UNIT 4 TESTING AND EVALUATION: PHYSICAL METHODS

Structure

4.0 OBJECTIVES

After reading this unit, you should be able to:

- understand colour in quantitative basis;
- describe methods for measurement of colour;
- understand viscosity, consistency and texture of foods; and
- describe methods for their measurement.

4.1 INTRODUCTION

Physical methods are used for both analysis and quality control. Analytical methods based on physical properties of food constituents are covered in detail under “Instrumental methods of analysis” in Block 7.3. In this unit, some of the important quality control parameters such as colour and Texture are described.

4.2 COLOUR

We associate colour and appearance of food with its quality. Quite often, colour plays the dominant role in assessing the overall quality of a food material. Examples are colour of fruits, vegetables, sweet meats, bakery products, ice creams and so on. Colour changes in foods during processing and storage are common. Change of the green chlorophyll colour of vegetables, browning reactions etc. is examples. In order to make foods more attractive to the consumer, natural and artificial colorants are some times added.

What is colour? Why an object is red, yellow or green? Colour is an appearance property attributable to the spectral distribution of light. Light as we commonly refer to is that part of the electromagnetic radiation to which the human eye is sensitive. The radiations of different wavelengths are called the spectrum of the radiation. The visible region of the spectrum is only a very minute part of the electromagnetic spectrum in the range of 380 to 780 nm. You will be learning more about the properties of electromagnetic radiation in the unit on 'Instrumental methods of analysis'.

As you may know, visible light can be split into its spectrum by passing it through a prism. The spectrum consists of the colours red, orange, yellow, green, blue, indigo and violet. If the light radiation striking the retina of the eye does not contain all the wavelengths of the visible spectrum, or if their intensities differ considerably, the sensation of colour results. This happens because when light radiation strikes an object, it may interact with the object in different ways depending on the nature of the object, one being absorption of the radiation. The absorption of all the wavelengths of the radiation may not take place uniformly. As a result, some wavelengths are reduced in intensity and the resultant radiation having certain dominant wavelength of the radiation is either reflected (opaque medium) or transmitted (transparent medium). The reflected or transmitted light is perceived as the colour of an object by the eye. Measurement of the transmitted radiation is the basis of spectrophotometry, which you will be learning in the next block. The measurement of the reflected light radiation is the basis of objective measurement of colour of objects like food products.

4.2.1 Factors Affecting the Colour of Objects

The perceived colour of an object in terms of its shade, brightness etc. is dependent on three major factors:

i) the chemical and physical nature of the object;
ii) the spectral power distribution in the light from the light source;
iii) the sensitivity perception system.

The colour of an object is primarily dependent on the colour producing chemical substances present in it. However, the shade, brightness and appearance of the colour can be greatly affected by its physical form. For example the colour of a whole apple is different from the crushed apple, or the colour of roasted coffee beans is different from ground coffee. In case of liquid foods, the colour varies with the depth of the solution (light path).

The perceived colour of an object is also dependent on the light illuminating it. A colour may appear dull in dim light but bright in bright light. The colour also depends on the spectral distribution of the light. The colour of an object viewed under a coloured light is different from the colour under white light.

The object properties and illumination interact to provide the stimulus for the receptor mechanism i.e. the eye and the brain system to perceive the colour. Perception of colour is unique to the individual. They change with colour vision abilities. Approximately 8% of the population perceive colour in a different way from the remainder. The other 92% of the population do not perceive colour in exactly the same way.

The above factors make it necessary to evolve an agreed terminology for colour description and measurement. Colour measurement implies expressing the above concepts in numerical dimensions.

4.2.2 Approaches to Colour Measurement

Two approaches are possible for colour measurement. The simplest method is to use a numerical index, which defines a colour adequately for specific purposes and enables comparison. This could be termed '**colour comparison'.** Obviously, this method does not specify all the attributes of a colour, which is required for several purposes. The second approach is to quantitatively specify the colour by determining the recognizable attributes of the colour.

4.2.3 Colour Matching

The eye has tremendous capacity to discriminate colours. However the capacity of the brain for remembering them is poor. For example, the brain cannot exactly remember the colour of a fruit of a previous year. During storage studies of food products, its colour changes and the original sample with out the colour change may not be available for comparison. Therefore, matching the colour with a colour order system is followed. Colour dictionaries (atlases), disc colorimeters and tintometers are usually used for the purpose.

Colour dictionaries: Colour dictionaries usually consist of sets of colour charts grouped into different hues. In order to get reliable data, matching of colours should be done by individuals with normal colour vision using standard viewing and lighting conditions. One of the most popular colour atlases used for horticultural crops is the **Royal Horticultural Society (RHS) Charts.**

Another colour atlas, which used to be widely quoted in food industry, is the **Munsell System.** In the Munsell System, colour dimensions are Hue (H), Value (V) and Chroma (C). The Figure 4.1 below is a sketch of the Munsell colour solid.

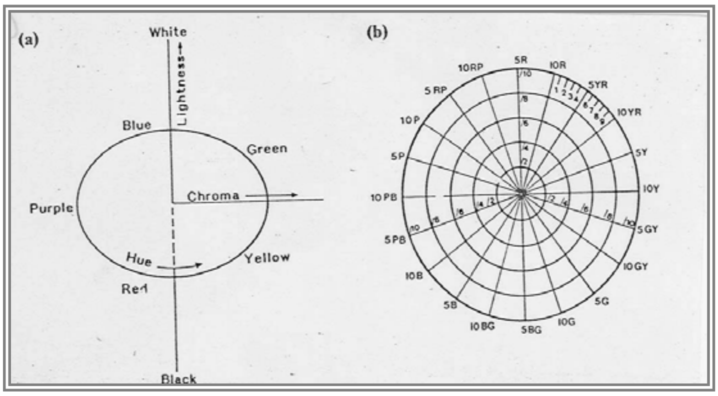


Figure 4.1: The Munsell colour system: a) dimensions of the Munsell colour system solid; b) organization of Hue and Chroma in the Munsell System solid.

The hue circle consists of ten major hues, each divided into ten equally spaced steps. The central achromatic Value (lightness) axis consists of ten equal steps, extending from ideal black = 0 to ideal white=10. The distance from this axis indicates an increase in Chroma that is an increase in hue content, and departure from grey. The Chroma is zero at the achromatic axis, and increases in visually equal steps to /10, /12, /14 or greater for particularly saturated colours. The Munsell atlas consists of pages of coloured chips. The chips are arranged so that the vertical axis of the pages represents an increase in V, the horizontal axis an increase in C. The Munsell description of a yellow-red colour of hue 3YR, Value 5/, and Chroma 6/ is denoted as 3YR 5/6.

Munsell system is some times used in conjunction with Disc colorimeters like the Macbeth- Munsell Disc colorimeter. In the Disc colorimeter, rapid spinning mixes two or more colours in the form of interleaved discs. The resultant hue is the average hue of the sample, which is useful in certain situations like colour of vegetables or homogenised samples, but not for comparing non-uniform colour surfaces like the colour of fruits like apple.

Tintometers: The Lovibond Tintometer used to be widely used in the food industry for a long time before more refined instruments became available. It is still in use for specific applications. The instrument is provided with sets of red, yellow and blue glass slides as permanent standards. The slides form an evenly graded series from very light tints (0) to deep colours (20), numbered according to their depth of colour. The three series are so related that when three slides of equal value are combined and viewed against white, they appear grey or neutral in colour. With the help if an optical system in the instrument, the illuminated sample is made to occupy half the field of view while the other half receives reflected light from a standard white surface, which passes through the selected coloured glass. When the colour is matched, it is specified by the values of red, yellow and blue slides required as for example 14.0 R + 6.0 Y + 1.0 B.

4.2.4 Quantitative Measurement of Colour

A complete specification of colour requires measurement of three attributes of colour.

i) **Hue**: the kind of colour, red, blue or green.

ii) **Saturation**: the depth or strength of the hue or the extent to which the pure hue is mixed with white.

iii) **Lightness**: the extent to which the hue is diluted with black. It is associated with brightness of the hue.

The International Commission on Illumination (CIE: *Commission Internationale de l'Eclairage*, 1931) adopted a set of standards, which has made it possible to define the colour in absolute terms. The system is rather elborate and hence only some salient points are explained here.

4.2.5 The CIE System

The CIE system is based on the principle that any colour can be matched exactly by a suitable mixture of only three colours selected from the red or amber (R), green (G) and blue (B) parts of the light spectrum. The three colours are called "**primaries**" and their relative amounts required to match a colour are called "**tristimulus**" values of the colour. This postulate has been confirmed by colour matching using additive mixing of monochromatic lights of wavelength 650 nm (R), 530 nm (G), and 460 nm (B) to obtain colour matches by observers with normal colour vision called the standard observer. The amount C of each colour (C) is matched using amounts of R, G, and B of each particular stimulus (R), (G), and (B). i.e.

$$C\,(C) = R\,(R) + G\,(G) + B\,(B)$$

When C is unity:

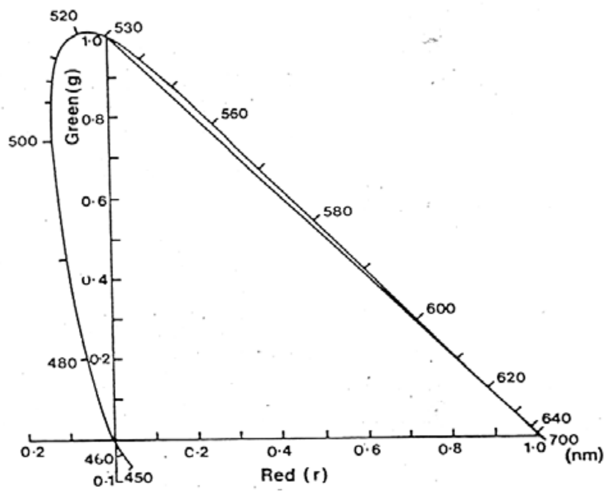
$$1.0\ (C) = r\,(R) + g\,(G) + b\,(B)$$

where:

$$r = \frac{R}{R+G+B}, \quad g = \frac{G}{R+G+B}, \quad b = \frac{B}{R+G+B}$$

Where: r, g and b are chromaticity coordinates of the colour i.e., r+g+b = 1

Therefore, if any two of r, g and b are specified, the third can be calculated. Hence, the results can be shown in the form of the two-dimensional **chromaticity diagram** in which r and g are usually plotted as x and y axis (Figure below).



The data from Fig. 7.3 plotted as a chromaticity chart. The matching stimuli used were 650, 530 and 460 nm (Wright 1969, with permission).

Figure 4.2

The spectral colours, for which the wavelengths are noted on the diagram, are shown as spectrum locus. The blue of wavelength approximately 460 nm, near one end of the locus is at the origin where r and g are zero and b = 1. The locus progresses to a wavelength of 530nm, where r is zero and g = 1 (and b is therefore zero).

It can be seen from the above figure that r, g and b have negative values. This is because the spectrum locus is convex and hence no real primaries exist which will always yield positive values. Therefore, CIE decided to use three unreal primaries (X), (Y) and (Z) so that the chromaticity coordinates x, y and z will always be positive. The modified chromaticity diagram is called the **CIE Chromaticity Chart,** which is shown below. Any given colour to be described in CIE terms can now be located in the spectrum locus by the relative distances along the x and y coordinates, representing respectively the values of X and Y.

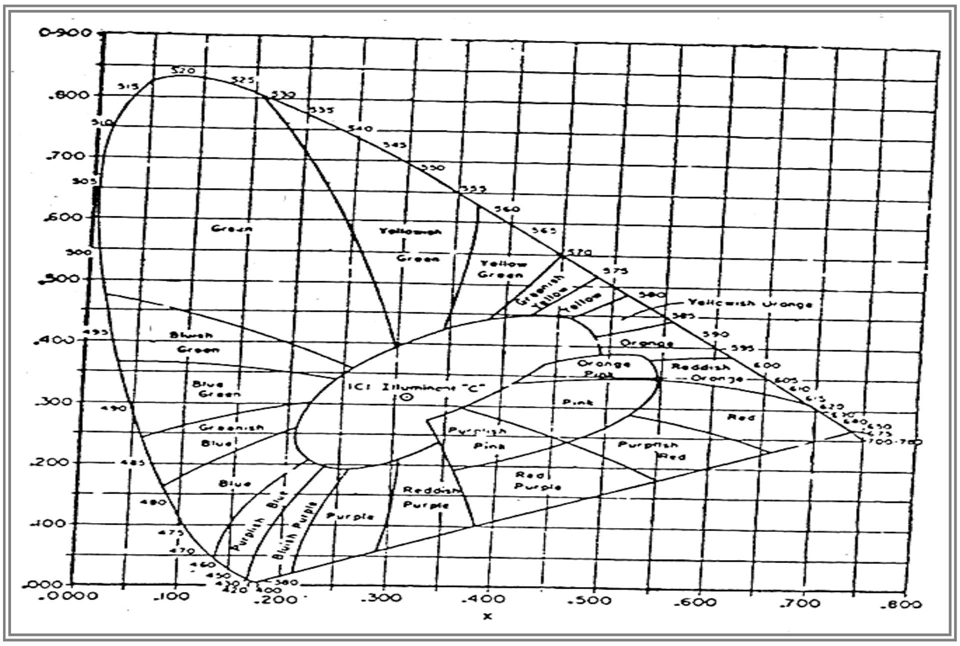


Figure 4.3: Chromaticity diagram

Having located a given colour in the Chromaticity chart from its chromaticity coordinates, it is necessary to find out its light intensity or brightness factor. This is done by assuming that all of the light energy represented by a colour is regarded as coming from Y stimulus. Therefore, the amount of Y is a direct measure of the brightness or lightness of the colour. If Y values are plotted perpendicularly to the chromaticity plane, the irregular colour solid is created within which any colour can be defined as a unique point with the CIE coordinates x, y and Y.

To determine the other visual dimensions of a colour, the colour (C) and the illuminant (S) used are marked on the chromaticity diagram as shown below.

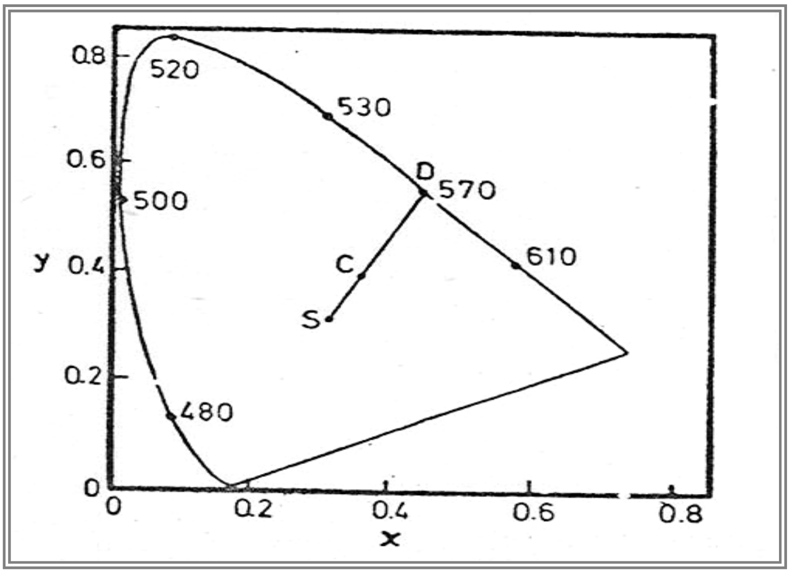


Figure 4.4: Determination of dominant wavelength and purity of colour

A line is drawn joining the two points and extrapolated to the spectrum locus (D), which is the **dominant wavelength** of the colour. Now the specification of the colour can be represented with reference of the above figure as:

Hue of the colour C is given in terms of the **dominant wavelength**

Saturation or chroma of the colour C is measured in terms of purity, which is the ratio of the distance SC to the distance SD. The ratio is usually expressed as percent.

Lightness of the colour C is given by its Y coordinate perpendicular to the chromaticity plane and is represented as Y%.

As mentioned earlier, the colour of an object is also dependent on the illuminant. Therefore, CIE system has defined three standard illuminants and their trichromatic coefficients. The illuminants are:

Illuminant A: Corresponds to the light from a gas filled tungsten lamp operated at a colour temperature of 2,856^{o}K.

Illuminant B: Corresponds to the more yellow type of average daylight, and consists of the standard illuminant in conjunction with a colour filter.

Illuminant C: Corresponds to light from the sky rather than sunlight. It consists of the illuminant A in conjunction with a different filter.

A spectrophotometric curve giving the intensities of light at different wavelengths of the visible region gives a complete specification of the colour. This can be calculated from the spectral data, which is quite tedious and hence not given here. This is made easy in the present day spectrophotometers, which automatically records the spectral curve and compute the CIE values Hue, Chroma and Lightness values.

4.2.6 Hunter Colour System and Colour Difference Meter

In the Hunter colour meter, tristimulus amber, green and blue filters together with suitable detection and measuring devices provide close approximation of the X, Y and Z functions of the CIE System. The Hunter colour space is slightly different to the CIE colour space (Figure below).

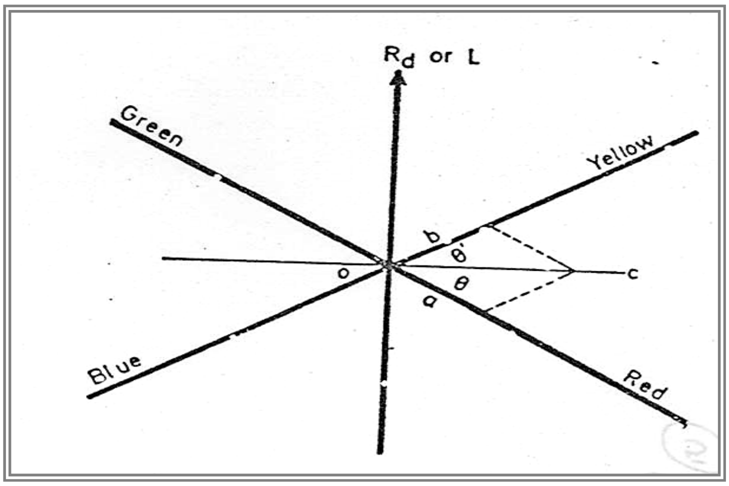


Figure 4.5: Hunter colour dimensions

The chromaticity plane is defined by dimensions *a* and *b*. The white point is at the origin. The Hunter positive *a* values indicate redness and negative *a* values greenness. The Hunter positive *b* values indicate yellowness and negative *b* values blueness. The *a* values are functions of x and y and *b* values those of Z and Y. For a particular colour C, hue or dominant wavelength is given by the ratio *a/b.* The saturation is given by the distance from the colour point C to the white point, which is $(a^2 + b^2)^{1/2}$. The Hunter R_d (diffuse reflectance) or visual lightness (L) is directly comparable to the Y of the CIE system.

Hunter values permit calculation of the colour difference (ΔE) between two colours like sample and standard colours. ΔE is given by:

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{½}$$

The modern Hunter colour difference meters are capable of providing outputs of the various colour parameters.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. What is colour of an object?

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2. Which are the components of the complete specification of colour.

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3. Describe the CIE system of colour measurement.

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4. Describe the Hunter system of colour measurement.

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4.3 VICOSITY AND CONSISTANCY

The kinaesthetic attributes of food products, viz. viscosity, consistency and texture are perceived by human senses of sight, touch and mouth feel. We are able to judge whether a fluid food is thin or thick by watching how it flows, feeling it with fingers or by mouth feel. We decide the texture of fruits, vegetables etc. by finger feel. We also assess texture by biting or chewing. Obviously these assessments are subjective and tend to differ from individual to individual. Therefore, objective measurement of these quality attributes is important in quality control and product development.

Food products exist in various physical forms like thin liquids, viscous liquids, semi-solids and solids. You have observed that most of the thin liquids like beverages, milk etc. just flow out from containers. Products like tomato ketchup or sauces require some initial push (like hitting the bottom of the bottle) before they start to flow. Solids like fruits require much more pressure to compress and finally break (deformation). The study of flow and deformation of materials is called **rheology**.

Viscosity and consistency are flow properties of fluids while texture is the deformation property of solids. Obviously, the force required to initiate solid deformation is much higher than that required to initiate liquid flow. If the force required is 1.0 gravity or less, the term used is viscosity or consistency and when the force required is more than 1.0 gravity, the term used is texture.

4.3.1 Flow Behaviour of Fluids

Fluids (liquids) are classified as Newtonian or non-Newtonian depending on their flow behaviour. This can be explained easily with the help of a simple diagram.

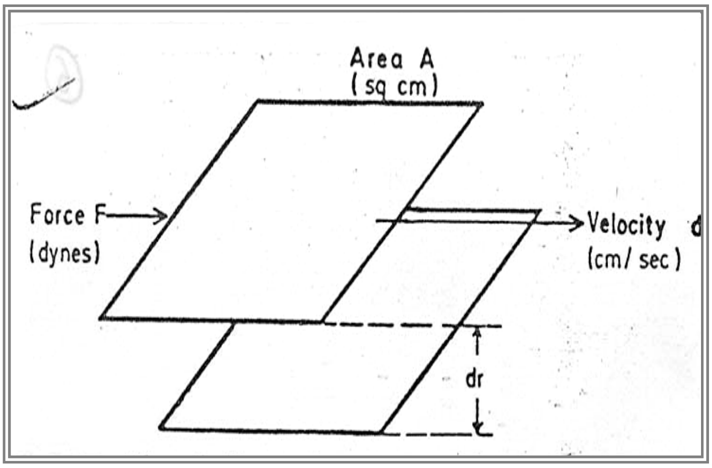

Figure 4.6: Schematic diagram illustrating the response of fluids to an imposed shearing force

Let us assume two layers of a fluid; each having an area of A cm^2 are separated by a distance dr cm. If the top layer moves parallel to the bottom layer at a velocity of du cm/sec relative to the bottom layer, a force of F dynes is required for maintaining the velocity. The velocity gradient represents the deformation, and is commonly referred to as the **shear rate**, which has the unit of per second. The shearing force per unit area (F/A) is the **shear stress** and is denoted by the symbol T. The relationship between the shear stress and shear rate is used to define the flow properties of fluid foods.

Newton's law states that for flowing fluids, the shear stress required to maintain the flow is proportional to the shear rate.

i.e. $$F/A = \mu \frac{du}{dx}$$

Where du/dx = velocity gradient (shear rate) and μ is called the viscosity (poise) of the fluid. This is equal to:

$$\mu = \frac{F}{A} \times \frac{dx}{du}$$

$$= T \cdot \frac{1}{\gamma}$$

$$\mu = T / \gamma$$

where T = Shear stress
γ = Shear rate

where γ is the shear rate.

The unit of viscosity (poise) is dynes.sec/cm^2. In SI units it is equal to 0.1 N s/m^2 where N is Newton. As this unit is large, usually centipoise (cp), which is 1/100 poise, is used.

Fluids having this type of flow behaviour are called Newtonian fluids. Several fluid foods like fruit pulps, fruit juice concentrates, ketchup and sauces do not obey this law. Therefore, such fluids are called non-Newtonian fluids. For such fluids, if measurements are made at different shear rates, the ratio of shear stress to shear rate will not be constant. This ratio is called the apparent viscosity (μ_a or μ_{app}) or consistency. The consistency of non-Newtonian fluids can be expressed by the power law equation:

$$\tau = K (\gamma)^n + C$$

where, K = fluid consistency coefficient (dynes^n sec cm^2)
n = flow behaviour index (non dimensional)
C = yield stress (dynes / cm^2)

It can be seen from the equation that in the case of Newtonian liquids, n is equal to one and K becomes the viscosity. The constant, n for non-Newtonian liquids is a measure of the extent of departure from Newtonian behaviour, and hence is called the **flow behaviour index**. The constant K is more a measure of viscosity or consistency and is termed the fluid consistency coefficient. The viscometric parameters of non-Newtonian fluids can be determined with either capillary tube or rotational viscometers. Since determination of the parameters is very elaborate and not required for routine quality control of products, the same is not discussed here. Instead, a few viscometers and consistometers commonly used are described here.

4.3.2 Bostwick Consistometer

The Bostwick consistometer is a simple devise widely used in the industry for measuring the consistency of tomato ketchup and sauce. The instrument is based on the principle that the length of flow of the sample is proportional to its consistency.

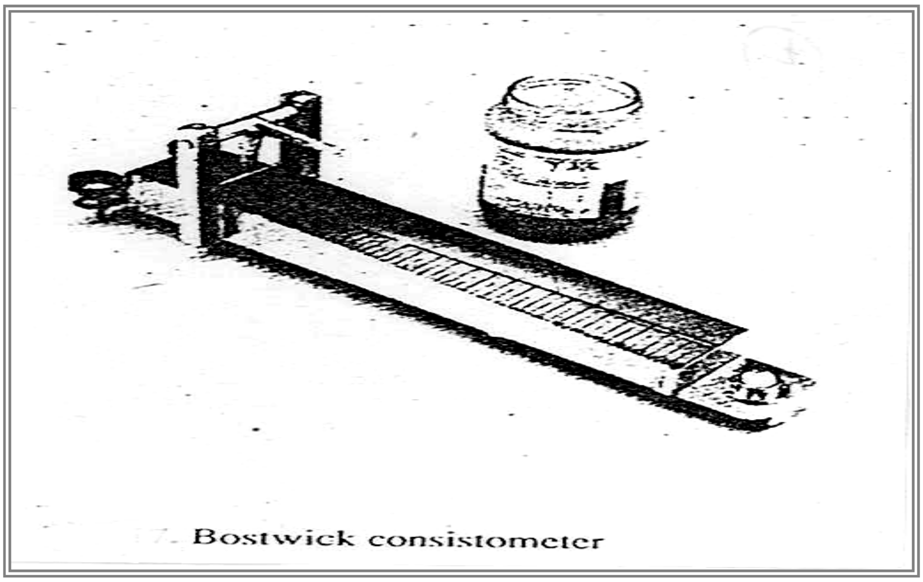

Figure 4.7: Bostwick consistometer

The Bostwick consistometer (Figure above) consists of a channel with sides. It has a triggered gate on one side and a centimetre scale is itched on the floor of the channel. Before taking measurements, the consistometer is levelled by adjusting the levelling screws provided at the bottom of the instrument. Then the gate is closed by engaging the trigger release mechanism and the sample is filled in the sample holding compartment fully. The gate is released by the trigger and simultaneously a stopwatch is started. The consistency is measured after 30 sec by recording the extent of flow of the sample on calibrated scale, taking an average of the values at the centre and sides of the scale. The Bostwick consistometer readings are expressed as cm per a fixed time.

4.3.3 Brookfield Synchrolectric Viscometer

The Brookfield synchrolectric viscometer is a versatile instrument that can be used for measuring viscosity of Newtonian liquids as well as the consistency of non-Newtonian liquids. The instrument is based on measurement of resistance to rotation of a spindle immersed in the test material. The resistance is recorded in terms of torque by a calibrated spring. The dial of the instrument is graduated and the viscosity in centipoises can be read directly from the factor finder for different sizes of spindles supplied along with the instrument. As the instrument is supplied with different sizes of spindles, a wide range of viscosity measurements can be made.

The instrument is provided with a high torque motor, which is geared for different speed. Therefore, measurements can be made at different shear rates, which is required for non-Newtonian liquids. Brookfield viscometer is widely used to measure the consistency of products like tomato products, custards, dairy products, cream style corn etc.

4.4 TEXTURE

Texture is the property of food, which is associated with the sense of feel or touch experienced by fingers or the mouth. Texture of foods perceived by the mouth is a very complex phenomenon. It is perceived in three stages of ingestion of food viz. initial, masticatory and residual each consisting of different textural parameters. Therefore, objective quantitative description of the texture perceptions is quite difficult.

The physical or the mechanical textural characteristics of foods are related to the reaction of the food to stress and can be divided into parameters of hardness, brittleness, chewiness, gumminess, cohesiveness, viscosity, elasticity and adhesiveness.

In objective measurement of texture, food is subjected to compression, tension, shear and flow and the resultant deformation is measured. Measurements are made in terms of integral powers of force (m), length (l) and time (t).

All texture measuring instruments/ devices have a few essential parts. They are: I) driving mechanism to apply force, ii) probe element in contact with the sample, iii) mechanism to suitably direct the applied force, iv) sensing element, and v) read out system.

The instrumental methods of measuring the texture are based on applying force under controlled conditions. Standardisation of test cells for different types of products is crucial for getting useful data, which can be interpreted to give meaningful results. Each product in each test cell produces a characteristic force-deformation curve. Under controlled conditions of the test, the magnitude of the curve is influenced by the textural behaviour of the material tested. A typical force- deformation curve is shown in the following Figure.

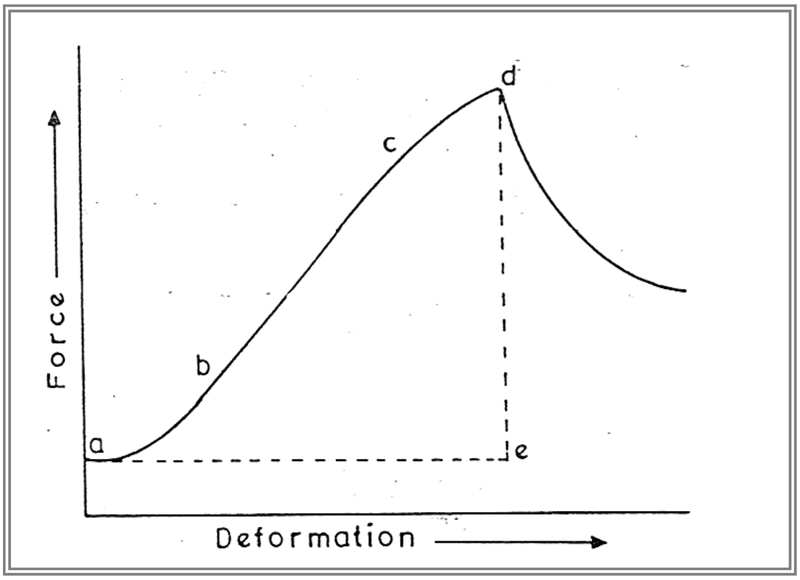

Figure 4.8

In general, the curve exhibits the following characteristics.

i) An initial non-linear portion representing packing of the cellular components of the sample under the applied stress.

ii) An approximately linear portion as the material is compressed. This slope of this portion of the curve represents the force required to attain a given deformation and hence a measure of the firmness.

iii) An abrupt change in the slope is seen when the sample begins to rupture.

iv) After the rupture point d, the force reduces.

There are different types of texture measuring instruments. Some instruments are very simple, measuring only a single mechanical textural characteristic of the product. Quite often, this is sufficient for quality control purposes. Fruit pressure tester like the Magness-Taylor pressure tester is an example of such an instrument. However, for research and development, one would like to get more extensive information on the various textural parameters of the product. This is called **texture profile analysis**.

4.4.1 Magness-Taylor Pressure Tester

This hand held instrument is widely used to determine the softening of fruits during maturation. The pressure tester uses a spring to measure applied force and a spring scale indicates the maximum test force. The tester consists of a metallic barrel inside which a spring is placed. A shaft to which a removable punch (plunger) is attached supports the spring (Figure 4.9). A small chuck at the end of the shaft ensures the fixed length of penetration. The instruments are available with springs of different force ranges to suit objects of different firmness. Each instrument is provided with punches of different diameters. The smaller diameter punches are used on firmer material and the larger on softer material.

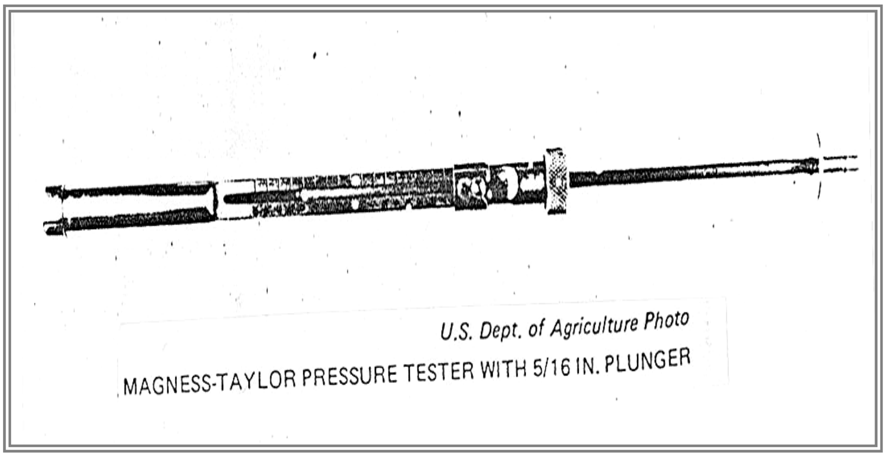

Figure 4.9

For measuring the pressure of a fruit, the plunger is held against the surface of the fruit and forced into the fruit with steady pressure applied by the hand to attain the necessary force necessary for breaking the flesh. The fruit may be peeled to overcome the interference of the skin with the action of the plunger. The force recorded on the scale indicates the maturity of the fruit. Typical range of pressure values of one variety of apples at different maturity stages is given below:

Degree of maturity/ripeness	Pressure test reading (lb) Delicious apple
Hard	17-20
Firm	14-17
Firm-ripe	11-14
Ripe	8-11

4.4.2 Instron Testing Machine

This is a versatile instrument capable of obtaining texture profiles of different types of objects. The machine consists of two parts: i) the drive mechanism, which drives a moving cross head in a vertical direction in selected speeds of 0.05 to 50 cm / min and ii) the load sensing and recording system for loads in the range of 2g to 5,000 Kg. There are different types of fixtures like flat compression plates, cylindrical compression box, assortment of needles and punches, a single star-shaped needle etc. A careful selection of the fixtures permits the measurement of different texture parameters. The instrument measures force- deformation of force- time functions. It is extensively used to measure the texture of fruits, vegetables and processed food products.

4.4.3 Measurement of Jellying Property of Pectins

Jams, jellies and marmalades are important commercial products. Pectin is commonly used to obtain the characteristic jelly like texture to the products. Therefore, the jellying quality of the pectin used determines the product quality. There are different methods for assessing the quality of pectin. Physical methods for determining jelly strength are two types. The first group of methods measure the breaking strength of jellies when they rupture after exceeding their elastic limits and the second group of methods measure jelly strength by taking into account the deformation of jellies within their elastic limits. Here one method in each group is described.

Pectinometer

The Luers-Lochmuller Pectinometer (Figure 4.10) measures the force required to pull a disc embedded in the jelly being tested upwards. The apparatus is shown below. It consists of a moving load (weight) put on one arm of a balance and the disc in the jelly attached to the other arm through a double pulley arrangement. The jelly container (corrugated) is held in a fixed position on the base of the balance (B). The disc (A) is suspended in the corrugated container (C). The jelly being tested is poured hot into the container and allowed to cool for at least one hour before the test is carried out. Now, weights are applied on the pan (W) till the jelly breaks. The corrugated sides of the container prevent slipping of the jelly in the container. The indicator (I) measures the extent of compression of the jelly. Breaking values pf jellies range from 200 to 300 g depending on the type of jelly. For quality control purposes a narrow range (± 15g) is usually fixed.

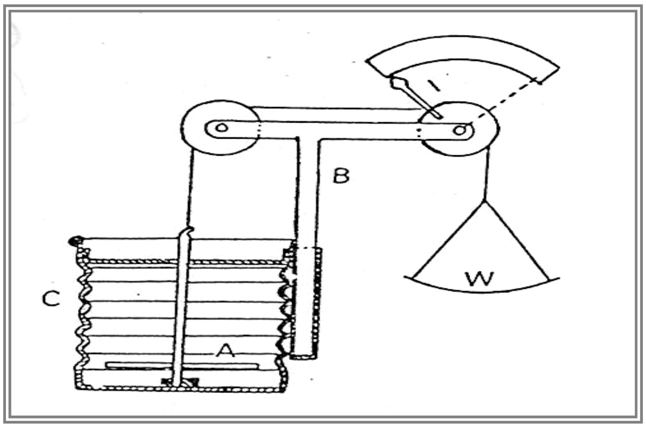

Figure 4.10: Luers and Lochmuller pectinometer

Ridgelimeter (Cox-Higby Sag Method)

Ridgelimeter measures the percentage sag or slump occurring when a test jelly is removed from its supporting container and inverted upon a glass plate. The Fig. below shows the instrument with a sample of jelly in measuring position and jelly glasses (containers). The glasses are of standard sizes of 3.125 in (79.4 mm) depth. The instrument as such has only a micrometer screw fixed on a stand. The screw has 32 threads to an inch so that one revolution moves the point by 0.03125 in., which is equal to 1% of the height of the jelly. Therefore, if the depression of the jelly as measured by the instrument is 0.03125 in. it is equal to 1% sag. For determining the jelly strength of a pectin sample, the following procedure is followed.

Weigh 48.8 g of tartaric acid in distilled water and make up to 100 ml in a volumetric flask. The quantity of pectin to be taken for the test depends on the assumed grade of the pectin. For example commercial pectin is usually supplied as 150 grade. Therefore, the assumed grade of the pectin is taken as 150. Since jellies should contain 65% sugar (TSS) i.e. 65 g sugar in 1000 g jelly, the weight of pectin to be used is 650/assumed grade of the pectin (650/150 = 4.33 g). Weigh 646 g sugar and 4.33 g pectin. Mix the weighed pectin with about 20-30 g of the weighed sugar in a dry beaker. The tare weight of a stainless steel saucepan along with a stirrer (about 1 lit. cap.) is noted and 410 ml of distilled water is taken in the pan. The pectin-sugar mix is added to the water in the pan and stirred. The pan is placed on a hot plate and heated to boil the solution. The remaining sugar is added and heating and stirring continued till the sugar dissolves completely. Heating is continued until the net weight of jelly is 1015 g. If the net weight is less, distilled water is added in slight excess and boiled down to exact weight. The entire heating time should not exceed 5-8 min. The material is allowed to stand for 1 min., any foam or scum is skimmed off and allowed to cool to 95^{o}C (check with a thermometer) while stirring gently. Pour the hot jelly into three Ridgelimeter glasses (after fixing gummed tapes to a height of 0.5 in. above the rims) almost to overflowing, each containing 2 ml of the tartaric acid solution. After 15 min., the glasses are covered with metal lids and allowed to cool for 20-24 hr. at 25^{o} ± 3^{o}C.

After cooling, the lids are removed and the gummed tapes are tore off. The jelly exposing beyond the brims of the glasses is sliced off with a stretched wire. Now the jelly from one glass is removed with the help of a spatula and directly placed on to the glass plate provided along with the instrument. Start a stopwatch as the jelly is placed on the glass plate, and place the jelly directly below the micrometer screw. After exactly 2 min. bring the point of the micrometer screw just into contact with the jelly surface. Read the sag to the nearest 0.1%. Repeat the measurements with the jellies in the other two glasses also and take the average. The true grade of the pectin is calculated by multiplying the assumed grade with the corresponding factor for the measured sag provided in a tabular form along with the instrument. For example if the assumed grade is 150 and the factor for the measured sag of say 25 is 0.936, the true grade of the pectin is:

$$150 \times 0.936 = 140.4 \text{ or } 140 \text{ grade}$$

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. State Newton's law and differentiate between viscosity and consistency?

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2. Describe the use of Bostwick consistometer.

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3. What is meant by the texture of a material?

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4. Describe a simple instrument to measure the pressure of a fruit.

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5. Which are the essential components of the Instron Testing machine? What is its speciality?

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6. How the Ridgelimeter is used to measure jelly strength?

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4.5 LET US SUM UP

Measurement of colour, viscosity and texture of foods is very important for quality control.

When visible white light falls on an object, some of the spectral colours of the light are partially or fully absorbed by the object. The resultant coloured radiation is reflected from a solid or semi-solid object or transmitted through a liquid object, which the eyes perceive as the colour of the object. Any colour can be matched by mixing the three primary colours viz. red, green and blue in appropriate proportions. The relative amounts of the three primary colours required to match a colour is called the Tristimulus value of the colour. This is the basis of quantitative specification of colours under the CIE system. The CIE system specifies a colour in terms of its Hue or dominant wavelength, Chroma and Lightness. Based on instrumental measurement of reflectance from an object over the entire light spectrum, it is possible to arrive at the complete specification of its colour. For routine quality control of some food products like fruits, vegetables, meat etc., simple comparison of their colour with standard colour charts gives useful data. The Hunter colour system which is related to the CIE system specifies a colour in terms of L, a, b values.

Foods can exist in the liquid, semi-solid and solid state. Liquid foods are classified as Newtonian or non-Newtonian liquids depending on their flow properties. Instruments are available to measure the flow properties of liquid foods.

Texture of solid foods is related to their reaction to stress and can be divided into parameters of hardness, brittleness, chewiness, elasticity etc. Texture of foods is determined by measuring the relationship between the applied pressure and the resultant deformation of the food material. There are simple instruments like the fruit pressure tester, which measure a single parameter of texture like the pressure required for puncturing a fruit. Such data are usually sufficient for some quality control purposes. However, more detailed texture analysis is required for many other products especially for research and product development. Such texture profile analysis is possible with instruments like the Instron Testing Machine.

Jams, jellies and marmalades are important commercial products. Quality control of such products require measurement of their jell quality. The gel quality is mainly determined by the quality of the pectin used for their preparation. The jell strength of pectin and the products are determined using simple instruments. The instruments are either based on measuring the force required to break a gel or the sag (loss of rigidity) of a gel on standing.

4.6 KEY WORDS

Hue : The colour attribute denoted by red, green, blue and so on.

Saturation : The depth or strength of hue.

Lightness : The brightness of colour.

Dominant wavelength : Wavelength of the spectrum light that, when combined in suitable proportions with the specified achromatic (colourless) light yields a match with the light considered.

Tristimulus values : The amounts of the three primary colours required to match a colour.

Rheology	:	Study of flow and deformation of materials.
Newtonian fluids	:	Fluids for which the shear stress required to maintain its flow is proportional to the shear rate.
Texture profile analysis	:	Determination of various texture parameters like hardness, cohesiveness, elasticity, adhesiveness, fracturability, gumminess, chewiness etc.

4.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:
   - Appearance property
   - Absorption of some spectral wavelengths
   - Reflection and transmission of light
2. Your answer should include the following points:
   - Hue
   - Saturation
   - Lightness
3. Your answer should include the following points:
   - Primary colours
   - Tristimulus values
   - Chromaticity coordinates
   - Chromaticity chart
   - Dominant wavelength
   - Standard illuminants
   - Standard observer
4. Your answer should include the following points:
   - L,a,b values
   - Colour difference

Check Your Progress Exercise 2

1. Your answer should include the following points:
   - Ratio of shear stress to shear rate constant
   - Power law equation
   - Flow behaviour index
2. Your answer should include the following points:
   - Flow meter
   - Flow per unit time

3. Your answer should include the following points:

   - Deformation due to application of force
   - Hardness
   - Cohesiveness
   - Elasticity
   - Fracturability
   - Gumminess
   - Chewiness

4. Your answer should include the following points:

   - Magness-Taylor Pressure tester
   - Force required for puncturing

5. Your answer should include the following points:

   - Drive mechanism
   - Load sensing and recording system
   - Texture profile

6. Your answer should include the following points:

   - Standard jelly
   - Measurement of per cent sag

4.8 SOME USEFUL BOOKS

1. Kramer, A. and Twigg, B.A. (1966) Fundamentals of quality Control for the Food Industry, The AVI Publishing Co., Inc., Westport.

2. Hutchings, J.B. (1994) Food Colour and Appearance, Blackie Academic & Professional, London.

3. Owen R. Fennema (1976) Principles of food science, Part II-Physical Principles, Marcel Decker Inc.; New York.

4. Ranganna, S. (2000) Handbook of Analysis and Quality Control for Fruit and Vegetable Products, Tata McGraw-Hill Publishing Co., Ltd., New Delhi.