2010), and by Stone et al. (2012).

Sensory testing utilizes one or more of the five senses to evaluate foods. *Taste panels*, comprising groups of people, taste specific food samples under controlled conditions and evaluate them in different ways depending on the particular sensory test being conducted. This is the *only* type of testing that can measure consumer preference and acceptability. When it comes to public opinion of a product, there is no substitute for tasting by individual consumers.

In addition to a taste-panel evaluation, objective tests can be established that correlate with sensory testing, which give an indication of consumer acceptability, although this may not always be sufficient. In the development of *new* foods or when changing an *existing* product, it is necessary to determine consumer acceptance directly, and objective testing is not sufficient, even though it may be a reliable, objective indication of food quality.

Sensory methods may be used to determine:

1. Whether foods differ in taste, odor, juiciness, tenderness, texture, and so on
2. To what extent foods differ
3. To ascertain consumer preferences and to determine whether a certain food is acceptable to a specific consumer group

Three types of sensory testing are commonly used, each with a different goal. *Discrimination or difference tests* are designed to determine whether there is a difference between products; *descriptive tests* determine the extent of difference in specific sensory characteristics; and *affective or acceptance/preference tests* determine how well the products are liked, or which products are preferred. There are important differences between these three types of tests. It is important to select the appropriate type of test so that the results obtained are able to answer the questions being asked about the products and are useful to the manufacturer or product developer.

The appropriate tests must be used under suitable conditions, in order for results to be interpreted correctly. All testing must be carried out under controlled conditions, with controlled lighting, sound (no noise), and temperature to minimize distractions and other adverse psychological factors.

Sensory Testing Procedure

Sensory testing is carried out by members of a taste panel, preferably in individual testing booths under controlled conditions. All distractions, bias, and adverse psychological factors must be minimized so that the evaluation is truly an evaluation of the sample being tested, and not a reaction to adverse circumstances, cultural prejudice, or the opinions of other testers. The noise level must be controlled to avoid distractions, temperature and humidity should be within an acceptable range, and lighting within the booth must also be monitored. In addition, there should be no extraneous smells, which may distract people from making judgments about the product under test.

Since color has a significant effect on subjective evaluation of a product, color differences may need to be masked. This is achieved by using red lights in the booths when necessary. It is important that people rate samples that may have different color intensities on *flavor* and not simply on the fact that they *look* different. For example, two brands of cheese puffs may look different because one is a deeper shade of orange than the other, and so one could tell the difference between them simply because of their color. However, there may not be a difference in the taste. If the color difference is masked by conducting the tests under red light, any differences detected could then be attributed to flavor differences, and not to color differences.

The samples are usually placed on a tray and passed to each panelist through a hatch in front of the testing booth. The tray should contain a ***ballot*** that gives specific instructions on how to evaluate the samples and a place for the panelist's response. A cracker and water are provided, in order to cleanse the palate before tasting the samples. It is important that tasters have not eaten spicy or highly flavored food before tasting food samples, or their judgment may be impaired. Preferably, panelists should not have eaten anything immediately prior to carrying out a taste test.

Additionally, it is important that panelists cannot identify the products they are tasting and that they do not know which sample is the same as their neighbor's sample, so that there is no room for bias in the results. This is accomplished by assigning three-digit random numbers to each product. For example, if two products are being tested (denoted product 1 and 2), each product is given at least two different random numbers. Panelists sitting next to each other will not be given samples with the same number, so that they cannot compare notes and agree with each other and introduce bias into the results that way.

If two products are being tested, 50 % of the panelists must test product 1 first, and the rest must test product 2 first; the order of testing must be randomized. This eliminates bias due to sample order, and also due to any changes in experimental conditions that may occur from the beginning to the end of the test. The specific product order and random numbers seen by each panelist are detailed on a ***master sheet*** to ensure that the test design is carried out correctly.

Sensory Tests

Discrimination or difference tests are used to determine if there is a perceivable difference between products. Such tests would be used if a company was changing the source of one of its ingredients or substituting one ingredient for another. Difference tests can also be used to see if the quality of a product changes over time or to compare the shelf life of a particular product packaged in different packaging materials. For example, a difference test could be used to determine if juices keep their flavor better when stored in glass bottles rather than in plastic ones.

A *small* group of panelists may be used to conduct such tests and they may be trained to recognize and describe the differences likely to occur in the products being tested. For example, if trained panelists are testing different tea blends or flavor bases, they have more experience than an average consumer in recognizing particular flavors associated with such products, and they are more sensitive to differences, and are able to describe them better. This is partly because they have been trained to identify such flavors.

However, they are likely to be experienced tea drinkers (or tea connoisseurs) with a liking for different teas before they are trained for taste-panel work. Such people may be employees of the company doing the testing or members of a university research group. They would be expected to detect small differences in the product flavor that would go unnoticed by most of the general population. Thus, their evaluation would be important in trying to keep a tea blend constant or in determining if there is a significant flavor difference when the source of an ingredient is changed.

It may also be important to know if small differences in a product can be detected by untrained consumers, who simply like the product and buy it on a regular basis. For this reason, difference tests are often conducted using larger panels of untrained panelists.

Two of the most frequently used difference tests are the triangle test and the duo–trio test. Typical ballots for these tests are given in Figs. 1.1 and 1.2. These ballots and the one shown in Fig. 1.3 were developed at the sensory evaluation laboratory at Texas Woman's University, Denton, Texas by Dr. Clay King, in conjunction with Coca-Cola® Foods. The ballots have been used for consumer testing of beverages and other foods at the university sensory facility.

In the ***triangle test***, each panelist is given three samples, two of which are alike, and is asked to indicate the *odd* sample. The panelists are asked to taste the samples from left to right, cleansing their palate before each sample by taking a bite of cracker and a sip of water. Then they circle the number on the ballot sheet that corresponds to the sample they believe to be different. If they cannot tell, they must guess. Statistics are applied to the results to see if there is a significant difference among the products being tested.

Since the panelists have to guess which is the odd one if they cannot detect a difference, one third of them would pick the correct sample as being odd just by guessing. Therefore, more than one third of the panelists must choose the correct answer for there to be a significant difference among the products.

For example, if there are 60 members on a taste panel, 27 would need to choose the correct answer for the results to be significant at a probability level of 0.05, and 30 correct answers would be needed for significance at a probability level of 0.01. A probability level (or ***p value***) of 0.05 means that out of 100 trials, the same result would be obtained 95 times, indicating 95 % confidence that the result is valid. A probability of 0.01 is equivalent to 99 % confidence in the significance of the results, because the same result would be expected in 99 out of 100 trials. Statistical tables are available to determine the number of correct answers required for significance at different probability levels.

In the ***duo–trio test***, each panelist is given a reference and two samples. He or she is asked to taste the reference first, and then each sample, working from left to right, and circle on the ballot the sample that is the same as the reference. Again, if a panelist cannot tell which sample is the same as the reference, he or she must guess, and statistics must be applied to the results to determine whether there is a significant difference among the products. If everyone guessed, 50 % of the panelists would get the correct answer, and so for the results to be significant, more than 50 % must choose the correct answer. For a panel of 60 people, 40 must give the correct answer for the results to be significant at the 0.01 probability level. Again, tables are available to determine if results are statistically significant (Roessler et al. 1978).

Affective, ***acceptance***, or ***preference*** tests are used to determine whether a specific consumer group likes or prefers a particular product. This is necessary for the development and marketing of new products, as no laboratory test can tell whether the public will accept a new product or not. A *large* number of panelists, representing the general public, must be used; thus, consumer testing is expensive and time-consuming. A relevant segment of the population needs to test the

Fig. 1.1 Ballot for triangle sensory test (obtained from Dr. Clay King at the Sensory Testing Laboratory at Texas Woman's University, Denton, Texas)

TEST#_____ **Panelist#_____**

TRIANGLE DIFFERENCE TEST

PRODUCT_____

INSTRUCTIONS: Proceed when you are ready. (Quietly so as not to distract others.)

FOR EACH SAMPLE:

1) Take a bite of the cracker and a sip of water to rinse your mouth.

2) Two of the samples are the same and one is different. **CIRCLE** the **ODD** sample. If you can not tell, guess.

_____ _____ _____

3) Describe the reason why the ODD sample is DIFFERENT. (Please be specific.)

Fig. 1.2 Ballot for duo–trio sensory test (obtained from Dr. Clay King at the Sensory Testing Laboratory at Texas Woman's University, Denton, Texas)

TEST#_____ **Panelist#_____**

DUO-TRIO DIFFERENCE TEST

PRODUCT_____

INSTRUCTIONS: Proceed when you are ready. (Quietly so as not to distract others.)

FOR EACH SAMPLE:

1) Take a bite of the cracker and a sip of water to rinse your mouth.

2) **CIRCLE** the number of the sample which is **THE SAME** as the reference R. If you can not tell, guess.

R _____ _____

3) Why are R and the sample you chose the same?

product. For example, if it is being aimed at over-50s, senior citizens must make up the taste panel, and not mothers with young children. The opposite would apply if the product was aimed at young children. (Products aimed at children would have to be acceptable to mothers as well, because they would be the ones to buy it.) Ethnic products must be tested either by the group for which they are aimed, or by a wide cross section of the public if the aim is to introduce the products to a broader market than is currently interested.

Panelists are not trained for this type of sensory testing. All that is required from them is that they give their opinion of the sample(s). However, they are normally screened to make sure that they are users or potential users of the product to be tested. Typically, they are asked to fill out a *screening sheet* and answer questions about how much they like the product (or similar products), and how often they consume it. Anyone who does not like the product is asked not to take the test. The screening sheet may also ask for demographic information, such as gender and age range of the panelists. The specific questions for each screening sheet are determined by whoever sets up the test, based on the consumer group they aim to target with their product.

The simplest preference tests are ***ranking tests***, where panelists are given two or more samples and asked to rank them in order of preference. In the *paired preference* test, panelists

Fig. 1.3 Ballot for likeability and paired preference sensory tests (obtained from Dr. Clay King at the Sensory Testing Laboratory at Texas Woman's University, Denton, Texas)

TEST#_____ **Panelist#_____**

LIKEABILITY RATING AND PAIRED PREFERENCE TEST

PRODUCT_____

INSTRUCTIONS: Proceed when you are ready. (Quietly so as not to distract others.) Evaluate one sample at a time, working from top to bottom.

FOR EACH SAMPLE:

1) Take a bite of the cracker and a sip of water to rinse your mouth.

2) Taste the sample then **CIRCLE** the number which best expresses your opinion of the sample.

SAMPLE CODE:_____

Likeability 1 2 3 4 5 6 7 8 9

Scale Dislike Extremely Like Extremely

SAMPLE CODE:_____

Likeability 1 2 3 4 5 6 7 8 9

Scale Dislike Extremely Like Extremely

Describe the DIFFERENCES between the two samples. (Please be specific.)

Taste the samples again, then circle the one you prefer.

_____ _____

Describe the reasons why you prefer the one you chose.

are given two samples and asked to circle the one they prefer. Often, the panelists are asked to taste a sample and score it on a 9-point hedonic scale from "dislike extremely" to "like extremely". This type of test is called a ***likeability test***.

Sometimes panelists are asked to test more than one sample, to score each on the 9-point likeability scale, and then to describe the differences between the samples. This would not be a difference test, as differences in this case are usually obvious, and the point of the test is to see which product is preferred. In fact, the differences may be considerable. An example might be comparison of a chewy brand of chocolate chip cookies with a crunchy variety. The difference is obvious, although consumer preference is not obvious and would not be known without carrying out preference tests on the two products. A paired preference or ranking test may be included on a same ballot and carried out along with a likeability test. An example of a typical ballot is given in Fig. 1.3.

Descriptive tests are usually carried out by a small group of highly trained panelists. They are specialized difference tests, where the panelists are not simply asked whether they can determine differences between the two products, but rather, are asked to *rate* particular aspects of the flavor of a particular product on a scale. Flavor aspects vary depending on the type of product being studied. For example, flavor notes in tea may be bitter, smoky, and tangy, whereas flavor notes in yogurt may be acid, chalky, smooth, and sweet. A descriptive "flavor map" or profile of a product is thus developed. Any detectable changes in the product would result in changes in the flavor map.

The training required to be able to detect, describe, and quantify subtle changes in specific flavor notes is extensive. Therefore, establishment of such panels is costly. When trained, the panelists function as analytical instruments, and their evaluation of a product is not related to their like or dislike of it. The descriptive taste panel work is useful to research and development scientists, because it gives detailed information on the types of flavor differences between products.

Objective Evaluation

Objective evaluation of foods involves *instrumentation* and use of physical and chemical techniques to evaluate food quality. ***Objective testing*** uses equipment to evaluate food products instead of variable human sensory organs. Such tests of food quality are essential in the food industry, especially for routine quality control of food products.

An objective test measures one particular attribute of a food rather than the overall quality of the product. Therefore, it is important to choose an objective test for food quality that measures a key attribute of the product being tested. For example, orange juice is both acidic and sweet; thus, suitable objective tests for this product would be measurement of pH and measurement of sugar content. These tests would be of no value in determining the quality of a chocolate chip cookie. A suitable test for cookie quality might include moisture content or the force required to break the cookie.

There are various objective tests available for monitoring food quality. Fruits and vegetables may be graded for size by passing them through apertures of a specific size. Eggs are also graded in this manner, and consumers may choose among six sizes, including small, large, or jumbo-sized eggs. Flour is graded according to particle size, which is required to pass through sieves of specific mesh size.

Color may be measured objectively by several methods, ranging from simply matching the product to colored tiles to using the **Hunterlab color and color difference meter**. The color meter measures the intensity, chroma, and hue of the sample and generates three numbers for the sample under test. Thus, small changes in color can be detected. This method of color analysis is appropriate for all foods. For liquid products, such as apple juice, a **spectrophotometer** can be used to measure color. A sample is placed in the machine and a reading is obtained, which is proportional to the color and/or the clarity of the juice.

Food Rheology

Many objective methods for measurement of food quality involve measurement of a specific aspect of texture, such as hardness, crispness, or consistency. As mentioned already, texture is related to the rheological properties of food, which determine how it responds when subjected to forces such as cutting, shearing, or pulling.

Rheological properties can be divided into three main categories. A food may exhibit *elastic* properties, *viscous* properties, or *plastic* properties, or a combination. In reality, rheological properties of most foods are extremely complex and they do not fit easily into one category.

Elasticity is a property of a solid and could be illustrated by a rubber band or a coiled spring.

If a force or *stress* is applied, the material will deform (stretch or be compressed) in proportion to the amount of force applied, and when the force is removed, it will immediately return to its original position. If sufficient force is applied to a solid, it will eventually break. The force required to break the material is known as the *fracture stress*.

Various solids are more elastic than others; examples of very elastic solids are springs and rubber bands. Bread dough also has elastic properties, although its rheology is complex, and includes viscous and plastic components as well. All solid foods exhibit elastic properties to some degree.

Viscosity is a property of a liquid and could be illustrated by a piston and cylinder (or a dashpot), or by a syringe.

Viscosity is a measure of the resistance to flow of a liquid when subjected to a shearing force. The thicker the liquid, the greater is its viscosity or resistance to flow. For example,

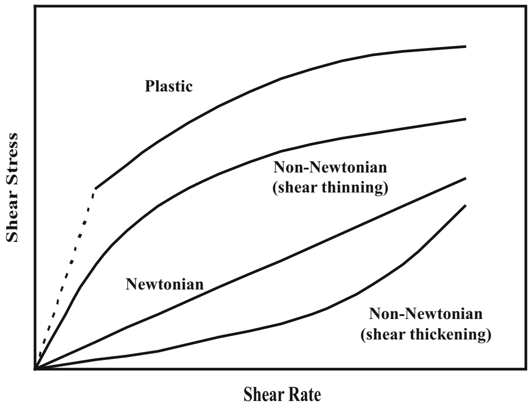

Fig. 1.4 Schematic representation of flow behavior of Newtonian and non-Newtonian liquids [modified from Bowers, 1992]

water has a low viscosity and flows readily, whereas catsup is considered "thick," has a higher viscosity, and flows relatively slowly.

Liquids can be separated into ***Newtonian*** and ***non-Newtonian*** fluids. In the case of a Newtonian liquid, the shear stress applied to the fluid is proportional to the shear rate or shear velocity of the flowing liquid. This means that the viscosity is independent of the shear rate. Therefore, viscosity will be the same, even if the viscometer used to measure it is operated at different speeds. A graph of shear stress against shear rate would give a straight line, and the viscosity could be calculated from the gradient of the line (see Fig. 1.4). The steeper the line, the greater the resistance to flow, and the greater the viscosity of the liquid.

Examples of Newtonian liquids/liquids include water, sugar syrups, and wine. However, most liquid/fluid foods are non-Newtonian, in which case the consistency or apparent viscosity depends on the amount of shear stress applied. This can be seen with catsup, which appears fairly solid, and is hard to get out of the bottle if it has been standing for a while. However, after shaking (applying a shear stress), the catsup becomes almost runny and will flow out of the bottle much more easily. If the bottle is again left to stand, the consistency of the undisturbed catsup will be regained after a short period of time. Shaking the bottle causes the molecules to align so that they flow over each other more easily, and the apparent viscosity decreases. A graph of shear stress against shear rate would not give a straight line for catsup, since the apparent viscosity is not constant. (Strictly speaking, the term "apparent viscosity" should be used for non-Newtonian liquids, whereas the term "viscosity" should be reserved for Newtonian liquids.)

A number of non-Newtonian liquids appear to get thicker when a shear stress is applied. In this case, the particles in the liquid tend to aggregate and trap pockets of liquid, thus making it harder for the molecules to flow over each other. Examples of such liquids include starch slurries and dilute solutions of a few gums, such as alginates, carboxymethylcellulose, and guar gum.

The viscosity of both Newtonian and non-Newtonian liquids is affected by temperature. Higher temperatures cause liquids to flow more readily, thus decreasing viscosity, whereas lower temperatures cause an increase in viscosity. For this reason, it is important to make measurements of viscosity at a constant temperature and to specify that temperature.

A ***plastic*** substance can be molded, because it contains a liquid, although only after a certain minimum force (the *yield stress*) is applied. At forces below the yield stress, it behaves as an elastic solid, yet above the yield stress, it behaves as a liquid. Examples of plastic substances include modeling clay, and foods such as warm chocolate, and hydrogenated vegetable shortenings that can be creamed easily.

Certain foods exhibit both elastic and viscous properties at the same time. They are termed *viscoelastic*. Bread dough is a good example of a viscoelastic material. When a force is applied, the material first deforms like an elastic solid, then it starts to flow. When the force is removed, it only partly regains its original shape.

The rheological properties of a food affect its texture and sensory properties. For example, brittleness, shortness, and hardness are related to the fracture stress of a solid food, whereas thickness and creaminess are related to the consistency or apparent viscosity of a liquid food. The rheological properties of many foods can be modified by adding stabilizers such as gums. These are added to increase viscosity, which in turn restricts movement of everything in the system and may delay undesirable changes, such as precipitation of solids or separation of emulsions.

Objective Measurement of Texture

Many objective methods for measurement of food quality involve measurement of some aspect of texture. For example, viscometers are used to measure viscosity or consistency of foods ranging from thin liquids such as oil to thick sauces such as catsup. The sophistication of these instruments also varies widely. The **Bostwick consistometer** is a simple device that involves filling a reservoir with the sample to be tested. A stopwatch is started, the gate holding the product in the reservoir is lifted, and the product is timed to flow a certain distance along the consistometer trough. At the other end of the scale, **Brookfield viscometers** are sophisticated instruments that may be used to measure viscosity under controlled temperature and when the sample is subjected to shearing forces of different magnitudes.

The **Instron Universal Testing Machine** has various attachments that allow it to measure different aspects of texture, including compressibility of bread and the force required to break a cookie or to shear a piece of meat.

The **Brabender amylograph** (Chap. 4) is an instrument that was developed to measure the viscosity of starch mixtures as they are heated in water. Another instrument with a very specific use is the mixograph, which is used to measure the ease of mixing of bread doughs.

Sophisticated equipment, such as the **mass spectrophotometer**, **gas chromatography**, and **high-performance liquid chromatography** equipment, are available in research and analytical laboratories for analysis of specific products or components.

The list of equipment used in the food industry for evaluating food quality would fill a complete textbook! Certain principles must be emphasized when considering objective tests to evaluate the quality of a food product:

- The objective test must be appropriate for the food product being tested. In other words, it must measure an attribute of the food that has a major effect on quality.
- Ideally, the objective test results should correlate with sensory testing of similar food products to make sure that the test is a reliable index of quality of the food.
- Most objective tests used to assess food quality are empirical; that is, they do not measure an absolute property of the food. However, the results are still meaningful, as long as instruments are calibrated with materials that have similar properties to the foods under test.
- Objective tests include all types of instrumental analysis, including laboratory tests to determine chemical composition, nutrient composition, and bacterial composition.
- Objective tests are repeatable and are not subject to human variation. If the equipment is properly maintained and is used correctly, it should give reliable results from day to day.

Objective tests are necessary to identify contaminants in foods and to reveal faulty processing methods as well as testing for deterioration such as rancidity in fats and oils. Objective tests are essential for routine quality control of foods and food products. However, they must correlate with sensory testing, because no single objective test can measure the overall acceptability of a specific food or food product.

An in-depth study of analysis of foods by objective methods is beyond the scope of this book. For more information, the reader is referred to Food Analysis by Nielsen (2010) and to the many other textbooks available on the subject.

Comparison of Subjective and Objective Evaluation

Both *sensory evaluation* and *objective evaluation* of food quality are essential in the food industry in order to routinely monitor food quality and to ensure that the foods being produced are acceptable to consumers. The two methods of evaluation complement each other.

Sensory testing is expensive and time-consuming, because many panelists are required to test a single product in order for the results to be meaningful. On the other hand, objective testing is efficient and, after the initial purchase of the necessary equipment, relatively inexpensive. One person can usually perform an objective test on many samples in a day, whereas it may take a day to perform a complete sensory test on one or two samples. Objective tests give repeatable results, whereas sensory tests may give variable results due to variation of human responses and opinions.

While sensory evaluation gives a judgment of the overall acceptability of a product, an objective method of evaluation is only able to measure one aspect of the food, and this may not always be sufficient to determine whether the quality of the product is acceptable. The only true judge of acceptability of a food product is a consumer! Therefore, objective tests must correlate with sensory tests to give a reliable index of food quality.

Objective tests are essential for routine quality control of food products. However, sensory evaluation is essential for product research and development. Only consumers can tell whether there is a perceivable difference in a product when the formulation or packaging is changed, and only consumers can determine whether a new product is acceptable or preferred over another brand.

Subjective vs. objective analysis—overview

Subjective/sensory analysis	Objective analysis
Uses individuals	Uses equipment
Involves human sensory organs	Uses physical and chemical techniques
Results may vary	Results are repeatable
Determines human sensitivity to changes in ingredients, processing, or packaging	Need to find a technique appropriate for the food being tested
Determines consumer acceptance	Cannot determine consumer acceptance unless correlated with sensory testing
Time-consuming and expensive	Generally faster, cheaper, and more efficient than sensory testing
Essential for product development and for marketing of new products	Essential for routine quality control

Conclusion

Food quality can be defined as the degree of excellence of a food and includes factors such as taste, appearance, and nutritional quality, as well as its bacteriological or keeping quality. Food quality goes hand in hand with food acceptability, and it is important that quality is monitored, both from a food safety standpoint and to ensure that the public likes a particular product and will continue to select it. Both sensory and objective methods are important in evaluation of food quality and the two methods complement one another. Sensory analysis is essential for development of new products, because only consumers can tell whether they like a product or not. However, objective testing is also important, especially for routine quality control of food products.

Notes

CULINARY ALERT!

Glossary

Affective or acceptance/preference tests Used to determine whether a specific consumer group likes or prefers a particular product.

Ballot Sheet of paper on which the panelist receives pertinent sample information and instructions, and on which observations are recorded during a sensory test.

Descriptive tests Specialized difference tests used to describe specific flavor attributes of a product, or to describe degree of difference between products.

Discrimination or difference tests Used to determine if there is a perceivable difference between samples.

Duo–trio test Samples include a reference food and two samples, one of which is the same as the reference.

Elasticity Ability of a material to stretch when a force is applied and to return to its original position when the force is removed.

Likeability test Panelists rate a sample on a hedonic scale from "dislike extremely" to "like extremely."

Master sheet Details the specific three-digit product numbers and positions for every panelist in a sensory test. Used to ensure that each product is seen an equal number of times in each position, so that bias is avoided.

Mouthfeel Textural qualities of a food as perceived in the mouth.

Newtonian liquid The viscosity is independent of the shear rate. Stirring or shaking does not make the liquid runnier or thicker. Examples are water, sugar syrups, and wine.

Non-Newtonian liquid/fluid Apparent viscosity depends on the shear rate. Catsup gets thinner with increasing shear rate, whereas some gums thicken with increasing shear rate.

Objective evaluation Involves use of physical and chemical techniques to evaluate food quality, instead of variable human sensory organs.

Plasticity Material flows when subjected to a certain minimum force; material can be molded.

***p*-Value** Statistical probability that a result is significant. A p value of 0.01 indicates 99 % confidence that a result is significant. In other words, out of 100 trials, the same result would be expected 99 times. The probability of the opposite result occurring is only 1 in 100 trials.

Ranking test Panelists rank two or more samples in order of preference or intensity for a particular attribute.

Rheology Science of the deformation and flow of matter, how a food reacts when force is applied; includes elasticity, viscosity, and plasticity.

Sensory testing Use of senses to evaluate products; involves consumer opinion.

Threshold Concentration required for identification of a particular substance.

Triangle test Three samples, two of which are alike, one is odd.

Umami Savory taste, given by substances such as monosodium glutamate.

Viscosity Resistance to flow of a liquid when a shear force is applied. Liquids with a low viscosity flow readily, whereas liquids with a high viscosity flow slowly.

References

Berry D (2012) Targeting texture. Food Product Design, pp 22–31

Bourne ML (1982) Food texture and rheology. Academic, New York

Bowers J (1992) Characteristics of food dispersions. In: Bowers J (ed) Food theory and applications, 2nd edn. pp 30, MacMillan, New York

Koetke C (2013) Umami's mysteries explained. Food Product Design, pp 62–68

Lawless HT, Heymann H (2010) Sensory evaluation of food. Principles and practices, 2nd edn. Springer, New York

Neilsen SS (2010) Food analysis, 4th edn. Springer, New York

Roessler EB, Pangborn RM, Sidel JL, Stone H (1978) Expanded statistical tables for estimating significance in paired-preference, paired-difference, duo–trio and triangle tests. J Food Sci 43:940–942

Sahin S, Sumnu SG (2006) Physical properties of foods: what they are and their relation to other food properties. In: Peleg M, Bagley EB (eds) Physical properties of foods. Springer, New York

Stone H, Bleibaum R, Thomas H (2012) Sensory evaluation practices, 4th edn. Academic, San Diego