

EXPERIMENTAL FOODS

M.Sc., FOODS AND NUTRITIONAL SCIENCES, II YEAR, PAPER- II

Specialization: Food Science and Quality Control

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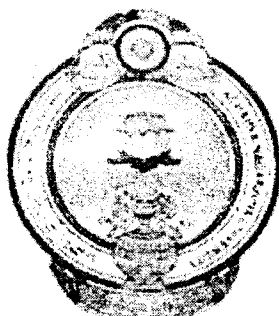
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FOREWORD

Since its establishment in 1976, Acharya Nagarjuna University has been forging ahead in the path of progress and dynamism, offering a variety of courses and research contributions. I am extremely happy that by gaining a B++ (80-85) grade from the NAAC in the year 2003, the University has achieved recognition as one of the front rank universities in the country. At present Acharya Nagarjuna University is offering educational opportunities at the UG, PG levels apart from research degrees to students from about 300 affiliated colleges spread over the three districts of Guntur, Krishna and Prakasam.

The University has also started the Centre for Distance Education with the aim to bring higher education within reach of all. The Centre will be a great help to those who cannot join in colleges, those who cannot afford the exorbitant fees as regular students, and even housewives desirous of pursuing higher studies. With the goal of bringing education to the doorstep of all such people, Acharya Nagarjuna University has started offering B.A. and B.Com courses at the Degree level and M.A., M.Com., M.Sc, M.B.A. and LL.M. courses at the PG level from the academic year 2003-2004 onwards.

To facilitate easier understanding by students studying through the distance mode, these self-instruction materials have been prepared by eminent and experienced teachers. The lessons have been drafted with great care and expertise within the stipulated time by these teachers. Constructive ideas and scholarly suggestions are welcome from students and teachers involved respectively. Such ideas will be incorporated for the greater efficacy of this distance mode of education. For clarification of doubts and feedback, weekly classes and contact classes will be arranged at the UG and PG levels respectively.

It is my aim that students getting higher education through the Centre for Distance Education should improve their qualification, have better employment opportunities and in turn facilitate the country's progress. It is my fond desire that in the years to come, the Centre for Distance Education will grow from strength to strength in the form of new courses and by catering to larger number of people. My congratulations to all the Directors, Academic coordinators, Editors and Lesson - writers of the Centre who have helped in these endeavours.

Prof. K. Viyyanna Rao

Vice - Chancellor,

Acharya Nagarjuna University

**M.Sc. (FOODS & NUTRITIONAL SCIENCES), SECOND YEAR
SPECIALIZATION - II : FOOD SCIENCE AND QUALITY CONTROL
Paper - 2: EXPERIMENTAL FOODS
SYLLABUS**

UNIT - I:

- Classification of foods (Basic 5 groups) Standardization of food preparations: Food Evaluation, sensory evolution, selection of taste panels.

UNIT - II:

- Cereal cookery/Starch cookery: Stages, Gelatin, factors effecting gelatin, Starch as thickness sources of starch, retro gradation of starch, quality of flour, dough, gluten formation.
- Sugar cookery: Stages of sugar cookery, crystallization, factors effecting size of crystals formed, fondant, fudges, caramels, brittles .Role of sugar in the preparation of cakes and Indian sweets, browning reactions.
- Fats and Oils: Properties, Smoking point, melting point, Hydrogenation, shortening effect. Changes during storage, rancidity – Oxidative and hydrolytic, whipped cream as double emulsion.

UNIT - III:

- Pulse cookery: Factors affecting the quality of cooked products. Effect of soaking, germination and fermentation.
- Milk cookery: Properties of milk proteins, cheese and other milk product
- Egg cookery: Properties of egg proteins and uses in egg preparations, egg as a binding, foaming and emulsify agent.
- Meat Cookery: Post mortem changes, changes in cooking, fish types, changes during heat treatment.

UNIT - IV:

- Vegetables and fruits: Structure of vegetable tissues- starches, sugars, pectin substances, celluloses and their effect on texture and palatability. Plant pigments, plant enzymes and uses extraction of papain and effect on meat, browning reactions.

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QUESTION PAPER PATTERN

Each Paper carries 100 marks, 20 marks Internal assessment through assignments and 80 marks for year end examination. The duration of examination for theory papers will be three hours.

Pattern :

The question paper is divided into five Units. Unit I, II, III, IV and V

Unit - I : (1*16 = 16 marks)

The unit consists of 2 questions, out of which the candidate has to write 1 question, which carries 16 marks

Unit - II : (1*16 = 16 marks)

The unit consists of 2 questions, out of which the candidate has to write 1 question, which carries 16 marks

Unit - III : (1*16 = 16 marks)

The unit consists of 2 questions, out of which the candidate has to write 1 question, which carries 16 marks

Unit - IV : (1*16 = 16 marks)

The unit consists of 2 questions, out of which the candidate has to write 1 question, which carries 16 marks

Unit - V : (1*16 = 16 marks)

The unit consists of 2 questions, out of which the candidate has to write 1 question, which carries 16 marks

EXPERIMENTAL FOODS

CONTENTS

Lesson 1 : Food Groups and Evaluation	1.1 – 1.13
Lesson 2 : Cereal Cookery / Starch Cookery	2.1 – 2.9
Lesson 3 : Sugar Cookery	3.1 – 3.8
Lesson 4 : Fats and Oils	4.1 – 4.9
Lesson 5 : Pulse Cookery	5.1 – 5.7
Lesson 6 : Milk Cookery	6.1 – 6.8
Lesson 7 : Egg Cookery	7.1 – 7.10
Lesson 8 : Meat Cookery	8.1 – 8.10
Lesson 9 : Structure of Vegetable and Fruit Tissues	9.1 – 9.14
Lesson 10 : Pectin Substances	10.1 – 10.7
Lesson 11 : Plant Enzymes	11.1 – 11.14
Lesson 12 : Plant Enzymes	12.1 - 12.18

LESSON – 1**FOOD GROUPS AND EVALUATION****1.0 OBJECTIVE**

After reading this chapter, you should be able to:

- Know the classification of food groups
- Describe the standardization of food preparations
- Methods of objective and sensory evaluation of food

STRUCTURE**1.1. Introduction****1.2. Food groups****1.2.1. Classification of Food Groups****1.3. Standardization of food preparations****1.4. Food Evaluation****1.4.1. Objective evaluation****1.4.2. Sensory evaluation****1.4.3. Evaluation card****1.5. Selection of panel members****1.6. Summary****1.7. Self Assessment Questions****1.8. Reference Books****1.1. INTRODUCTION**

Civilised man does not eat all the food as it is available in nature. He cuts, crushes, cools, processes and modifies in many ways before consuming, adding variety to the diet.

Food science is the production, processing, distribution, preparation, evaluation, and utilization of food. Food is a mixture of many different chemical components. The study of food science involves an understanding of the changes that occur in these components during food preparation, whether natural or induced by handling procedures. Many physical and chemical reactions occur during food preparation. These reactions may be a result of the interaction between components, with the medium of cooking, and the environmental conditions like heat, cold, light and air to which they are subjected during cooking.

Study of food science also includes understanding the nutritive value of different foods and methods of preserving them during cooking. This information provides a foundation of theory and method on which to build the study of food preparation.

Quality of a food product involves maintenance or improvement of the key attributes of the product—including color, flavor, texture, safety, healthfulness, shelf life, and convenience. To maintain quality, it is important to control microbiological spoilage, enzymatic degradation, and chemical degradation. These components of quality depend upon the composition of the food, processing methods, packaging, and storage.

1.2. FOOD GROUPS

Carbohydrates, proteins, fats, minerals, vitamins and water are the six major components of food. To maintain good health, ingesting a diet containing these nutrients in correct amounts is essential. A balanced diet is one which contains different types of foods in such quantities and proportions so that the need for calories, proteins, minerals and vitamins is adequately met and a small provision is made for extra nutrients to withstand short duration of leanness.

1.2.1. CLASSIFICATION OF FOOD GROUPS

Foods have been classified into different groups depending upon the nutritive value, for the convenience of planning diets. The five food group system suggested by ICMR is given below.

Food Group	Main Nutrient
I Cereals, grains and products: rice, wheat, ragi, maize, bajra, jowar, rice flakes, puffed rice.	Energy, protein, invisible fat, thiamin, folic acid, riboflavin, iron and fibre.
II Pulses and legumes: Bengal gram, black gram, cow pea, peas (dry) rajma, soyabeans.	Energy, protein, invisible fat, thiamin, riboflavin, folic acid, calcium, iron and fibre.
III Milk and meat products: Milk, curd, skimmed milk, cheese Chicken, liver, fish, egg and meat.	Protein, fat, riboflavin, calcium, protein, fat, riboflavin.
IV Fruits and vegetables: Mango, guava, tomato, papaya, orange, sweet lime, watermelon. Green leafy vegetables: Amaranth spinach, gogu, drumstick leaves, corriander leaves, fenugreek. Other vegetables: Carrots, onion, brinjal, ladies finger, beans, capsicum, cauliflower, drumstick.	Carotenoids, vitamin C, riboflavin, folic acid, iron, fibre. Riboflavin, folic acid calcium, fibre, iron, carotenoids Carotenoids, folic acid, calcium and fibre.
V Fats and Sugars: Fats: Butter, ghee, hydrogenated fat, cooking oils. Sugar and jaggery, Energy, jaggery has got iron	Energy, essential fatty acids and fat Soluble Vitamins

1.3. STANDARDIZATION OF FOOD PREPARATIONS

A food service operation may just heat prepared food, may prepare food from "scratch", or may do a little of both. In any case, standardized recipes will be needed to achieve the nutrition goals.

A standardized recipe is one that has been tested and adapted for use by a given food service operation and found to produce the same good results and yield every time when the exact procedures are used with the same type of equipment, and the same quantity and quality of ingredients. Standardized recipes have many advantages...

Quality Control: Standardized recipes provide consistently high quality food items that have been thoroughly tested and evaluated.

Portion and Yield Control: Standardized recipes accurately predict the number of portions from each recipe. This helps eliminate excessive amounts of leftovers and substitutions.

Cost Control: Standardized recipes provide better management of purchasing and storage because they specify exact amounts of ingredients.

Creativity: Standardized recipes support creativity in cooking. Employees should be encouraged to continuously improve recipes.

Accurate Nutrient Analysis: For an accurate nutrient analysis new menus under the changes in a modified recipe must be added to the local database. Under the Food-Based system, changes in a modified recipe should be kept on file.

1.4. FOOD EVALUATION

Each individual evaluates foods daily in terms of likes and dislikes. Sometimes comparisons are made between products of rival processors or between a product made at different intervals. Thus A's bread may be preferred to B's, and the cake baked last week is better than the one baked this week.

The terminology used in food acceptance tests varies with different investigators and with different time periods. Distinctions among foods made by the senses have been called organoleptic, psychometric, and sensory. The words objective and subjective have been used in various ways. The term objective refers to data obtained by physical, chemical, or microbial means; subjective refers to preferences or differences obtained by the use of the senses.

1.4.1. Objective evaluation

Methods of evaluating food quality that depend on some measure other than the human senses are often called objective methods of evaluation.

Objective tests determined the colour and maintain the colour standards of manufactured foods. Subjective ratings of tenderness of pastry, sponge cake and bread and meat are measured by tests on the shortometer, tensile strength apparatus, or the shearing apparatus, respectively. Thermometers, thermocouples and thermostats can be used to control the temperature for cooking and the temperature of the ingredients during various stages of preparation. The specific gravity of

foams, batters, and baked products can be determined. The microscope can be used to determine the relation of texture to various quality factors. Haugh units may be determined for egg quality.

1. Chemical methods:

Chemicals are estimated in food spoilage like peroxides in fats. Adulterants in food like presence of starch in milk, metanil yellow in turmeric powder and loss of nutrients during cooking can be estimated.

2. Physico-chemical methods:

Measurement of Hydrogen ion concentration can be found out by use of pH meter. It utilizes a glass indicating electrode and a reference electrode to complete the electrical circuit.

Sugar concentration can be found by refractometer. It is used to determine the concentration of a sugar solution. Light is refracted as it passes through sugar solution, with the specific values being calibrated in degrees, Brix, and indication of the percent of sucrose in the solution. Polariscope is used for quantitative analysis of sugar.

3. Microscopic examination:

Some properties of foods depend on their structure and valuable information can be obtained by microscopic examination. For example, type of organisms present in fermented products like idli batter, examination of starch cells under the microscope for identification, size of crystal in sugar is related to smoothness of the product and number or size of the air cells in batters and foams.

4. Physical methods:

Weight:

Weight of a food indicates the quality like in case of apple or egg.

Volume:

Liquid volumes can be measured by using measuring cups. Solid food volume can be found by seed displacement method. In this method the volume can be calculated by subtracting the volume of seeds held by a container with a baked product from that of volume of seeds without the baked product. Usually mustard seeds are used.

Specific volume:

The determination of specific volume of any product should be done with care and average of replicates is to be taken since experimental errors are likely to be large. Measurement of bulk volume in a porous and spongy product like idli is difficult. The volume may be measured by displacement with solvents like kerosene. The idli is given a momentary dip in molten wax to seal off the pores. Increase in volume is taken as the measure of its bulk volume.

Bulk volume

Specific volume = _____

Wt. of the substance

Index to volume:

Index to volume is a measurement made by first tracing detailed outline of a cross section of the food. This tracing can be done with a sharply pointed pencil or a pen or by making a clear ink blot of the cross section. The ink blot is made simply by pressing the cross section of the sample lightly onto an inked stamp pad and then making the imprint of the inked sample on paper.

Specific gravity:

It is a measure of the relative density of a substance in relation to that of water. The measurement is obtained by weighing a given volume of the sample and then dividing that weight by the same volume of water. This technique is used for comparing the lightness of products physically unsuited to the volume measurements e.g. egg white foams.

Moisture:

Press fluids: initial weight of the sample is noted. After the appropriate pressure has been applied for a controlled length of time, the sample is again weighed. The difference between the two weights represents the amount of juice contained in the original sample e.g. juiciness of meat, poultry and fish.

Drying: the weight of the original sample is determined and then the food is dried until the weight remains constant.

$$\text{Moisture content} = \frac{\text{Initial} - \text{Dried weight}}{\text{Initial weight}} \times 100 = \%$$

Wettability:

Baked products can be tested for moisture level by conducting a test for wettability. For this test, the sample is weighed before being placed for 5 seconds in a dish of water. Immediately at the end of the lapsed time, the sample is removed from the water and weighed again to determine the weight gain.

Cell structure:

Cell structure of baked products is an important characteristic to measure the uniformity, size and thickness of cell walls. Photocopies of cross-sectional slices give this valuable information. View into the cells on the cut surface of the sample and gives the actual size clearly.

Measurement of colour:

Colour is the first quality attribute a consumer perceives in food. Change of colour is generally accompanied by flavor changes.

In order to maintain quality, the color of food products must be measured and standardized. If a food is transparent, like a juice or a colored extract, colorimeters or spectrophotometers can be used for color measurement. The color of liquid or solid foods can be measured by comparing their reflected color to defined (standardized) color tiles or chips. For a further measurement of

color, reflected light from a food can be divided into three components: **value**, **hue**, and **chroma**. The color of a food can be precisely defined with numbers for these three components with tristimulus colorimetry. Instruments such as the Hunterlab Color and Color Difference Meter measure the value, hue, and chroma of foods for comparisons.

Texture evaluation:

The **texture** of food refers to the qualities felt with the fingers, the tongue, or the teeth. Textures in food vary widely, but any departure from what the consumer expects is a quality defect. **Texture** is a mechanical behavior of foods measured by sensory (physiological /psychological) or physical (**rheology**) means. Rheology is the study of the science of deformation of matter. Regardless of the reason for studying texture, classification and understanding are difficult because of the enormous range of materials. Moreover, food materials behave differently under different conditions. Texture testing in foods is based upon the action of stress and strain. Many of the methods are based upon compression, shearing, shear-pressure, cutting, or tensile strength. For example, the compressimeter was used to determine the compressibility of cakes and other "spongelike" products. Historically, the penetrometer, has been used to measure gel strength. The Warner-Bratzler shear apparatus has been the standard method of evaluating meat tenderness. The Instron has adapted many of the historical texture measuring instruments. It measures elasticity. The Brookfield viscometer will measure the viscosity in terms of Brookfield units. Other instruments used to measure texture include a succulometer and a tenderometer. Changes in texture are often due to water status. Fresh fruits and vegetables become soggy as cells break down and lose water. On the other hand if dried fruits take on water, their texture changes. Bread and cake lose water as they become stale. If crackers, cookies, and pretzels take up water, they become soft and undesirable. Various methods are used to control the texture of processed foods. Lipids (fats) are softeners and lubricants used in cakes. Starch and gums are used as thickeners. Protein can also be a thickener, or if coagulated as in baked bread, it can form a rigid structure. Depending on its concentration in a product, sugar can add body as in soft drinks or in other products add chewiness, or in greater concentrations it can thicken and add chewiness or brittleness.



(Source: USDA, ARS Image Gallery)

1.4.2. Sensory evaluation:

Sensory evaluation has been defined as 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 e. g. colour, size, shape, uniformity and absence of defects is of first importance in food selection.

The effective characteristic is not the property of the food but the subject's reaction to the sensory qualities of foods. This reaction is highly conditioned by a variety of psychological and social factors thus playing a vital role in the acceptance and preference of food.

Sensory Characteristics of Food:

Appearance:

Surface characteristics of food products contribute to the appearance. Scrambled egg with a very dry surface is not acceptable. Fudge with a glossy surface is rated high. Interior appearance can also be evaluated. Lumps in a pudding or gravy are not desirable can be judged by the eye. Sight plays a role in the assessment of the lightness of foods like the bread, cakes and idli. Perception of the size, shape and colour of the foods and of such characteristics as transparency, opaqueness, turbidity, dullness and gloss is mediated by the organs of sight.

Quality of fish can be ascertained by the brightness of the eyes of fish. Quality of sweet limes can be found out by appearance. If the skin is thin it is juicy. Infestation with insects can be found out in brinjal by the appearance of black spots on it. Completeness of cooking can be judged by appearance in products like meat and rice.

Colour:

In addition to giving pleasure the colour of food is associated with other attributes. Ripeness of fruits like banana, tomato, mango, guava, papaya and plum can be assessed by the colour.

Colour is used as an index to the quality of a number of foods. The strength of coffee and tea is judged in part by the colour of the beverages. Toast, dosa, and chapathi which are too brown are likely to be rejected in anticipation of scorched bitter taste.

Flavor:

The flavour of food has three components - odour, taste and a composite of sensations known as mouth feel.

Odour:

A substance which produces odour must be volatile and the molecules of the substance must come in contact with receptors in the epithelium of the olfactory organ. Aroma is able to penetrate even beyond the visual range when comparatively volatile compounds are abundant as is true in boiling sambar. The volatility of aromas is related to the temperature of the food. High temperatures tend to volatilise aromatic compounds, making them quite apparent for judging cool or cold temperatures that inhibits volatilization.

Taste:

Taste sensation on the taste buds is categorized as sweet, salt, sour or bitter. Taste buds near the tip of the tongue are more sensitive to sweet and salt. Those on the sides to sour and those near the back to bitter. The sensation known as sour is associated with hydrogen ions supplied by acids like vinegar and by those found in fruits and vegetables. Salt taste is due to ions of salt. Sodium chloride is said to be the only one with a pure salt sensation.

Substances which elicit the sweet sensation are primarily organic compounds like alcohols, certain amino acids, and aldehydes. Glycerol tastes mildly sweet. Sugars are the main source of sweetness in food. Not all sugars are equally sweet. Fructose gives the most intense sweet sensation followed by sucrose, glucose, maltose, galactose and lactose. Sweetness appears to be associated with the hydroxyl radicals on the sugar molecules. The concentration required for identification is known as the "threshold" for that particular substance. Individuals differ in their sensitivity to the four taste sensations and the threshold for each of the primary tastes is usually not at the same level in any one individual. The pleasant sensations in eating come more from odour than from taste.

Taste interaction: Foods contain mixture of substances which elicit all four taste sensations. Salt in subthreshold concentration reduces the tartness of acid. Some threshold concentrations of salt also increase the apparent sweetness of sucrose. The addition of salt to lime juice, sherbet, lassi, and to fruits like apple or guava improve the taste. Conversely acids in subthreshold concentration intensify the saltiness of sodium chloride so it is easy to over salt tart foods. Sugar in subthreshold concentration reduces the saltiness of sodium chloride so a pinch of sugar may improve vegetable soup that has been over salted. Sugar also reduces the sourness of acids and bitterness of coffee.

Mouth feel :

Texture and consistency and hotness or burning sensation of pepper can be felt in the mouth feel.

Temperature:

Hot and cold sensations contribute to the composite flavour of a food like coffee, soup or ice-cream. Taste sensations are less intense as the temperature of food is lowered below 20 °C and raised above 30 °C. Thus really hot coffee is not as bitter as that which has cooled in the cup, iced coffee is not as bitter as that which is warm but not really hot. Melted ice-cream tastes unpleasantly sweet although in the frozen state it is acceptable.

Texture:

Texture in ice cream depends upon the size of the crystals. How they feel on the tongue is characterized as coarse or fine. Coarse textured crystalline products are said to be grainy.

The brittleness of food is another aspect of texture. Tissues in a raw vegetable and fruit are brittle or crunchy. The cells offer moderate resistance to fraction by the pressure of the teeth, e.g. crispness of apple and raw carrots. Tenderness in fruits and vegetables depends on how easily the cells separate. In meats ease of separation of the lean (without fat) tissue determines the tenderness. Tenderness in pastry is assessed by the ease with which the crisp crust breaks.

Astringency:

It is dry puckery sensation due to precipitation of the proteins in the saliva and in the mucous membrane lining of the mouth which deprives them of their lubricating character. Astringent substances may also constrict the ducts leading from the salivary glands to the mouth. Unripe fruits like cashew fruit, wood apple, blue berry and gooseberry are astringent.

Consistency:

Ice-creams may be too hard or too soft which can be found out by mouth feel. Gravies, sauces and syrups range in consistency from thick to thin. Temperature may affect the consistency of food, e.g. ghee, butter, cheese and ice-creams. The consistency of soft custard besides being thick or thin may be smooth or curdled. Cream soups may be smooth or lumpy. Gels may be rubbery or fragile (easily breakable). Particles of cooked cereal can be pasty or separate in grains.

Psychological factors:

In addition to colour, odour, taste and mouth feel certain psychological factors contribute to the acceptability of foods. Food is accepted when there is pleasant association.

1.4.3. Evaluation card:

The questionnaire or score card should be prepared carefully for each test. The card should be clearly typed or printed. It should be simple and use unambiguous terms and directions in the desired sequence of action as a guide to the evaluation. The design of score cards for sensory evaluation is challenging and difficult because the key characteristics of the product need to be evaluated on paper in a way that permits the judges to transmit their assessments of the samples accurately to the researcher. A score card with too much detail and clutter may discourage careful judgment too brief a form may fail to obtain some important information.

A score card may be as simple as indicating which sample is different as is done when duo-trio or triangle testing is the mode being used. A sheet for indicating rank order for a single characteristic also is extremely simple. It is in the descriptive tests that the score card becomes a critical part of the planning for an experiment. A table utilising the hedonic ratings ranging from unacceptable to very acceptable is relatively easy to construct.

No single score card fits all experiments. Instead, the score card needs to be developed for the specific experiment. All score cards should contain the date and name of the judge.

Types of tests:

Different sensory tests are employed for food evaluation. The tests are grouped into four types.

- A. Difference tests.
- B. Rating tests.
- C. Sensitivity tests.
- D. Descriptive tests.

The selection of a particular test method will depend on the defined objective of the test, accuracy desired and personnel available for conducting the evaluation.

A. DIFFERENCE TESTS

Paired Comparison Test – test of difference in which a specific characteristic is designated to be evaluated in two samples. The sample with the greater level of the characteristic is to be identified.

Judge has a 50% chance of being right by chance alone.

Duo-Trio Test – difference test in which two samples are judged against a control to determine which of the two is different from the control.

Judge has a 50% chance of being right by chance alone.

Triangle Test – difference test in which 3 samples are presented (two of the samples are the same). Panelists are asked to identify the odd sample.

Judge has a 33.3% chance of guessing the right answer due to method of presentation.

B. RATING TESTS

Rank Order – samples are ranked in order of intensity of a specific characteristic. Valuable when several samples need to be evaluated for a single characteristic.

Hedonic Rating Test - Hedonic rating relates to pleasurable or unpleasant experiences.

The hedonic rating test is used to measure the consumer acceptability of food products. From one to four samples are served to the panelist at one session. He is asked to rate the acceptability of the product on a scale, usually of 9 points, ranging from 'like extremely' to 'dislike extremely'. Scales with different ranges and other experience phrases could also be used. The results are analysed for preference with data from large untrained panels.

C. Sensitivity tests: Sensitivity tests are done to assess the ability of individual to detect different tastes, odours and feel the presence of specific factors like astringency or hotness (pepper). These tests are used to select and train panel members for evaluating the quality of products containing spices, salt and sugar, e.g. tomato ketchup or sauce. For this purpose threshold tests for the recognition of basic tastes (sweet, sour, bitter and acid) are employed for selecting the panel members.

Sensitivity-Threshold Test: Sensitivity tests are to measure the ability of an individual to smell, taste or feel specific characteristics in food or beverages or pure substances are used frequently in selecting for evaluations in product research and development. Also, they are used to establish intensity of sensory response of a food.

D. Descriptive flavour profile method: This is both qualitative and quantitative description method for flavour analysis in products containing different tastes and odour.

1.5. SELECTION OF PANEL MEMBERS

The sensory qualities, particularly the flavour attributes are essentially to be measured subjectively. From early times this judging has been the preserve of experts who used to evaluate tea, coffee and wine. With the development of sensory evaluation techniques on scientific lines, the experts are being replaced by panels whose sensitivity and consistency have been established by training and repeated tests. The panel members analyse food products through properly planned experiments and their judgements are quantified by appropriate statistical analysis.

Selection of panel of judges:

Actually one extremely discriminating pains taking and unbiased individual would suffice for tasting. Further one individual may not be able to discriminate different aspects of food quality. Hence a panel of judges may be used. Members of the panel should be carefully selected and trained to find out difference in specific quality characteristics between different stimuli and also direction and intensity of difference. The requirements for an ideal panel member are as follows.

- * He should be able to discriminate easily between samples and should be able to distinguish appreciable differences in taste and smell.
- * He should have good health. If he is suffering from cold his sensitivity may be affected. A sick patient cannot judge the food correctly he should not be habituated to chewing pan
- * He should be experienced in the particular field.
- * He should have high personal integrity. He should not be prejudiced.
- * He should be able to evaluate objectively.
- * Willingness to spend time for the sensory evaluation work is required.
- * He should have interest in sensory analysis of samples and intellectual curiosity.
- * He should have ability to concentrate and derive proper conclusion.
- * He should be available and willing to submit to periodic test to get consistent results.

Different types of panels:

Trained panel: Laboratory panels must then be carefully trained for specific products or purposes. These tests aim at finding differences in specific quality characteristics between different stimuli and also direction and/ or intensity of the difference. Periodically the panel is given refresher training and tests. The number of members in the trained panel should be small varying from 5 to 10.

Discriminative, communicative or semi-trained panels: These panels are constituted of technical people and their families, who are normally familiar with the qualities of different types of food. They are capable, with few preliminary test runs, of following instructions for tests given, discriminating differences and communicating their reactions. Such panels of 25-30 are used to find the acceptability or preference of final experimental products prior to large scale consumer trials.

Consumer panels: Such panels are made up of untrained people chosen at random to represent a cross-section of the population for which the product is intended. The greater the number, the greater is the dependability of the result. A group of not less than 100 is considered the minimum.

Testing laboratory : Testing laboratory consists of five separate units –

- Reception room where the panel members meet the person in charge of the laboratory and get acquainted with the type of the samples to be tested
- The sample preparation room which is clean and well equipped for the preparation and serving of samples.
- The test booths are where the actual sensory evaluation of the samples are carried out by the panel members
- The entire testing laboratory should be air-conditioned, free from noise and extraneous odours.
- Whenever samples with difference in colours are tested, colour lights should be used to mask the colour of the samples.
- Stainless steel, glass dishes and cups as well as plain serving china are the most convenient as utensils.

Preparation of samples: Samples for presentation must be from homogeneous lot. Careful sampling of the food is necessary for sensory evaluation. Samples to be tested should be prepared by identical methods. All samples should be at the same temperature optimum level and kept constant during the test. Stainless steel forks and spoons can be used for tasting the samples. Samples are presented with 3 to 5 digit code markings to obscure the identify of the samples. The order of presentation should also be randomized within each test session.

Techniques of smelling and tasting: For odour tests of food products a special technique is used to perceive the aroma more clearly. Smelling is done with short, rapid sequence of sniffs. Tasting of coffee or tea or fruit juice is done by slurping. One teaspoon of the liquid is rolled on the tongue so that the liquid reaches all parts of the tongue where the taste buds are located.

Testing time: Testing should be done at a time when the panel members are fresh. The test time is generally between 10 AM to 12 noon. Too many samples should not be given as they may produce fatigue and lead to errors in the results. (Not more than 4 - 5 samples at a time).

Design of experiment: Experimental error can be minimized through the use of techniques of randomizing. A statistical design is used in order to measure variables separately and together and to establish the significance of results. The experiment should be designed on the basis of the accuracy needed and the amount of sample available.

1.6. SUMMARY

Consumers expect certain qualities from their food. These include color, flavor, texture, and even size. When these are missing or different than expected, the food is rejected. Food science determines and uses methods to measure food-quality factors. These methods ensure a consistent, reliable product. Some evaluation methods use chemical and mechanical techniques. Others are completely human, such as taste panels.

1.7. SELF ASSESSMENT QUESTIONS

1. Give the ICMR classification of food groups.
2. What points to be remembered in conducting objective evaluation of food?
3. Describe the sensory characteristics that can be evaluated.
4. Design a score card for an experiment you might conduct in the laboratory.

1.8. REFERENCE BOOKS

1. Francis, 2003, Encyclopedia of Food Science and Technology. The computype media, New Delhi 110 002.
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Dr. B. BABITHA

Lesson – 2**CEREAL COOKERY / STARCH COOKERY****2.0 OBJECTIVE :**

After reading this chapter, you should be able to :

- Describe the factors effecting galatin.
- Know the galatinization temperature retrogradation of starch.
- Gluten formation and dough their factors.

STRUCTURE**2.1 Introduction****2.2 Starch stages****2.3 Gelatinisation****2.3.1 Gelatinisation temper****2.4 Factors affecting gelatinization****2.5 Starch as thickness of sources of starch:****2.6 Retrogradation of starch****2.7 Cereal protein - Gluten****2.8 Dough****2.9 Factors that affect the gluten formation****2.10 Summary****2.11 Self Assessment Questions****2.12 Reference Books****2.1 INTRODUCTION**

Cereals supply the bulk of the food consumed by the human race. They are the cheapest source of food energy and constitute a high percentage of the calorie and protein intake of man, particularly in the developing countries. Cereals have been grown from primitive times. During the long period of the cultivation of cereal crops, new species and varieties have been evolved, to suit the cultural conditions of the different parts of the world. Cereals are also used as animal feed and for industrial purpose.

This is the principal food-reserve polysaccharide of the plant kingdom, where it occurs in cereal grains, pulses, tubers, bulbs and fruits in varying amounts from a few percent to over 75

percent in the case of several grains. Starch provides the major source of energy in the diet of man. Much of the starch is consumed without being isolated from the plants material in which it occurs. Refined starch, either natural or modified, plays an important role in food preparations.

Starches contain only glucose residues. They are mixtures of the structurally distinct polysaccharides, amylose and amylopectin. Cereal starches usually contain 25 per cent amylose and 75 per cent amylopectin. Waxy or glutinous starches like waxy corn starch contain little or no amylose. Waxy varieties of corn and sorghum starches have found use in food-pie fillings and puddings. Amylose has great industrial possibilities and hence, by breeding, corn with starch of high amylose content (about 85 per cent), has been obtained. In addition to these components, starch granules commonly contain small amounts of proteins, fatty substances and inorganic material. The non-carbohydrate constituents are of relatively little importance in relation to food use, but they affect the physical properties of starch.

2.2 CEREAL STARCH STAGES

Starch occurs as granules in the cytoplasm of the cells. The granules remain essentially intact during most types of processing, such as milling, separation and purification of starch, and even during most types of chemical modification. The microscopic appearance of starch granules from different sources is different, and thus they can be identified by this method alone. The unique characteristics of granules are their sizes, shapes, uniformity, location, and the appearance of granules under polarized light

Within the starch granules, a mixture of linear and branched molecules is arranged in concentric shells. When parallel association exists between adjacent linear molecules or between the outer branches of the branched molecules, they are held together by hydrogen bonds resulting in crystalloid regions or micelles, and this causes the granules to be birefringent. More loosely packed regions are amorphous and they exist between the micelles in each concentric shell. Water can easily enter the amorphous regions of the grain.

Table : Characteristics of Starch Granules

Source	Range in sizes in microns	Average Size in microns	Appearance
Corn	4-26	15	polygonal continuous distribution of sizes
Waxy Com	4-25	15	-
Sorghum	6-30	15	-
Barley	2-35	-	Round and elliptical
Rice	3-9	5	Small Polygonal
Wheat	2-38	20-22	Mixture of small round and large Lenticular Granules

Two different types of chains may be distinguished in a starch molecule. The linear is termed amylose and the branched amylopectin. Amylose is soluble in water. One type of starch differs from another both in the length of amylose and amylopectic chains and in the proportion of each type of starch chains. The gelling ability of a starch depends upon the amylose content and a high amylopectin levels lower the ability of the starch to form a satisfactory gel. Table 2.9 gives amylose percentage of different cereals.

Table : Amylose percentage of some starches

Starches	Amylose percentage
Waxy com	0
Rice	16
Potato	20
Wheat	22

2.3 GELATINISATION

Starch granules do not dissolve readily in cold water but they will form a temporary suspension with the starch tending to settle out as soon as the mixture is allowed to stand. When heated with water, the intramolecular hydrogen bonding is broken and grains absorb water and (a) swell, (b) the viscosity increases until a peak thickness is reached and (C) the translucency of the mixture also increases.

The term gelatinization is used in general to describe these changes. The changes appear to be gradual over a temperature range during gelatinization. The change transforms the temporary suspension into a more permanent one.

The swelling of starch particularly amylose resulting in the formation of a gel with water is believed to occur through the binding of water. In starch, the amylose and amylopectin molecules are loosely bound together by hydrogen bonds of the hydroxyls. The hydrogen on the hydroxyl on one molecule is attracted by the negative charge of the oxygen of a hydroxyl on other molecule and this attraction forms a weak link between the molecules.

As the temperature increases of the starch water mixture, the hydrogen bonding decreases for both the starch-starch bonds and water-water bonds and the size of the particles diminishes. Increasing water molecules begin to penetrate freely between the starch molecules when their kinetic energy becomes great enough to overcome the attraction between starch molecules. Two starch molecules which were originally bound together are now two starch molecules with water in between. The sticking together of granules is the result of molecules from adjacent granules becoming attracted and enmeshed in one and other. The changes brought about by hot water on starch are irreversible.

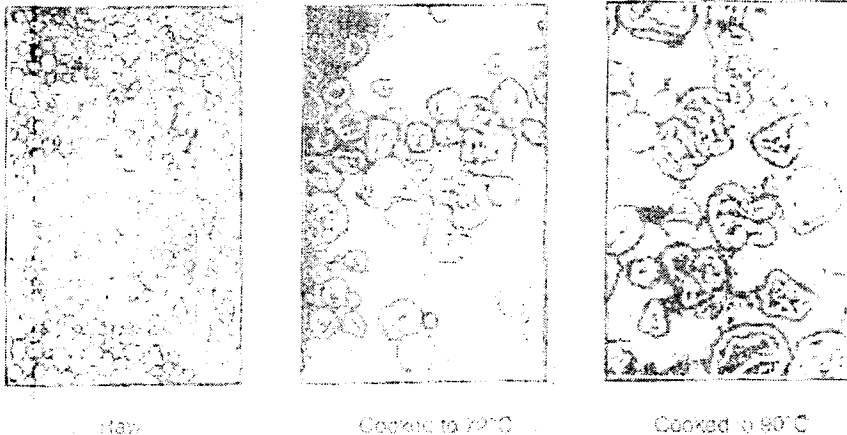


Figure 2-4: Microscopic examination of raw and cooked corn starch.

Source: Benjamin M., 1994, *Introductory Foodsc*, Prentice-Hall Inc.

2.3.1 Gelatinisation temperature:

A starch mixture will start to thicken somewhere between 70°C and 88°C but complete gelatinization will not occur until the mixture is close to or at the boiling point. This will vary with the type of starch and size of the grain. The gelatinization temperature range is characteristic of a starch and serves as an additional index for identification.

Larger grains swell at a lower temperature, gelatinization is complete for starches such as potato at a lower temperature because of the larger size of the granules. In any case, swelling is usually complete at a temperature of 88°C-99°C. Depending on the variety and storage conditions, gelatinization temperature varies.

The increase in the viscosity of the heated starch mixture is caused by the action of the enlarged starch granules bumping against each other, trapping the water and inhibiting its free flow. Once a starch mixture has reached the temperature at which gelatinization takes place, the mixture needs to only be held at that temperature until the flavour of the uncooked starch has disappeared.

Completely gelatinized starch should not be stirred unless necessary since the swollen granules are easily broken. The broken grains and fragments will thin out of the mixture. As the cooked starch mixture cools there is a marked increase in stiffness of the gel formed. This is due to the decrease in kinetic energy which keeps the molecules from reassociating.

Basmati rice are preferred because after cooking, they are soft non sticky, possess pleasant aroma and show linear kernel elongation without significant increase in breadth.

2.4 FACTORS AFFECTING GELATINIZATION

Temperature and time of heating: Starch pastes may be prepared most quickly by bringing them to a boiling temperature over direct heat, constantly stirring as they thicken and simmering

them for approximately one minute. Under carefully controlled conditions, starch pastes that are heated rapidly are somewhat thicker than similar pastes heated slowly.

Proportions of starch: More concentrated dispersions of starch show higher viscosity at lower temperatures than do less concentrated mixtures because of the larger number of granules that can swell in the early stages of gelatinization. Each type of starch gelatinizes over a characteristic temperature range; although this range may be affected by starch concentration.

Types of starches: The starches vary in their thickening power. Wheat starches gelatinize earlier compared to rice, sorghum or corn starch. Corn or sorghum starch give opaque pastes of higher viscosity than wheat starch at the same concentration. Waxy corn starch (more amylopectin) does not form a gel and remains clear because of lack of amylose. Flour that has been browned has less thickening power as some of the starch molecules had been converted to dextrins.

Agitation or stirring: Stirring while cooking a starch mixture is desirable in the early stages for obtaining uniform consistency. However if agitation is too intense or continued too long it accelerates the breakdown or rupturing of the starch and decreases viscosity and may give a pasty mouth feel.

Addition of other ingredients:

Sugar: The sugar added decreases the thickness of the cooked product. Sugar limits the swelling of starch grains while competing with them for water. In addition, it elevates the temperature at which starch grain begins to thicken a liquid. It also makes the swollen grains more resistant to mechanical rupture after they are gelatinized.

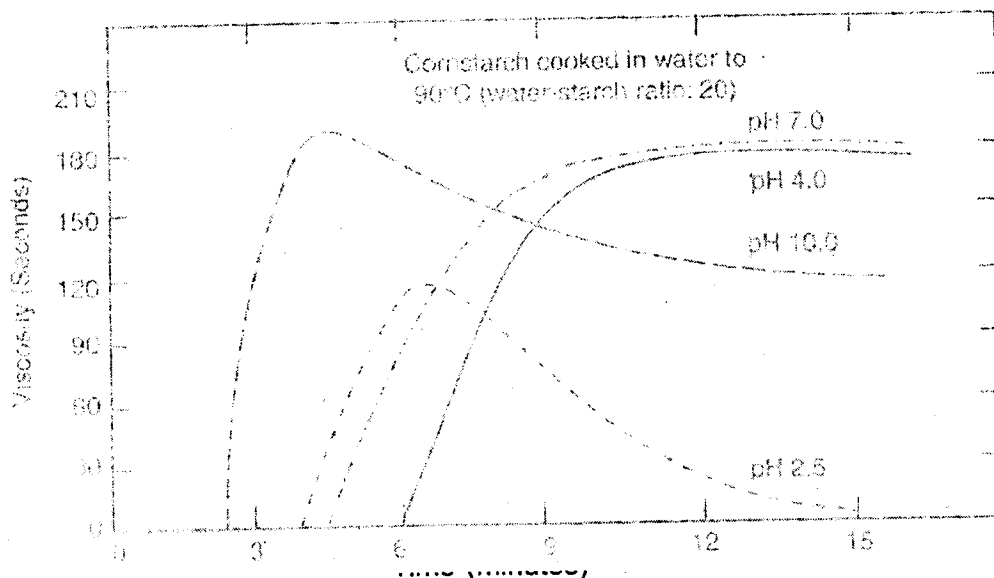


Figure 2-g : Effect of pH on gelatinization and breakdown of corn starch

Source : Paul, C. Pauline and Helen Palmer, 1976, Food theory and Application, John Wiley & Sons, Inc., New York.

In a recipe calling for a large amount of sugar, only part of the sugar needs to be added before cooking. After the starch mixture has been cooked, the remainder of the sugar can be added with much less effect on viscosity.

Acid: Acid in the form of vinegar or lime juice reduces the thickness of hot starch paste and the firmness of the cooled paste. The decrease in thickness and stiffness has been attributed in part to fragmentation of swollen granules and hydrolysis of starch molecules. Acid and heat catalyse the hydrolysis of starch to dextrins. Acid hydrolysed starch, when it is boiled hydrates at lower temperature than the unmodified starch. Acid thinned starch is often used in confectionery industry.

In cooked starch mixtures like custards containing fruits some amount of thinning occurs. When a high concentration of sugar is also present in a starch paste, the sugar may help to decrease the effect of acid, because sugar limits the swelling of starch granules and starch molecules are therefore not as available for hydrolysis of acid. Acid juices such as lemon juice can also be added after the starchy paste has been cooked. This limits the acid's contact with starch molecules.

Fats and Proteins : The presence of fats and proteins which tend to coat starch granules and thereby delay hydration also lower the rate of viscosity development.

2.5 STARCH AS THICKNESS OF SOURCES OF STARCH

As a starch thickened mixture is cooled without stirring after gelatinization is completed, additional changes ensue.

Gelformation: Gelation takes place on cooling of the starch paste after the starch granules have been gelatinized. Gel formation in cooked starch pastes is a gradual process that continues over a several hour period as the paste cools. Waxy varieties of starch without amylose do not form gels. Starches containing relatively large amounts of amylose such as corn starch, form firmer gels than starches with a somewhat lower concentration of amylose, such as tapioca.

Many starch molecules are disrupted during the process of gelatinisation as the starch granules swell. Some of the molecules of amylose, the linear starch fraction leach out from the granule. Two or more of these chains may form a juncture point, creating a new bond, which gradually leads to more bonds and more extensively ordered regions. Bonding with the amylose molecules begins immediately after cooking. Amylopectin, the branch fraction, usually remains inside the swollen granule where it more slowly forms new bonds between branches in a process of recrystallization. Bonds formed between the branches of the bushy amylopectin molecules are weak and have little practical effect on the rigidity of the starch paste; however, bonds between the long chain amylose molecules are relatively strong and form readily. This bonding produces a three-dimensional structure that results in the development of a gel with the amylose molecules forming a network that holds water in its meshes. The rigidity of the starch mixture is increased.

2.6 RETROGRADATION OF STARCH

As starch thickened mixture continues to stand after gel formation is complete, the process of retrogradation may occur. Additional bonds are formed between amylose molecules – as it was in the original state. Structural transformation occurs during storage. As starch pastes are cooled and stored, the starch becomes progressively less soluble. Starch becoming less soluble, like in its original state, is called retrogradation. Amylose undergoes retrogradation at more rapid pace than does amylopectin.

Freshly-baked chapathis are soft, pliable and elastic but on storage become hard and brittle. Similar problem has been encountered in case of stale bread, where in the crumb becomes hard, dry and crumbly. Retrogradation of starch is the prominent factor bringing about staling. Hardening of crumb structure is due to physical changes in branched chain wheat starch molecules within the swollen granules amylose fraction retrogrades rapidly during initial cooling. Retrograded amylopectin can be reverted to its amorphous state, when energy equivalent to a 40-50°C temperature increase is applied. Retrogradation of amylose is not reverted by heat. Stale bread reverts to freshly-baked bread when the bread in a moist state is heated at 95°C. Surfactants may also be helpful in restoring original freshness.

Syneresis: Some of these molecules aggregate in a particular area in an organized, crystalline manner. As the amylose molecules pull together more tightly, the gel network shrinks and water is pushed out of the gel. The process of weeping called syneresis results from the increased molecular association as the starch mixture ages ultimately an ordered crystalline structure develops.

2.7 CEREAL PROTEIN – GLUTEN

Although all cereals are more or less similar in protein content the unique presence of glutenin and gliadin in the wheat makes it suitable for certain recipes. Glutenin or glutelin is the protein which gives toughness and rubberiness to gluten. Gliadin gives elasticity. Glutenin is a much larger molecule than gliadin. Greater the amount of gliadin, softer will be the gluten.

Gliadin and glutenin proteins have their own tertiary structure due to various types of bonds including the disulphide (S-S) bonds. During dough formation, the disulphide (S-S) bonds are cleaved the sulphahydril bonds also make important contributions to dough development.

2.8 DOUGH

During the mixing of a dough the long strands of glutenin evidently become aligned in the directions of mixing and associated with gliadin molecules to form a strong elastic uniform film that envelops the starch granules in the dough. In the presence of lipids, water and with mechanical agitation, the protein fraction forms a tough elastic complex termed gluten which is capable of retaining gases and by doing so a leavened product is obtained. Due to its elastic property, the dough can be rolled since gluten is not developed.

Gluten from strong flour is more perfect colloidal gel, as shown by its greater hydration capacity than gluten from a soft flour. Baking quality of flour depends on both the quantity and quality of gluten that can be formed from it. High structural products like bread and bun require stronger quality of gluten while low structural products like biscuits and cakes do not require strong gluten.

The insoluble protein gluten can be separated readily from flour by adding water to form stiff dough and then kneading in water to wash away other constituents, largely starch. The wet gluten is a cohesive, elastic mass that expands greatly on baking to form a light porous ball. Baked gluten contains about 85 per cent protein, 8 per cent lipids and variable amounts of starch depending on the thoroughness of washing. Baking the gluten shows that it expands greatly as the steam within it expands and that it coagulates when heated to form the structure of the baked product.

2.9 FACTORS THAT AFFECT THE GLUTEN FORMATION

Mechanical action: In the dough is under mixed, enough gluten is not developed to retain the gas well, with the result the loaf is heavy and poor in volume. Over-kneading declines the elasticity of gluten and the dough becomes sticky and the volume of the loaf poor. In making chapattis, too little or too much gluten results in poor quality.

Proteolytic enzymes: These are a group of enzymes present in wheat flour which catalyze the hydrolysis of proteins. They are also present in malted flour and yeast. Since the strength of the gluten depends on the intact protein, any reaction which hydrolyses part of the protein reduces the amount of gluten. If too much of these proteolytic enzymes is present, too much hydrolysis occurs and the dough becomes sticky, difficult to machine in the mixers and yields bread of poor volume. Some protease activity is desirable, since it improves the glutes. Doughs of low proteolytic activity are tough and inelastic. It does not machine well and it also produces loaves of poor volume since the dough will not stretch around the gas bubbles. The quantity of proteolytic enzymes must be balanced so that enough hydrolysis occurs to produce an elastic gluten but not so much that the gluten is sticky.

Oxidising agents: Potassium bromated, potassium iodate are dough conditioners. Chlorine, chlorine dioxide and nitrosyl chloride, bleach, mature and improve the flour.

If an oxidising agent is added either to flour or to gluten the strength of gluten is increased. If large amounts are added gluten becomes tough with little elasticity. Reducing agents have the opposite effect. They reduce the strength of gluten making it more extensible and sticky.

Fermentation, oxidation and kneading change the bonding of protein molecule. Oxidation affects the sulphhydryl group and increases the number of S-S links. If the S-S links are formed between the polypeptide chains, they will hold the molecule together more firmly and increase its strength. The amount of oxidation is critical and although the amount of oxidizing agents needed is small, sufficient must be present to yield gluten strong enough to retain the gas formed but not so tough that it will be unable to stretch around the gas bubbles.

Other factors: Raw milk decreases the proteolytic enzymes and makes gluten sticky. Heating the milk to 82.2°C for 30 minutes has no detrimental effect on gluten strength. Milk should be scalded before use in a dough.

In general calcium salts present in the hard water tend to increase the elasticity of gluten. NaCl likewise affects gluten. Acids also alter gluten strength. Too much of vinegar diminishes gas retention. Fats in small amounts increase the ability of dough to retain gas.

2.10 SUMMARY

In the confectionery industry, maize starch powder and its derivatives like liquid glucose, thin-boiling starch, dextrin, dextrose, sorbitol and malto-dextrin are being used in large quantities. In our country, there is negligible use of these products except for liquid glucose which is used in substantial amounts.

Maize starch powder itself is used in the manufacture of chewing gum, pastries and panned sweets. In India, starch is generally used as a dusting powder in the confectionery industry. Starch derivatives like crystalline dextrose, sorbitol and maltodextrin are used in the confectionery industry

because they confer special characteristics to confectionery, such as prevention of drying, improvement of shelf life, increase of nutritive value, etc. As already stated, the use of these derivatives in the confectionery industry in India is negligible.

2.11 SELF ASSESSMENT QUESTIONS

1. Describe what happens when dry starches are heated. What is this process called?
2. Describe what happens when starch granules are heated in water. What is the process called?
3. Describe the general effect to each of the following on the thickness of a cooked starch mixture;
 - a) rate of heating
 - b) excessive stirring
 - c) addition of sugar.
4. Distinguish between
 - a) Gelatinization and gelation.
 - b) Retrogradation and syneresis.
 - c) Amylose and amylopectin.

2.12 REFERENCE BOOKS

1. Food Science (fifth edition) – B. Srilakshmi (2009)
2. Foods – Facts and Principles – N.Shakuntala Manay & M.Shadaksharaswamy (2001).

Mrs. CH. MANJULA

Lesson – 3

SUGAR COOKERY

3.0 OBJECTIVE :

After reading this chapter, you should be able to :

- Know the stages of Sugar cookery
- Describe crystalline and non-crystalline candies
- Roll of sugar in the preparation cakes and Indian sweets, browning reaction

STRUCTURE

3.1 Introduction

3.2 Stages of sugar cookery

3.3 Crystallisation

3.4 Factors affecting crystallization

3.5 Crystalline candies

3.5.1 Method of making fondant

3.5.2 Fudge

3.6 Non-Crystalline candies

3.6.1 Brittles

3.6.2 Caramels

3.7 Role of sugar in Indian sweets

3.8 Browning Reactions (Nonenzymic)

3.9 Summary

3.10 Self assessment questions

3.11 Reference Books

3.1 INTRODUCTION

Sweeteners have been used for food since prehistoric times, probably beginning with the discovery of honey. Desire for sweet taste is inherent in every individual. Sugar and jiggery are used in beverages and other foods to increase palatability. India produced 192 lakhs tones of sugar in the year 2005-06. It is expected to produce 230 lakh tones for the year 2006-07.

Molasses, which contains the natural ash of the plant juices from which it is made, furnishes some nutrients other than carbohydrate such as a small amount of calcium and iron.

Solubility: In the natural state of foods, sugars are in solution. Crystallisation of sugar occurs from a sufficiently concentrated sugar solution, and use of this is made in the commercial production of sugar from sugarcane and beets. The most-soluble sugar is fructose, followed by sucrose and lactose. The sugar that is the most soluble such as fructose is most difficult to crystallize than that the least-soluble sugar, lactose.

Absorption of moisture: Sugars rehygroscopic. Fructose is more hygroscopic than the other sugars. Cakes made with honey, molasses remain moist for a long time.

Fermentation: Most sugars, except lactose, may be fermented by yeasts to produce carbon dioxide gas and alcohol. This is an important reaction in making bread and other baked products. The carbon dioxide leavens the product and the alcohol volatilizes during baking.

Acid hydrolysis: Sucrose is easily hydrolysed by acid but maltose and lactose are slowly acted on. The end products of sucrose hydrolysis are a mixture of glucose and fructose. This mixture is commonly called *invert sugar*. The monosaccharides are not appreciably effected by acids. Heat accelerates the action of acid.

Enzyme hydrolysis : The enzyme sucrose also called invertase is used in the candy industry to hydrolyse some of the sucrose in cream fondant to fructose and glucose. This is done to produce soft, semifluid centres in chocolates. The enzyme is commonly added to the fondant layer around the fruit in chocolate coated cherries.

Melting point and decomposition by heat:

Caramelisation : With the application of sufficient dry heat, sugar melts or changes to a liquid state. Heating beyond the melting point brings about a number of decompositional changes. As sucrose melts around 160°C, a clear liquid forms that gradually changes to a brown colour with continued heating. At about 170°C, caramelisation occurs with the development of characteristic caramel flavor along with the brown colour.

Caramelisation is a complex reaction, involving the removal of water and eventual polymerization, Caramel has a pungent taste, is often bitter, is much less sweeter than the original sugar from which it is produced, and is non-crystalline. It is soluble in water. Fructose caramelizes at 110°C, and maltose caramelizes at about 180°C, galactose at 170°C.

Decomposition by alkalies:

The monosaccharides are markedly decomposed by alkalies and flavor may become strong and bitter. Sucrose is least affected by alkalies.

Sweetness: Of the sugars, lactose is the least sweet, followed by maltose, galactose, glucose and sucrose with fructose being the most sweet. A maximum sweetness from fructose is most likely to be achievement when it is used slightly with acid, cold foods and in beverages.

3.2 STAGES OF SUGAR COOKERY

Testing the doneness of sugar mixtures by measuring the temperature of the boiling solution is a method of estimating the concentration of sugar in the mixture. The final concentration of

sugar is related, in general to the consistency of the product when it is completely prepared, the more concentrated the sugar solution, the firmer the consistency of the finished product.

Table : Stages of Sugar cookery

<i>Product</i>	<i>°C</i>	<i>°F</i>	<i>Doneness</i>	<i>Description of test</i>
Syrup (Gulab Jamun, Jalebi)	110-112	230-234	Thread	Syrup spins a 2-inch thread between thumb and first finger.
Barfi Fondant Fudge	112-115	234-240	Soft ball	Syrup when dropped in cold water forms ball that flattens on removal from water.
Boondi Laddoo	118-120	244-248	Firm ball	Syrup when dropped into very cold water, forms a ball that does not flatten on removal from water.
Divinity Marshmallows	121-130	250-256	Hard ball	Syrup when dropped into very cold water, forms a ball that is hard enough to hold its shape.
Butterscotch Toffies Athirasan	132-143	270-290	Soft crack	Syrup when dropped into very cold water, threads that are hard but not brittle.
Brittle Glace Chikki	149-154	300-310	Hard crack	Syrup when dropped into very cold water threads that are hard and brittle.
Barley Sugar	160	320	Clear liquid	Sugar liquefies.
Caramel (Peanut brittle)	170	338	Brown liquid	Liquid becomes brown.

Source: Manay Shakunthala, N. and Shadaksharaswamy, M., 2001, Foods—Facts and Principles, New Age International Publishers, New Delhi.

3.3 Crystallisation

A crystal is composed of closely-packed molecules arranged in a pattern. Crystallisation occurs only if the solution is supersaturated. The size of the crystals produced will depend on the rate of the formation of nuclei about which the crystals grow and the rate of growth of crystals around the nuclei. If only one or two nuclei are formed, the size of the crystals produced will be large but if the rate of formation of nuclei is very rapid, many small crystals will form. Both the rate of crystallization and the rate of nuclei formation are modified by many factors.

Microscopic examination of crystals:

Place a drop of turpentine on a microscope slide and add a very small grain of the candy. Place a cover slip on top and move it around to make a very thin layer of the candy crystals. View under the microscope and compare the size of crystals.

3.4 FACTORS AFFECTING CRYSTALLIZATION

Nature of the crystallizing substances: Some sugars like glucose do not have the ability to produce very large crystals, rather they produce nuclei rapidly. Thus formation of many small crystals take place Probably because it causes the breaking of many nuclei from crystals already formed.

Concentration of the solution (saturation): Fairly large amounts of sugar dissolve easily in water. Higher the temperature of water, greater the amount of sugar that will dissolve in it. Maltose and Glucose are less soluble than sucrose. Hence, when syrups containing a large proportion of these sugars are used, more water must be added to dissolve them. The right conditions for rapid crystallization is to have the syrup to heat upto the right temperature or adjust to the right concentration. The lower the temperature the smaller the size of the crystals. Gulab jamun and jalebi syrups are not supersaturated solutions hence do not crystallize.

Agitation or stirring: Agitation favour the formation of finer crystals than are produced spontaneously. Stirring brings the supersaturated solution in contact with each crystal. It is important to stir crystalline candy not only until crystallization starts, but until it is complete.

Impurities: Impurities that may be deposited on the crystals reduce the growth of the crystals. The presence of glucose interferes with the crystallization of sucrose. Another way an impurity may interfere with crystallization is by coating the crystals. The use of fat, flour, milk, coconut, nuts, interfere with the crystal formation. For example, in making mysore pak, flour and fat are added which interfere with crystallization.

Addition of acid: An acid ingredient like cream of tartar, lemon juice or vinegar may be added to hasten the inversion of sucrose to glucose and fructose. For example, addition of citric acid and jams and jellies prevent crystallization. In sweet pickles when mango is used crystallization of prevented.

Boiled sugar solutions may be treated to produce either crystalline or non-crystalline candies. Crystalline candies are generally soft. If properly made, they are so smooth and creamy that the tiny sugar crystals that make up their microscopic structure cannot be felt on the tongue. The principal crystalline candies are fondant, mysore pak and coconut burfi.

Non-crystalline candies are sometimes called amorphous which means "without form". In their preparation, by use of various techniques, crystallization of sugar is prevented. Non-crystalline candies may be chewy, such as caramels or hard such as butter scotch, toffees and brittles.

3.5 CRYSTALLINE CANDIES

Fondant is the soft smooth candy that results from the cooking of a sucrose solution to a certain temperature, after which the solution is cooled and beaten until crystallization occurs. Addition of acid accelerates inversion and use of milk or creams as the liquid, increases the creamy character of fondant.

3.5.1 Method of making fondant

1. Mix 200 g sugar with 120 ml of water and boil till 113-114°C.
2. Allow it to cool to 40°C without disturbing.

3. Beat continuously until it becomes a creamy mass. At first the mixture becomes cloudy from the air beaten to it and then sets into a stiff mass.

As the hot syrup cools to 40°C it becomes saturated and then super-saturated because it is holding in solution more solute (Sugar) than is normally soluble at the lower temperatures.

An important aim in making crystalline candies is to produce a very smooth texture. For this, many fine crystals, rather than few large crystals must be formed. For this many nuclei are required. These act as centres around which crystal formation may begin.

Ripening: As crystalline candy stands after crystallization is complete, it becomes somewhat more moist and smooth and kneads more easily, because some of the very small crystals dissolve in the syrup. Changes that occur during the initial period of storage are called ripening. Absorbed substances that interfere with crystallization aid in retarding the growth of crystals during storage.

Fondants are used in making mints. Fondants are used in confectioneries for numerous purposes. Softened fondant is used in coating fruit and nut mixtures that are moulded and sliced.

3.5.2 Fudge

The principles of making fudge do not differ from those of making fondant. Usually, the butter or margarine, the fat of chocolate and the milk furnish the substances that interfere with crystallisation.

Recipe

Sugar	200 g	Butter	15 g
Milk	120 g	Chocolate	20 g

Method

- Melt chocolate and butter. Add sugar and mix well.
- Add milk and heat till the sugar dissolves completely.
- Cook the syrup to a soft ball stage – 112°C.
- Allow it cool to about 70°C and transfer to a greased pan and cut into pieces.

The presence of substances that interfere with crystallization of sucrose in fondant and other candies is desirable, but at an optimum level. Glucose, corn syrup or invert sugar either added directly or formed by acid hydrolysis, affect crystallization because they make the sugar solution more soluble and therefore, decrease the case of crystal formation. Other substances including fats from milk, cream, butter, margarine and chocolate and proteins from milk and egg white do not themselves crystallize. They physically interfere with the process of crystallization, retarding the growth of crystals. All these interfering substances aid in fine crystal formation and smooth texture in crystalline candies.

The temperature at which crystallization occurs affect the size of crystals, primarily because it affects the rate of crystallization. In general, the higher the temperature at which crystallization occurs, the faster the rate of crystallization and the more difficult is to keep the crystals separated, resulting in larger crystals. Cooling the mixture to about 40°C before starting to beat it favours the

formation of more nuclei and finer crystals. The viscosity of a solution is also greater at lower temperatures. High viscosity is a further aid in the production of fine crystals because it retards crystallization. Too low a temperature may also hinder the formation of many nuclei.

3.6 Non-Crystalline candies

Sugar does not crystallize in non-crystalline candies. The crystallization is prevented by cooking at very high temperatures so that the finished product hardens quickly before the crystals have a chance to form, adding such large amounts of interfering substances that the crystals cannot form or combining these methods.

3.6.1 Brittles

Brittles are cooked to temperatures that are high enough to produce a hard, brittle candy that solidifies before it has a chance to crystallize. The brown colour and characteristic rysta of brittles result from non-enzymatic browning reactions, probably both the maillard-type and the caramelisation of sugar. The development of caramel also helps to prevent crystallization of sugar in the brittles because it is non-crystalline.

Some brittles and groundnut chikkis are made merely by melting and caramelizing sucrose. Soda is sometimes a constituent of brittles and is added after cooking is completed. It neutralizes acid decomposition products and forms carbon dioxide gas, which gives the candy a porous texture. The rysta is also made milder and less bitter by the use of soda. The degree of bitterness in a brittle depends on the extent of decomposition of the sugar. Brittles include butterstotch and toffee.

3.6.2 Caramels

Caramels are firm non-crystalline candies containing large amounts of interfering substances. These are cooked to temperatures between those for crystalline candies and those for hard brittle candies. The added substances that interfere with crystallization are usually butter or margarine and viscous corn syrup, molasses which contain glucose, fructose and invert sugar. Corn syrup also contains dextrin which does not crystallize.

3.7 ROLE OF SUGAR IN INDIAN SWEETS

- It is used as sweetening agent in ice-creams and beverages like coffee, tea, cocoa, milk shake and sharbath and sweets.
- It lowers the freezing point which is important in making ice creams.
- It is used in the form of syrup in preparations like gulab jamun and rasgulla.
- In high concentration, it prevents the growth of micro-organisms. This principle is used in preserving jams and jellies.
- Sugars and bulk.
- Caramel sugar is used in puddings to improve colour and rysta.
- It is used in making bread to increase the fermentation of yeast.

- It gives not only sweetness but also body to the products like jam, pudding, fondant and ice-cream.
- It helps in improving the texture of cake and confectionery.
- Property of crystallization of sugar is used in preparations like badushah, laddoo, fondant and fudge.
- Improve colour and antioxidant activity by Maillard reactions.

The role of Sugar in preparation of cakes:

It has a tendering effect on the gluten and egg protein of the batter. Greater the amount of sugar the more pronounced is its effect. A batter with too much sugar will produce a cake of small volume with sugary crumb. A finely granulated sugar has the advantage of blending completely with the other ingredients. The function of sugar in a floured mixture is to sweeten, to develop gluten strength, to develop colour and crispness. It acts as a creaming agent with fat.

3.8 BROWNING REACTIONS (Non-enzymic)

The nonenzymic browning reactions are responsible for the colour and rysta of foods, such as dates, honey and chocolate. The distinctive flavours that coffee beans, groundnuts, cashewnuts and breakfast cereals develop after roasting is due to browning reactions. The presence of reactive reducing sugars are responsible for browning in foods. On heating they undergo ring opening, enolisation, dehydration and fragmentation. The unsaturated carbonyl compounds that are formed react to produce brown polymers and rysta compounds. The heat-induced browning reactions occur in two ways; caramelization and the Maillard reaction.

Caramelization : Sugars in dry condition or their syrups, when heated undergo a number of reactions, depending upon the temperature and presence of catalysts. Generally, there will be reactions leading to equilibration of anomeric and ring forms, inversion of sucrose, condensation reactions leading to the formation of oligosaccharides and polysaccharides, isomerization, dehydration and fragmentation, leading to the formation of unsaturated polymers with brown colour. With the use of proper catalysts it would be possible to conduct caramelization to provide either flavouring or colouring caramel for food use. For the manufacture of caramel colours for use in beverages, glucose syrups treated with dilute sulphuric acid partially neutralized with ammonia are used.

Maillard reaction: The Maillard reaction is actually a complex group of many reactions. The carbonyl group of acyclic sugars readily combines with the basic amino groups of proteins, peptides, and amino acids, resulting in browning is known as the Maillard reaction. The sugar-amines undergo resulting in brown colour at a lower temperature than that for the formation of the colour by caramelization. Hence, Maillard-reaction products predominate in brown foods. The condensation product of sugar and amine undergoes enolization and rearrangement and then undergoes condensation and polymerization forming red-brown and dark-brown compounds. The brown to black, amorphous unsaturated heterogeneous polymers are called "melanoids".

Inhibition of the Maillard-browning reaction can be accomplished by keeping the pH of the amino acids, peptides and proteins and by keeping the temperature as low as possible during

processing and storage. Use of nonreducing sugars, such as sucrose, under conditions not favouring inversion also helps bring down Maillard browning. Sulphur dioxide and sulphites used in extending the storage life of dehydrated foods, fruit juices and wines also inhibit the browning reaction.

3.9 SUMMARY

Apart from their nutritional value, sugars have other functions in foods. They function as humectants (compounds which absorb moisture from air), plasticizers, texturizing agents, rista producing agents and sweeteners. The first three of these functions depend upon the sugar-water relationship. The rista-producing function depends upon the reactions sugars undergo when subjected to heat in sterilization, cooking and dehydration processes. The sweetness of sugars depends upon their ability to form hydrogen bonds with water, with other polar compounds and among themselves.

Carbohydrates are hydrophilic to different degrees depending upon their structures. The rates and extent of water absorption by sugars depend upon their absolute purity, their anomeric purity, whether or not they form stable crystalline hydrates and the homogeneity of their crystalline structure. Water uptake causes dissolution, equilibration of anomeric forms and acyclic forms, and hydrolysis of glycosidic bonds. The hygroscopicity of sugars, dextrans and their mixtures is an important factor affecting the acceptance of confections, bakery toppings and instantly reconstitutable powders or granules that must not become sticky. Sugars like maltose and lactose, with their limited uptake of water, are particularly useful in such products. More hygroscopic liquid sugars, such as invert sugar or glucose syrup, are used to help retain moisture in baked foods, plastic confectionery and fillings that should not become brittle. To retain plasticity and inhibit crystallization, starch hydrolysates (which contains noncrystallizing maltooligosaccharides), or sorbitol, are used. Concentrated syrups are used to give a firm texture to fruits. These withdraw water from fruits by osmosis and sugar molecules enter the cells to form complexes with cell-wall polysaccharides, resulting in firmer structure.

3.10 SELF ASSESSMENT QUESTIONS

1. Explain the different stages of sugar cooker.
2. How does Crystallization of sugar take place? Explain the factors affecting crystallization.
3. Name any four Indian sweets and explain the precautions to be taken in preparing them.
4. What is caramel?

3.11 REFERENCE BOOKS

1. Food Science (fifth edition) – B. Srilakshmi (2009).
2. Foods – Facts and Principles – N.Shakuntala Manay & M.Shadaksharaswamy (2001).

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Lesson – 4**FATS AND OILS****4.0 OBJECTIVE**

After reading this chapter, you should be able to:

- Know the properties of fats and oils
- Describe the smoking point, melting point, hydrogenation and shortening affects of fats and oils.
- Know the changes during storage and rancidity

STRUCTURE**4.1 Introduction****4.2 Properties****4.3 Effect of heating****4.3.1 Smoke point, flash point and fire point****4.3.2 Melting point****4.4 Hydrogenation****4.5 Shortening effect of fat****4.6 Rancidity****4.6.1 Hydrolysis****4.6.2 Oxidation****4.6.3 Spoilage by microorganisms****4.6.4 Spoilage of salad dressings****4.6.5 Prevention of rancidity****4.7 Summary****4.8 Self Assessment Questions****4.9 Reference Books****4.1 INTRODUCTION**

Oils and fats have been used by man in food preparations for many centuries now. In the past, butter or ghee was used because it added richness of flavor and colour to the food preparation.

Today, in addition to butter, many oils and fats of animal and vegetable origin and many products developed from them are consumed by man. He also consumes fats in invisible forms. Many foods contain large amounts of fats that are not apparent in their appearance, e.g., avocados contain 16 per cent, egg-yolk 31 per cent, chocolate 35 per cent, beef (some cuts) 41 per cent, almonds 58 per cent and cheese 32 per cent fat.

Nutritional Importance of Oils and Fats

Oils and fats are important sources of our energy requirements. Weight for weight, they furnish 2.25 times more energy than proteins and carbohydrates. Thus, they help reduce the bulk of food we take. Besides being an important source of energy, oils and fats are excellent sources of fat-soluble vitamins A, D, E and K, and play a part in the biosynthesis of several long-chain alcohols.

Oils provide the essential fatty acid, linoleic acid, which is needed for human health. Excessive intake of saturated fatty acids increases the level of serum lipids and the incidence of arteriosclerosis and heart disease. A high level of consumption of unsaturated acids is thus necessary for normal health. Fatty acid composition of oils commonly used in India.

Essential fatty acids from fats are components of membranes of living cells. They are also used by the body to make prostaglandins involved in a large variety of vital physiological functions. They also play a role in immunity. Decreased availability of essential fatty acids can also lead to impaired growth and diminished mental and physical capacities.

Fats are slow in leaving the stomach and hence retard digestion. This delays the pangs of hunger. There is, however, no difference in the digestibility of different fats that are ordinarily constituents of foods; they are utilized to the extent of 95-98 per cent. The difference in digestibility that does exist is related to the melting point of the fat. Those which melt below 43°C are completely digested while those melting above 43°C are more slowly digested and less completely absorbed.

4.2 PROPERTIES

- They are concentrated source of energy. Weight for weight, they furnish 2.25 times more energy than proteins and carbohydrates. All oils and fats except butter give 900 kilocalories per hundred grams. Butter gives 729 calories as it contains more moisture.
- They reduce bulk in the diet.
- They are excellent source of fat-soluble vitamins A, D, E and K. Consumption is low because it is expensive. Butter contains 15,000 I.U. of vitamin A. Refined vegetable oil and hydrogenated shortenings contain little or no vitamin A but vegetable oils are good source of vitamin E.
- They play a part in the biosynthesis of several long chain fatty acids.
- They provide essential fatty acids, which are components of membranes of living cells.
- They are also used by the body to make prostaglandins involved in large variety of vital physiological functions. Fish is an excellent source of eicosapentaenoic acid (EPA) from which the body can make a hormone-like compound called a *prostaglandin*. This particular prostaglandin reduces the blood-clotting rate and thus the likelihood of a clot blocking the coronary arteries.

- Fats are slow in leaving the stomach and hence retard digestion. This delays the pangs of hunger. There is no difference in the digestibility of different fats. They are utilized to the extent of 95-98 per cent. Digestibility is related to melting point. Those which melt below 43°C are slowly digested and less completely absorbed.

Table : The important natural fatty acids and their occurrence

Fatty acids		Occurrence
Saturated acids		
Short chain		
Butyric acid	C ₄ : 0	Butter
Caproic acid	C ₆ : 0	Butter, coconut oil
Caprylic acid	C ₈ : 0	Butter, coconut oil
Medium chain		
Capric acid	C ₁₀ : 0	Butter, coconut oil
Lauric acid	C ₁₂ : 0	Butter, coconut oil
Myristic acid	C ₁₄ : 0	Butter, vegetable foods
Long chain		
Palmitic acid	C ₁₆ : 0	Most vegetable and animal fats
Stearic acid	C ₁₈ : 0	Most vegetable and animal fats
Arachidic acid	C ₂₀ : 0	Butter, lard, peanut oil
Behenic acid	C ₂₂ : 0	Vegetable oils
Monounsaturated acids		
Palmitoleic acid	C ₁₆ : 1	Olive oil, fish oil, beef fat
Oleic acid	C ₁₈ : 1	Olive oil, Canola oil
Erucic acid	C ₂₂ : 1	Rape seed oil, Canola oil
Polyunsaturated acids		
Linoleic acid	C ₁₈ : 2 (n-6)	Vegetable seed oils (Safflower, corn, soyabean, cotton seed)
Linolenic acid	C ₁₈ : 3 (n-3)	Vegetable seed oils (Soyabean oil)
Arachidonic acid	C ₂₀ : 4 (n-6)	Fat and phosphate fractions of animal tissues particularly liver, lard, meat
Eicosapentaenoic acid	(20:5) (n-3)	Fish oils and
Docosahexaenoic acid	(22:6) (n-3)	Shell fish

4.3 EFFECT OF HEATING

Fat gradually soften on heating, they do not have a sharp melting point. Since fats can be heated substantially above the boiling point of water they can brown the surfaces of foods.

4.3.1 Smoke point, flash point and fire point

Smoke point of a fat is the temperature at which smoke comes continuously from the surface of the fat. Because fats differ in their smoke points, fats to be used for frying should be chosen on the basis of their resistance to smoking at the temperature used.

When heated further smoke point they flash and burn. The temperatures at which these occur are known as the Flash point and Fire point.

Factors that lower smoking point

- The development of free fatty acids by some hydrolysis of the fat during frying causes a decrease in the smoke point.
- A fat that has had repeated or prolonged use will begin to smoke at a temperature too low for frying.
- Suspended matter such as flour or batter particles also lower the smoke point. And the greater the surface of the fat exposed, the lower is the smoke point.
- Fats heated in shallow wide pans with slightly sloping sides begin to smoke at lower temperatures than do those heated in smaller pans with vertical sides.

Table : Smoking temperatures of fats

Fat oil	Smoking temperature (°C)
Butter fat	208
Cotton-seed oil	230
Coconut oil	138
Groundnut oil	149-162
Hydrogenated fat	221-232
Lard	194
Olive-oil crude	176
Olive oil refined	234
Soyabean oil	230

The smoke point of a fat is partly a matter of its natural composition and partly a matter of the processing it has received. Soyabean, cotton seed, peanut and corn have smoke points of about 230°C (446°F). Hydrogenated fats smoke at 221° to 232°C. Shortenings containing monoglyceride as an emulsifier smoke at a lower temperature about 176°C. First, smoke is given off by the emulsifier and later the smoke point may raise from 190° to 193°C (375° to 380°F).

4.3.2 Melting point

Melting point of a fat is the temperature at which fat gets to melts is called as melting points of fat.

4.4 HYDROGENATION

By hydrogenating vegetable oils, it is possible to simulate a widely acceptable product like ghee. The process of hydrogenation changes liquid oils into more solid plastic shortenings and to increase the stability of the oils to prevent spoilage from oxidation. Oxidation of oil results in undesirable rancid flavour and odours.

Hydrogenation takes place in a reactor, where hydrogen gas is bubbled through the liquid in the presence of a nickel catalyst, which speeds up the reaction. In the process of hydrogenation some of the double bonds between carbon atoms of the fatty acid portion of the triglyceride molecule are broken and hydrogen is added. There is a decrease in the number of double bonds, an increase in the proportion of trans double bonds and a randomization of double-bond positions along the chain. This chemical change makes the fatty acids more saturated. The melting point of the fat is thereby increased. With sufficient hydrogenation it becomes solid at room temperature. Careful control of temperature and pressure in the hydrogenation process allows achieving the desired end result, that is, the proper degree of plasticity. The fat can then be creamed and blended with other ingredients. Hydrogenated fat is suitable for making cakes and biscuits.

Soyabean oil, cotton seed and palm oil are used for hydrogenation. Hydrogenation greatly improves the stability of soyabean oil and therefore its resistance to the development of undesirable flavours. Examples for hydrogenated fat are margarine, vanaspati, salad dressings and shortenings.

Indian vanaspati is prepared by partial hydrogenation of vegetable oils. It contains > 20% trans fatty acids and > 60% saturated fatty acids. (NIN-2000).

Hydrogenation changes the nutritional properties of fat. Polyunsaturated fatty acids not only become more saturated but the essential linoleic acid and possibly other unsaturated fatty acids lose biological activity when they are converted to the transform.

4.5 SHORTENING EFFECT OF FAT

Fat has a shortening power, that is, it interlaces between protein and starch structures and makes them tear apart easily. It makes the protein strands short rather than allow them to stretch long. Thus, they tenderize baked foods by preventing the cohesion of wheat gluten strands and are used in making biscuits, cakes, doughnuts, pastries and breads. The different layers developed in puffs, and in (khari) biscuits is due to the addition of fat which acts as shortening agent. The fat added to maida dough results in soft roti due to shortening property of fat.

One of the most important functions of fat is to shorten baked products which otherwise are solid masses firmly held together by strands of gluten. Being insoluble in water, fat interferes the hydration of gluten and cohesion of gluten strands during mixing, thus literally shortening them and making the product tender.

For products like pastry and biscuits, intimate mixture of the fat with the other ingredients is purposely avoided so that the fat will form layers between the strands of gluten. These products are likely to be flaky as well as tender. As flour and fat are mixed more thoroughly, the products may become more tender but less flaky. In making recipes like puffs and pastries too much mixing is avoided.

Manipulation, temperature, ingredients like flour and fat and their concentration affect the shortening power of fat.

Lard has a very high shortening value and butter, a lower value with hydrogenated shortenings intermediate. This is true in pastry made from water, flour and fat.

Different shortening agents are used in baking of different products. The usual fat used, if any, in yeast bread is butter or margarine. In biscuits, a hard fat must be used so that the fat can be distributed in small pieces to give the desired flakiness to the biscuits. Shortened cakes are made using plastic fat which combines readily with the ingredients in the flour mixture. Butter is used in puff pastry.

4.6 RANCIDITY

Spoilage of fats may occur on storage, particularly if the fats are highly unsaturated and the conditions of storage are conducive to chemical change in the fats. Rancidity is of two types—hydrolytic and oxidative.

4.6.1 Hydrolysis

Hydrolysis is brought about by enzymes that decompose fats into free fatty acids and glycerol. Butyric and caproic acids which are the volatile fatty acids predominating in butter are largely responsible for the odour and flavour of rancid butter. These acids may render butter inedible even when they are present in low concentrations.

Long-chain fatty acids such as stearic, palmitic and oleic acids do not usually produce a disagreeable flavour unless other changes such as oxidation also occur.

Heating thoroughly to destroy the lipase enzyme that catalyses the hydrolysis of triglycerides should prevent hydrolytic rancidity. Contaminating micro-organisms may also produce lipase and these can similarly be destroyed with sufficient heating.

4.6.2 Oxidation

Only unsaturated fats and foods which have lipoxygenase are susceptible to oxidative changes. Highly hydrogenated and saturated fatty acids are relatively resistant to oxidation. Hydroperoxides that are formed, break readily producing smaller volatile substances that give the characteristic odours of rancid fat. The reaction is a chain reaction that is self-perpetuating.

The development of rancidity is objectionable not only because of the undesirable changes in odour, flavour, colour and consistency of fat but because, it is accompanied by the inactivation of vitamin A and E. Oxidative rancidity may be a problem in dry foods containing only small quantities of fat, such as prepared cereals.

Fats subjected to either or both of these types of changes may contain fatty oxy and hydroxylacids, ketones and lactones may include trimethylamine, with its fishy odour.

4.6.3 Spoilage by microorganisms

Some of the pigments produced by micro-organisms are fat-soluble and therefore can diffuse into fat producing discolourations ranging through yellow, red, purple and brown. The fat soluble pigment is an oxidation-reduction indicator that changes from yellow to green to blue and

finally to purple as the fat becomes more oxidized by the peroxides formed by the bacteria. Yellow, pink and red fat soluble pigments may be produced by various bacteria, yeasts and moulds.

Among the bacteria that can decompose fats are species of *Pseudomonas*, *Micrococcus*, *Bacillus* and *Serratia*, *Achromobacter* and *Proteus* and among the moulds *Penicillium*, *Aspergillus*, *Cladosporium* and *Monilia*. Some yeasts are lipolytic, Copra and cocoa butter may be spoiled by moulds.

4.6.4 Spoilage of salad dressings

Salad dressings may contain oil which may become oxidized or hydrolysed and enough moisture to permit microbial growth. The three types of spoilage of mayonnaise and similar dressings are.

1. Separation of the oil or water from the emulsion.
2. Oxidation and hydrolysis of the oils by chemical or biological action.
3. Growth of micro-organisms to produce gas, off-flavours or other defects. Darkening often takes place.

Species of *Zygo saccharomyus* and *saccharomyces* have spoil mayonnaise, salad dressing and French dressing. *Bacillus subtilis* cause gas, rancidity and separation. Moulds can grow on salad dressings if air is available and are favoured by the addition of starch or pectin to the dressing.

4.6.5 Prevention of rancidity

Fats can be protected against the rapid development of rancidity by controlling the conditions of storage.

1. Storage at refrigerator and freezing temperatures prevent rancidity by reducing autooxidation.
2. Rays of light catalyse the oxidation of fats. By the use of coloured glass containers that absorb the active rays, fats can be protected against spoilage. Certain shades of green bottles and wrappers and yellow transparent cellophane wrappers are effective in preventing rancidity.
3. Vacuum packaging also helps to retard the development of rancidity by excluding oxygen.
4. Antioxidants naturally present in the food such as vitamin C, beta carotene and vitamin E protect against rancidity.
5. Antioxidants can also be added like butylated hydroxy anisole (BHA) butylated hydroxytoluene (BHT), tertiary butyl hydroquinone (TBHQ) and propyl gallate.
6. Substances like citric acid may be used alongwith antioxidants in foods as synergists. A synergist increases the effectiveness of an antioxidant but is not as effective an agent when used alone. Some synergists may be effective because of their ability to bind or chelate the metals and prevent them catalyzing the oxidation process. Chelating agents are sometimes called sequestering agents.

4.7 SUMMARY

In addition to their nutritional function oils and fats have their uses in cookery which are derived principally from their distinct physical properties. Fat is used in shallow and deep fat frying. Cooking oil is a better heat transfer medium than air or water in that it heats up very quickly because of its greater specific heat, and its operating temperature of about 200°C is considerably higher than that of water.

Pan frying is used to cook dosas, Chapatis, omelettes, cutlets and tikkis. Moderate temperatures are used as smoking of fat is a definite indication that decomposition is occurring and should never be permitted. In pan frying, the amount of fat used can be limited.

In basting, foods to be grilled like meat, poultry or vegetables are applied with fat to prevent the surfaces drying. Deep fat frying method is used in preparing pooris, vadas, cutlets, bajja and pakodas.

In deep fat frying, there is a direct transfer of heat from the hot fat to the cold food that continues until the food is cooked. Water is lost from the exterior surface of the food as it is converted to steam. The steam carries off energy from the surface of the food and prevent charring or burning. Water then migrates from the central portion of the food outward to the edges to replace that loss by evaporation. Finally the interior of the food is cooked. Sufficient heat must be transferred to gelatinize starch and coagulate proteins that may be present in the food. Most foods are fried at 117°C to 196°C.

Most oils and fats are suitable for use in frying but there are some exceptions like butter because the water content restricts the cooking temperature and the presence of short chain esters leads to rapid breakdown and discolouration on heating. Longer chain fatty acids in margarine is less vulnerable to thermal decomposition.

A satisfactory fat is one that has high decomposition point, a high smoking temperature with no undesirable odour. Suspended matter, such as flour or batter particles also lowers the smoke point. The greater the surface of the fat exposed to air, the more rapidly the smoke point is lowered.

Heated oils and their degradation products interact with the food being fried. Some materials are leached from the food into the frying fat and some of the fat itself is gradually broken down or degraded. Oxygen from the air may react with the fat as the fryer at the oil-air interface. This creates many different chemical compounds in the frying fat in addition to the basic triglyceride molecules that originally made up the fat. Some of the chemicals produced the surfactants that are molecules that interact at the air-oil or oil-food interfaces and lower the surface or interfacial tension.

4.8 SELF ASSESSMENT QUESTIONS

1. Define rancidity. Explain types of rancidity.
2. How does fat act as a shortening agent? Explain.
3. Define smoking point of fat. What changes occur in fat on heating?
4. Explain the changes that take place during rancidity. How do you prevent rancidity of fats?
5. Give four hydrogenated fats available in the market.

4.9 REFERENCE BOOKS

1. Food Science (fifth edition) – B. Srilakshmi (2009).
2. Foods – Facts and Principles – N.Shakuntala Manay & M.Shadaksharaswamy (2001).

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Lesson – 5

PULSE COOKERY

5.0. OBJECTIVE:

- To enhance nutrients through soaking and germination of pulses.
- To create the importance of pulse cookery in food science.
- To develop proper handling methods in pulse cookery.

STRUCTURE

5.1. Introduction

5.2. Pulse cookery

5.2.1. Factors affecting the quality of cooked products

5.3. Processing of pulses

5.3.1. Soaking

5.3.2. Germination

5.3.3. Fermentation

5.4. Various factors related to pulses

5.5. Summary

5.6. Self Assessment Questions

5.7. Reference Books

5.1. INTRODUCTION:

India is the largest producer of pulses in the world. The common pulses grown are chickpea, pigeonpea, mungbean, urdbean, lentil, fieldpea, moth bean, horse gram and lathyrus, containing small amount of fat, and offers a relatively cheap source of protein. Consumption of pulses is highest in India.

Pulses are relatively a cheaper source of protein than milk, cheese, cashew, almond, meat and fish etc., hence valuable for developing countries. The seeds of pulses are most commonly eaten can be economically stored well for future use. The food values of seeds of pulses is high, have about the same calorific value per unit weight as cereals and are fair sources of some vitamins and minerals. Their protein contents are generally about double that of most cereals. Consumption of pulses is highest in India as compared to other pulses growing countries due to low purchasing

power and religious restrictions on non-vegetarian diet. Pulses constitute essential components of vegetarian diet. Pulses are major source of protein in Indian vegetarian diet. These are main source of protein providing most of the essential amino acids to a certain degree. Economically, pulses are cheapest source of protein. Pulses are Bengal gram, pigeon pea, black gram, green gram, lentil, etc. Pulses are mainly consumed in the form of dehusked split pulses, as these are rich in proteins. In vegetarian diet pulses are main source of protein.

The pulses are subjected to various processing techniques like milling, dehulling, soaking, germination, fermentation and cooking. These processing techniques not only save time, energy and fuel but have several nutritional advantages and produce edible products having a higher nutritional value and lower toxic compound. The degrees of elimination of toxic compound depend on the type of pulses and processing techniques.

5.2. PULSE COOKERY:

Pulses may be defined as the dried edible seeds of cultivated legumes. They belong to the family of peas, beans and lentils. The English word pulse is taken from the Latin pulse, meaning pouage or thick pap. The pulses are a large family and various species are capable of surviving in very different climates and soils.

Green gram, red gram, bengal gram, horse gram, cluster bean, field bean, cow pea are some of the common types of pulses. In general, their protein content is high and is commonly more than twice that of cereal grains, usually constituting about 20 per cent of the dry weight of seeds. The protein content of some legumes like soyabean is as high as 40 per cent.

Toxic constituents of pulses

The seeds of pulses include both edible and inedible types. Even amongst the edible legumes toxic principles occur and their elimination is important in order to exploit them for edible purposes. Two thermolabile factors are implicated in toxic effects. Inhibitors of the enzymes trypsin, chymotrypsin and amylase haemagglutinins, which impede the absorption of the products of digestion in the gut. In addition, legumes also contain a goitrogen, a toxic saponin, cyanogenic glycosides and alkaloids.

Elimination of Toxic Factors

It has already been indicated that soaking, heating and fermentation can reduce or eliminate most of the toxic factors of the pulses. Correct application of heat in cooking pulses can eliminate most toxic factors without impairment of nutritional value. Cooking also contributes towards pulse digestibility. Heat causes the denaturation of the proteins responsible for trypsin inhibition, haemagglutination and the enzyme responsible for the hydrolysis of cyanogenic glycosides. The mode of application of heat is important. Autoclaving and soaking followed by heating are effective. Another way of eliminating toxic factors is by fermentation, which yields products more digestible and of higher nutritive value than the raw pulses.

Decortication:

A simple method is to soak the seeds for a short time in water; the husk takes up more water than the seeds and may be easily separated by rubbing while still moist. In the alternative, the soaked grains may be dried and the husk removed by pounding and winnowing. Roasting also renders the

husk easier to separate. Roasted legumes like those of Bengal gram and peas are widely used in India.

Cooking:

Cooking destroys the enzyme inhibitors and thus improve the nutritional quality of food pulses. Cooking also improves the palatability.

Pulse milling

Pulses are usually converted into Dhal by decutlating and splitting. Both dry and wet milling processes are employed. By and large carborundum emery rollers are used for dehusking and burr grinders for splitting. Decuticling is seldom complete in single pass requiring multiple passes, each pass producing 1.5 to 2% fines reducing recovery of dhal.

Basic processes in dhal milling are cleaning, dehusking, splitting, separation and bagging. Major variation is involved with dehusking process only. Dhals like Arhar, urad, moong and lentil are difficult to dehusk as a result repeated operations by dehusking rollers are required. Rewetting and drying is done to loosen portions of husk sticking after repeated rolling. Linseed oil is used to impart shine or better appeal to the milled dhal.

The removal of the outer husk and splitting the grain into two equal halves is known as milling of pulses. To facilitate dehusking and splitting of pulses alternate wetting and drying method is used. In India trading milling methods produce dehusked split pulses. Loosening of husk by conditioning is insufficient in traditional methods. To obtain complete dehusking of the grains a large number of abrasive force is applied in this case as a result high losses occur in the form of brokens and powder. Yield of split & pulses in traditional mills are only 65 to 75% due to the above losses compared to 82 to 85% potential yield.

Milling of Pulses

In India, there are two conventional pulses milling methods; wet milling method and dry milling method. The latter is more popular and used in commercial mills.

5.2.1 Factors effecting in quality of cooked products:

The hardness is of two types, hard shell and sclerema. Hard shell is described as a physical condition in which the seed fails to absorb water. Sclerema takes place in the cotyledon and induced by various factors.

Inherent Character: Some varieties are hard-to-cook inherently.

Storage condition: Cooking quality is influenced by time, temperature and relative humidity during storage. Cooking time for the same hardness increases with storage time. Moisture content during storage above 10% may cause deterioration in the cooking quality.

Seed maturity: High temperature at the time of maturing effects the cooking time. Cooking time increases in seed maturity. The very hard mature seeds take long time to cook.

Dehulling: This reduces the time by 70 percent and increases digestibility.

Soaking: Hard to cook condition can be eliminated by soaking seeds in salts solution consisting of 1 percent NaCl and 0.75 % NaHCO_3 instead of only water. Separation of cotyledon cell occurs in salt solution soaked seeds. Carbon of bicarbonate not only acts as an alkaline agent and buffer but also act as a protein dissociating, solubilising or tenderizing agent.

Pre-cooking: The cooking time for precooked lentil seeds is less compared to untreated ones. pre-cooking is done by cooking, treating with enzymes and dehydrating in controlled conditions.

Phytin content: High available phosphorus in the soil contributes to high phytin content in the seed and consequently to good cooking. Phytin has a softening action on peas during cooking by acting as a calcium absorbent, consequently preventing the formation of insoluble calcium pectate. When legumes are cooked in hard water, they take long time to get cooked. Hard water contains chlorides and sulphates of calcium and magnesium salts. They appear to react with pectic substances and phytates, harder the cellulose and delay the cooking of pulses.

Cellulose: The thickness of the palisade layer and the content of lignin and alpha cellulose in the seed coats are probably important factor in the cooking quality of pulses. Compared to other pulses, lentils require shorter time to cook due to their soft seed coat content. Sodium bicarbonate softens the cellulose and hastens cooking.

It has been proposed the polymerization of polyphenolic compounds in the seed coat where the substances are found and changes in the microbial structure of the cotyledons involving carbohydrates-pectic substances, phytic acid and potassium, calcium and magnesium ions, effects on cooking quality.

5.3 PROCESSING OF PULSES:

Processing of pulses is of primary importance in improving their nutritive value. The processing methods used are soaking, germination decortications, cooking and fermentation

5.3.1. Soaking:

Soaking in water is the first step in most methods of preparing pulses for consumption. As indicated above, soaking reduces the oligosaccharides of the raffinose family. Soaking also reduces the amount of phytic acid in pulses. soaking (in water and bicarbonate solution), ordinary and pressure cooking, germination and fermentation in reducing or removal of anti nutritional factors usually present in cowpeas (protease inhibitors, tannins, phytic acid and flatus-producing oligosaccharides (raffinose and stachyose). The results showed that long-time soaking (16 h) in bicarbonate solution caused remarkable reduction in the anti nutritional factors. Pressure cooking was more effective than ordinary. Cooking pre germinated cowpeas was most effective.

Advantages of soaking are an extra rinse and a shortened cooking time. It is debatable whether it is worth soaking split peas; they can be soaked in cold water for up to 6 hours to save approximately 30 minutes in cooking time. Soaked whole yellow peas, on the other hand, will produce a more viscous puree than unsoaked. For whole yellow peas, soak in cold water for 8 to 10 hours to shorten cooking time by 1 hour or more. Over-soaking whole yellow peas can cause germination to begin, producing "off" flavours.

5.3.2. Germination:

Germination improves the nutritive value of food pulses. The ascorbic acid content of pulses increases manifold after 48 hours germination. Germinated and sprouted pulses have been used to prevent and cure scurvy. The riboflavin, niacin, choline and biotin contents of all pulses increase during germination. The germination process reduces and/or eliminates most of the antinutritional and toxic factors in several pulses.

Sprouts from beans, pulses grains and seeds are super healthy for you. As healthy as they are on their own, the nutritional value they give increases by almost 30 - 60 percent when the sprout! That is significant and thus worth looking into. The goal here is germinating and sprouting the seeds or beans.

5.3.3. Fermentation:

The processing of food pulses by fermentation increases their digestibility, palatability and nutritive value. Fermentation process improves the availability of essential amino acids and, thus, the nutritional quality of protein of the blend. In general, the nutritive value of the legume based fermented foods has been shown to be higher than their raw counterparts.

Fermentation completely removed trypsin inhibitor, oligosaccharides and reduced remarkably phytic acid. However, tannins noticeably increased.

The nutritional value of pulses may be adversely affected by the presence of anti physiological or toxic substances such as trypsin and chemotrypsin inhibitors, phytates, lectins, polyphenols, flatulence causing agents, cyanogenic compounds, lathyrogens, esterogens, goiterogens, Saponins, anti-vitamins and allergens. These substances reduce the nutritive value of foods by inhibiting digestibility and utilization of proteins. It is therefore necessary to eliminate these substances by processing by genetic manipulation. Processing plays an important role in improving nutritive value of pulses and by decreasing anti nutritional factors up to a tolerable limit.

Lectins are protein aceous in nature and commonly found in some of the beans. Seeds of some of the edible species of pulses such as lentil and pea also contain phytohemagglutinins. It was observed that extracts from many edible crude bean seeds agglutinated red cells, but no toxic action was detected in these seeds. These are proteins which possess a specific affinity for certain sugar molecules. Most of the lectins contain 4 to 10% carbohydrates. The lectins from mung bean are non toxic, whereas the lectins obtained from immature seeds of pigeon pea and rice bean are harmful. Lectins reduce the bioavailability of nutrients, which is due to direct action of lectin on digestive enzymes. Preliminary soaking prior to autoclaving or cooking is required for complete elimination of the toxicity of lectins.

Tannin (Polyphenol) is known to form complexes with proteins under certain pH conditions. Tannins-protein complexes are reported to be responsible for low protein digestibility, decreased amino acid availability and increased fecal nitrogen. These complexes may not be dissociated and may thus be excreted with the feces. Among pulses, pigeon pea, urdbean and pea have highest tannins in seeds. It appears that tannins content in pulses varies with colour of the seed coat. Lower amount of tannins, in general are observed in light coloured seeds than brown dark coloured pulses. White seeded varieties of *Phaseolus vulgaris* are contain almost negligible tannins, while coloured varieties contain large quantities of tannins.

Benefits of fermentation

- The acid produced in sour fermentation helps to preserve the food. In fermented porridges, the main acids are lactic and acetic acids.
- In Tanzania, children given fermented porridge have less diarrhoea than children given unfermented porridge. Porridges are often contaminated with bacteria that cause diarrhoea because of impure water or poor hygiene. Fermentation helps to reduce contamination because these harmful bacteria cannot multiply as easily in fermented foods.
- Fermentation improves the absorption of important nutrients, particularly iron and zinc.
- Fermentation improves the protein content and adds vitamins and minerals.
- Many people prefer the flavour of fermented food. It has been suggested that the sour taste helps to restore appetite when people are ill.
- Fermentation reduces the toxin (cyanide) that is naturally present in cassava, particularly in the bitter varieties. The traditional way of making gari and farinha by grating cassava and then letting it soak in water to ferment, cleverly allows the acid to release the toxin. The benefit of this practice was appreciated by our ancestors, although the 'science' of it has been known only recently.

Fermentation is a good example of traditional wisdom! Unfortunately its use is in danger of declining in favour of western products. In Kenya the decline in some areas has been attributed to missionaries discouraging the preparation of sour porridges in the mistaken belief that they contain alcohol. Also, health workers tend to stress the need to prepare fresh food and so discourage the use of fermented foods. Encourage people to value their traditional fermented foods.

5.4. VARIOUS FACTORS RELATED TO PULSES:

Economically, the family is second only to the grasses in importance. Legumes provide valuable and nutritive foods because the food stored for the embryo in the seed (e.g., the pea) is rich in protein. In many regions, especially where meat is scarce or expensive, legumes—notably peas, beans, lentils, peanuts, carob, and soybeans—are staples of the diet. The Fabaceae are equally important as fodder and forage plants; clover, alfalfa, vetch, lupine, beggarweed, lespedeza, sainfoin, and soybeans are among the numerous valuable types.

5.5. SUMMARY:

Cooking methods play an important role in food science. Cooking of pulses soaking, use of sodium bicarbonate, acids, alkali or calcium salts affects the quantity of cooked pulses. Soaking and germination improves the quality and enhance the nutrients to the diet. Pulse are the best supplements for cereals. Thus cereal pulse combination improves the nutritional quality of diet. This combination is the most economic way to provide protein.

5.6. SELF ASSESSMENT QUESTIONS

1. Discuss the Factors that are effecting in quality of cooked products?
2. Explain about processing of pulses?
3. Describe the pulse cookery in detail?

5.7 REFERENCE BOOKS

- 1 Francis, 2003, Encyclopedia of Food Science and Technology. The computype media, New Delhi 110 002.
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Mrs. V. Chinnari Harika

Lesson – 6**MILK COOKERY****6.0 OBJECTIVE**

- To know properties of milk and milk products
- To create awareness in milk cookery
- To understand the composition of milk products

STRUCTURE

- 6.1. Introduction
- 6.2. Physical properties of milk
- 6.3. Handling of milk
- 6.4. Composition of milk
- 6.5 properties of milk protein
- 6.6. Summary
- 6.7. Self Assessment Questions
- 6.8. References

6.1. INTRODUCTION:

Milk is the one food for which there seems to be no adequate substitute. All mammals produce milk after the birth of the young ones and man has used the milk of many animals as his food. The cow is the most important of all these animals as supplier of food but buffalo or goat milk is also used.

Milk is a rich source of calcium. It is produced by the glands of mammals, humans included. They are processed in a sense so as to be sold and can be used by households. Raw milk is rich in essential vitamins and minerals. Cow's milk is the most widely use milk in the world and it is also used for other dairy products such as cheese, gelatto, ice cream and yogurt. Milk is a complex mixture of lipids, carbohydrates, proteins and many other organic compounds and inorganic salts dissolved or dispersed in water. The most variable component of milk is the fat followed by protein.

6.2. PHYSICAL PROPERTIES OF MILK:

Physically, milk is at once a rather dilute emulsion, colloidal dispersion and true solution.

Acidity:

Fresh milk has a pH of about 6.5 – 6.7 at 25°C. As milk stands exposed to air, its acidity decreases slightly because of the loss of carbon dioxide. Raw milk, which normally contains some lactic acid producing bacteria gradually increase in acidity on storage. Pasteurisation destroys lactic acid bacteria.

Viscosity:

Factors affecting viscosity of milk are state and concentration of the protein and fat, temperature of milk, age of milk. Conditions and treatments that affect the stability of casein are important in the viscosity of milk such factors as acidity, salt balance, heat treatment and the action of various enzymes and bacteria. The effect of milk fat depends on such factors as the amount of fat, size of the globules and the extent of clustering of the globules. Homogenisation and ageing increase viscosity.

Freezing point:

The freezing point of milk is -0.55°C. The freezing point is affected by the soluble constituents lactose and ash which are constant. This fact makes it possible to determine whether or not milk is diluted. Addition of 1% of water to milk decreases the freezing point by -0.0055°C.

Boiling point:

Milk boils at 100.2°C at which temperature all organisms are destroyed. The loss of some of the nutritive value of boiled milk is more than compensated by the avoidance of milk borne diseases.

There are twenty two different kinds of amino acids that are combined in different orders to form proteins. All but nine of the amino acids can be produced by your body. These nine amino acids are called essential amino acids because they are essential to good health and must be part of our diet.

Milk has many proteins, including the nine essential amino acids. The two basic types of proteins in milk are called casein and whey. Based on their chemical composition and physical properties, the two groups of milk proteins are Casein and whey.

Casein proteins contain phosphorus and will coagulate at pH 4.6. Casein proteins group together form sphere-like structures called micelles. Casein micelles are not solid throughout. Instead, the way the protein molecules group together leaves spaces, much like tunnels through the micelles. These spaces allow the liquid part of milk to flow in and out of the micelles. Casein micelles are too large to dissolve and form a solution, like salt in water does. Casein micelles are too small to sink, like sand in water does. Instead, the micelles float around in the milk. This type of mixture is called a colloid.

Whey proteins, also called serum proteins, do not contain phosphorus and do not coagulate at pH 4.6. Whey proteins are individual protein molecules spread throughout the liquid part of the milk.

When casein micelles come apart, the proteins forming it are not soluble in the liquid. Thus they "come out of solution." This means that these proteins separate from the liquid. These proteins now coagulate, which means they clump together into a mass called curd. Casein proteins, unlike most proteins, are not denatured by heat. For example, when an egg is heated, the protein making up the liquid surrounding the yellow yolk changes to a white solid. The protein has been denatured—changed in some chemical way. So, heating milk does not cause the casein proteins to be denatured to coagulate.

Aggregation of casein in milk protein concentrates (MPCs) is altered by changes in calcium content. Emulsifying properties of MPCs and stabilities of emulsions formed with MPCs were investigated by examining emulsions formation, adsorption behaviours of proteins and emulsion microstructures. Compared with emulsions formed with higher calcium MPCs at a given protein concentration, emulsions formed with low calcium MPCs were finer, the total surface protein concentration was lower and the protein composition on the surface of the emulsion droplets was altered. Thus, the aggregation state of casein dominates the emulsifying capability of MPC products and the adsorption behaviours of proteins in MPCs. In low-calcium-MPC-stabilized emulsions, the stability of the emulsions decreased with an increase in the emulsion size at low protein concentrations and decreased with increasing protein concentration beyond a maximum level, suggesting that the protein state in low calcium MPCs may cause depletion flocculation in the emulsions.

6.3. HANDLING OF MILK AND MILK PRODUCTS:

In pasteurisation, milk receives mild heat treatment to reduce the number of bacteria present. In sterilisation, milk is subjected to severe heat treatment that ensures almost complete destruction of the microbial population. The product is then said to be commercially sterile. Time/temperature treatments of above 100°C for 15 to 40 minutes are used. The product has a longer shelf life than pasteurised milk.

Another method of sterilisation is ultra-heat treatment, or UHT. In this system, milk is heated under pressure to about 140°C for 4 seconds. The product is virtually sterile. However, it retains more of the properties of fresh milk than conventionally sterilised milk.

Butter is made as a means of extracting and preserving milk fat. It can be made directly from milk or by separation of milk and subsequent churning of the cream.

Sources of contamination:

In addition to bacteria present in the milk other sources of bacteria in butter are (1) equipment, (2) wash water, (3) air contamination, (4) packing materials, and (5) personnel.

In smallholder butter-making, bacterial contamination can come from unclean surfaces, the butter maker and wash water. Packaging materials, cups and leaves are also sources of contaminants. Washing and smoking the churn reduces bacterial numbers. But traditional equipment is often porous and is therefore a reservoir for many organisms.

When butter is made on a larger processing scale, bacterial contamination can come from holding-tank surfaces, the churn and butter-handling equipment.

A wooden churn can be a source of serious bacterial, yeast and mould contamination since these organisms can penetrate the wood, where they can be destroyed only by extreme

heat. If a wooden churn has loose bands, cream can enter the crevices between the staves, where it provides a growth medium for bacteria which contaminate subsequent batches of butter. However, if care is taken in cleaning a wooden churn this source of contamination can be controlled. Similar care is required with scotch hands and butter-working equipment.

Wash water can be a source of contamination with both coli form bacteria and bacteria associated with defects in butter. Polluted water supplies can also be a source of pathogens. Contamination from the air can introduce spoilage organisms: mould spores, bacteria and yeasts can fall on the butter if it is left exposed to the air. Moulds grow rapidly on butter exposed to air. Care is required in the storage and preparation of packaging material. Careless handling of packaging material can be a source of mould contamination.

A high standard of personal hygiene is required from people engaged in butter-making. For example, in New Zealand the 1938 dairy produce regulations stated "no person shall permit his bare hands to be brought in contact with any butter at any time immediately following manufacture or during the wrapping, packaging, storage and transport of such butter".

Personnel pass organisms to butter via the hands, mouth, nasal passage and clothing. Suitable arrangements for disinfecting hands should be provided, and clean working garments should not have contact with other clothes.

Control of micro organism in butter:

Salting effectively controls bacterial growth in butter. The salt must be evenly dispersed and worked in well. Salt concentration of 2% adequately dispersed in butter of 16% moisture will result in a 12.5% salt solution throughout the water-in-oil emulsion.

Washing butter does little to reduce microbiological counts. It may be desirable not to wash butter, since washing reduces yield. The acid pH of serum in butter made from ripened cream or sour milk may control the growth of acid-sensitive organisms.

Microbiological analysis of butter usually includes some of the following tests: total bacterial count, yeasts and moulds, coliform estimation and estimation of lipolytic bacteria.

Yeast, mould and coliform estimations are useful for evaluating sanitary practices. The presence of defect producing types can be indicated by estimating the presence of lipolytic organisms.

All butter contains some micro-organisms. However, proper control at every stage of the process can minimise the harmful effects of these organisms.

6.4. COMPOSITION

Factors affecting the composition of the milk:

1. The composition varies according to the species. The nutritive value of human milk differs from cow's or buffalo's milk.
2. Variation in the composition of milk occur with the breed of cow. Some breeds of cow gives milk which is always higher in fat and protein than that of others.

3. The time of the year has an effect on the composition of milk. This may be indirect since the diet of the herd and the amount of green pasture consumed varies with the time of the year.
4. Composition of the milk varies with the time of the day. The evening milk tends to contain more fat and less water than morning milk.
5. It varies with the portion of milking. Milk which is first removed from the udder contains a smaller amount of fat than that removed in the final phase of milking.
6. The diet of the cow has a very marked influence on the quantity of milk produced but only a limited effect on the composition. Dietary deficiency is reflected in decreased milk production. Vitamin D and carotene content of milk reflect the level in the cow's diet.
7. Composition also varies with the time of the lactational period. Initially the animal secretes colostrum. It is lower in water, sugar milk. The most striking difference between normal milk and colostrums is the globulin which often reaches 12% to 13% in the colostrums. Threonine level in milk protein is 15% higher at the end of lactational period than 60 days after the birth of the calf. Milk which is secreted after the delivery of the calf contains large fat globules. There is considerable decrease in size until about the second month. Towards the end of the lactation period the milk produced by a cow often has a salty taste due to less amount of lactose and more amount of chloride. The most remarkable difference between colostrums and milk is the extremely high content of immunoglobulins of the former.
8. Fat percentage increases slightly from the first to the second or third lactation period and then remains the same.
9. When the cow is excessively fat, it provides liberal amount of milk.
10. The longer the interval between milking greater the quantity of milk and lower the fat content.
11. Within the limits of the same breed and with uniform environmental conditions, a considerable range of individual variations occur especially in the fat percentage..

Milk fat:

Milk fat or butter fat is of great economical and nutritive value. The flavor of milk is due to milk fat. Milk is a true emulsion of oil-in-water. Fat globules are visible under a microscope. Each globule of fat is surrounded by a thin layer which is composed of a lipid-protein complex and a small amount of carbohydrate. The lipid portion includes both phospholipids and triglycerides.

Fat globules vary widely in size from 2-10 μ m (micro metres) μ m and in number 3×10^9 per ml. During the first part of the lactation period the fat globules are relatively large and as lactation progresses the granules become larger. The larger fat granules come to the surface of milk more quickly due to low specific gravity. In cheese making, if the fat globules are large they will move up quickly before the coagulated milk could check their movement and as a result the loss of milk fat in whey is somewhat large. In milk transport, large fat globules churn more readily after being transported some distance and show the formation of butter granules on the surface.

Milk fat is a mixture of several different glycerides. They contain about 64% fatty acids ranging from 4-26 carbon atoms. Milk contains considerable amounts of short chain fatty acids which give the characteristics flavor and off flavor. Due to their low melting point, they give soft solid consistency to butter. Saturated fatty acids account for like butyric and caproic acid 62% and unsaturated 37%. Of the unsaturated fatty acids 3.8% constitute polyunsaturated fatty acids.

Other lipid materials present in milk are phospholipids, sterols, free fatty acids, carotenoids and fat soluble vitamins. Carotenes are responsible for the yellow colour of milk fat.

Melting point of milk fat is 10-12°C. It is low because of presence of short chain fatty acids. Milk fat absorbs volatile odour very readily. Milk, butter and cream should not be exposed to strong odours.

6.5. PROPERTIES OF MILK PROTEINS

Casein:

Casein constitutes 80% of the total nitrogen in milk. It is precipitated on the acidification of milk to pH 4.6 at 20°C. The remaining whey protein constitutes lactoglobulin and lactalbumin. Milk protein contains proteoses, peptones and milk enzymes.

Casein is classified as a phosphoprotein because of the phosphoric acid that is contained in its molecular structure. At the normal acidity of fresh milk (about pH 6.6) casein is largely combined through the phosphoric acid part of its structure with calcium caseinate. Hence casein occurs in milk as a colloidal protein calcium phosphate complex. In milk α - casein 66%, β - casein 29%, γ - casein 5%. δ - casein which is part of α - casein plays an important role in stabilizing the tiny casein particles in a colloidal dispersion. Casein occurs in milk as a colloidal protein - calcium phosphate complex.

Casein is also a glycoprotein. The calcium content of whole casein is about 8.2% carbohydrates are present to the extent of 5.7% in casein. Glutamin acid is the predominant one in casein. Proline, aspartic, leucine, lysine and valine are also present. Casein is a good source of essential amino acids.

Casein can also be separated from the milk by the addition of rennin an enzyme secreted by the young calves.

Whey proteins:

Whey proteins are made up α - lactalbumin and β - lactoglobulin, serum albumin, the immune globulins, enzymes and proteose - peptones β - lactoglobulin accounts for about 50% of total whey proteins. These are not precipitated by acid or rennin; they can be coagulated by heat. By a process involving ultrafiltration, whey protein concentrates is produced. Whey protein isolates are also produced. Whey also contains small amounts of lactoferrin and serum transferrin.

Milk sugar:

The chief carbohydrate present in milk is lactose or milk sugar is a disaccharide, although trace amounts of glucose, galactose and other sugars are present. Lactose gives on hydrolysis glucose and galactose. Lactose has only one sixth the sweetness of sucrose and one third - one fourth of its solubility in water. When milk is heated lactose reacts with protein and develops a

brown colour. The development of brown colour is due to non-enzymatic browning. It is called Maillard reaction. Reducing sugar reacts with the amino acid Lysine and brown colour develops. As the amino acid lysine is involved the quality of protein is decreased. The brown colour in condensed milk, khoa, basundi and gulabjamun is due to maillard reaction.

Lactose is acted upon by bacteria to produce lactic acid. The acid produced by the action of intestinal microorganisms on lactose checks the growth of undesirable putrefactive bacteria and promotes absorption of minerals. The acid fermentation is used in making butter, cheese and curd. Milk sugar due to its controlled glycaemic effect is preferred as a source of carbohydrate.

Salts:

Chlorides, phosphates, citrates, sulphates and bicarbonates of sodium, potassium, calcium and magnesium are present. These salts influence the condition and stability of the proteins, especially the casein fraction. Copper and iron are important in the development of flavours in milk and milk products. In addition to this, milk contains trace elements like copper, zinc, aluminium, molybdenum and iodine.

Enzymes:

The enzymes found in milk can originate from the mammary gland as any other native constituent or may be released by contaminating bacteria.

Alkaline phosphatase exist as lipoprotein and is distributed between the lipid and aqueous phases. This enzyme is inactivated by normal pasteurization procedures and its activity is tested to determine the effectiveness of pasteurization.

More than one type of lipase occurs in milk. The release of membrane material from the fat globule predisposes the fat lipolytic attack by plasma lipase. Milk lipase is responsible for the development of rancid flavours in milk. Bacterial lipase is very resistant to heat and can cause serious quality defects. Lipases may be important in the development of desirable flavours in some cheeses.

Xanthin oxidase occurs in the fat globule membrane. It is a conjugated protein complexed with FAD, iron and molybdenum. The enzyme degradation of FAD gives FMN and riboflavin. The riboflavin content of milk may thus be due to xanthin oxidase. Xanthine oxidase enzyme concentration averages 160 mg/l. Xanthine oxidase can catalyse the oxidation of aldehydes which are some of the aroma constituents in fermented dairy products. The enzyme is not destroyed by pasteurization.

Catalase is an enzyme that promotes the decomposition of hydrogen peroxide to water and molecular oxygen. Fresh milk from a healthy cow contains insignificant amounts of catalase as compared to the milk from diseased udders.

Lactoperoxidase catalyses the transfer of oxygen from peroxides, especially hydrogen peroxide to other readily oxidisable substance.

Colour:

White colour of milk is caused by the reflection of light by the colloiddally dispersed casein, calcium and phosphorus. Yellowish colour of milk is due to the presence of carotene and riboflavin. The fat soluble carotenes are found in the milk fat; the riboflavin is water soluble which can be visible clearly in whey water.

Flavour and Aroma:

Milk is slightly sweet because of its lactose content. Flavour sensation in mouth is due to milk fat in the serum or watery portion of milk and the colloidal structure of the protein and some of the salts such as calcium phosphate. The slight aroma of fresh milk is produced by a number of low molecular weight compounds such as acetone, acetydehyde, dimethyl sulphide and short chain fatty acids. Some of the volatile compounds to the flavor of milk are unique to the fat portion of milk.

The effect on flavor of heating to pasteurize milk, including the use of ultra high temperatures for very short periods in minimal and tends to disappear during storage. Boiling changes the flavour of fresh milk more than pasteurization. Oxidized flavor can result from the oxidation of phospholipids in the milk. Since traces of copper accelerate the development of oxidized flavor, copper containing equipment is not used in dairies. Off flavor in milk may be influenced by the health of the cow or the feeds that are consumed by the cow, action of bacteria, chemical changes in milk, or the absorption of foreign flavours after the milk is drawn.

Many chemical off flavours are rancid or oxidized flavours. Some of the polyunsaturated fatty acids are particularly susceptible to oxidation in the presence of oxygen and unpleasant flavor substances are produced. Anything that alters the membrane and permits contact of the lipases with the fat will promote rancidity and off flavor, are also produced when milk is exposed to light. In this reaction tryptophan and riboflavin may be involved and their content decreases when the off-flavour develops.

6.6. SUMMARY

Milk products contribute the nutritive value to the diet. The chief carbohydrate present in milk is lactose or milk sugar is a disaccharide, although trace amounts of glucose and galactose and other sugars are present, physical properties of milk enhance the quality of milk when the pasteurization or boiling techniques are followed well.

6.7. SELF ASSESSMENT QUESTIONS

1. Write short notes on proteins present in milk?
2. Discuss the factors effecting in handling milk and milk products?
3. Describe the composition of milk?

6.8. REFERENCE BOOKS

- 1 Francis, Encyclopedia of Food Science and Technology. The computer type media, New Delhi 110 002, 2003.
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Lesson – 7

EGG COOKERY

7.0 OBJECTIVE:

- To understand the role eggs in cookery.
- To understand the uses of egg preparations.
- To understand the properties of egg protein.

STRUCTURE

7.1. Introduction

7.2. Evaluation of egg quality

7.3. Egg cookery

7.3.1. Properties of Egg protein

7.4. Uses in Egg preparations.

7.5. Egg characteristics

7.5.1. Binding agent

7.5.2. Foaming agent

7.5.3. Emulsifying agent

7.6. Summary

7.7. Self Assessment Questions

7.8. Reference Books

7.1. INTRODUCTION:

Eggs are used in many preparations due to the variety they provide to food. Eggs are important ingredients of recipes for breakfast, lunch or dinner for any person. Nutritive importance, flavor, pleasing colour, thickening power, foam forming ability, emulsifying capacity, stabilizing capacity and the binding property of eggs are utilized in menu planning.

The regulations apply to eggs from laying hens sold for human consumption. They also cover hatching, farmyard poultry chicks, and in shell for human consumption, hen, turkey, goose, duck, and guinea fowl eggs.

For years, eggs have been held up as a powerhouse of nutrition. This reputation has been due to eggs' exceptional nutrition profile as a nutrient-dense food containing high quality protein

and a substantial amount of many essential vitamins and minerals. Unfortunately their position on the nutrition pedestal fell with the discovery that they are also a source of dietary cholesterol. The most recent scientific research not only returns eggs to their golden past, but elevates their position as a functional food and ultimately provides more reasons than ever to consume eggs.

Egg is an excellent food for man and hence its quality is of very great importance. Fresh eggs have best quality. Quality of egg can be determined by many factors.

Size:

By weight we can find out the quality. The normal weight of an egg is 40-70g. The weight depends on the inheritance, stage of laying, season of laying, age, diet and health of the bird. Size does not reflect the quality. Usually small eggs contain higher proportion of yolk than large eggs.

Shell:

Though this is not consumed its condition is important because of the protection it gives to the edible portion. The factors to be considered are its strength, porosity and cleanliness. The strength of the shell depends upon its thickness which in turn depends on the nutrition of the bird. A high porosity of the egg shell will hasten the deterioration on the quality of egg contents as it permits the evaporation of moisture and allows dissolved carbon dioxide to escape from the contents during the storage of egg. The texture of the shell does not affect the quality of inner content. Any dirt on the egg shell means the presence of the large number of contaminating microorganism. Weak shells, rough handling results in damage to the shell. The egg should be unbroken.

Air cell:

As the quality of the egg deteriorates the size of the air cell increases due to loss of moisture through the cell especially in warm, dry atmosphere. In good quality egg the depth of the air cell is $1/8 - 3/16$ inches. In poor quality the depth of the cell would be more than $3/8^{\text{th}}$ of an inch.

Egg white:

A fresh egg when broken on to a plate stands up in rounded form due to the viscosity of the thick portion of the egg white that surrounds the yolk. As egg deteriorates the percentage of thin white increases. Possibly due to proteolysis, reduction of S-S bonds and interaction of mucin and lysozyme. The increase in thinning correlates with an increase in alkalinity and alkaline hydrolysis of the disulphide bonds of ovomucin to yield a lower molecular weight protein. As the quality deteriorates the pH of white increases from 7.6 to 9.7. There is loss of carbon dioxide also. Increased alkalinity also decreases the volume of cakes.

Egg Yolk:

In deteriorated egg the yolk also takes up water from the white and the yolk membrane i.e., vitelline membrane stretches and when broken on to a plate the deteriorated egg flattens and tends to spread over the plate. If stretched excessively by movement of water into the yolk, the yolk membrane is weakened and may break when the egg is removed from the shell. Separation of the yolk from the white is thus difficult or impossible. Yolks of fresh eggs are slightly acid pH, that is, 6-6.2 and as there is increased loss of carbon dioxide, alkalinity is increased. The pH of the eggs

may be kept lowered or less alkaline during storage if the egg shells are coated with a thin layer of oil.

Chalazae:

As egg deteriorates they start to disintegrate and cannot hold the yolk in the centre of the egg.

7.2 EVALUATION OF EGG QUALITY:

Candling:

The quality of the egg in the shell is evaluated by candling. The egg is held up to an opening behind which is a source of strong light. Candling will reveal

- A crack in the shell.
- The size of the air cell.
- The firmness of albumin.
- The position and mobility of yolk and
- The possible presence of foreign substances like blood spots, moulds and developing embryo.

As the eggs deteriorate, the chalaza weakens and the yolk tends to settle toward the shell rather than remain suspended in the firm white. Under such circumstances the yolk is more fully visible when the egg is candled. Dark yolks cast a more distinct shadow than light coloured yolks.

Although candling is the best available method for rating unbroken eggs it may not be totally reliable.

Floating in water:

If the egg sinks it is considered as good. Poor quality egg floats (due to increase in air cell). It shows that the egg floating in water has lost in weight due to dehydration.

Haughes Unit:

Measurement of the height of the thick white in relation to the weight of the egg gives haughes unit. Good quality egg has 72 haugh units and as the quality deteriorates it comes down to 36-60. Micrometre is used to measure the height of thick white.

White Index:

The height of the thickest portion of the white is divided by the diameter of the egg gives white index.

Yolk Index:

Measurement of the height of the yolk in relation to the width of the yolk gives the yolk index.

Grading:

The interior quality of the egg deteriorates from the time it is laid to until it is consumed. With proper care, however, this decline in quality can be minimized.

In India eggs are graded according to the weight into 4 grades. Extra large- more than 60 g, large- 53-59 g medium- 45-52 g, small- 38-42 g. Clean eggs with unbroken shell are graded on quality depending upon depth of the air cell. Centering of the yolk and free from defects are given as grade A and B in India.

Deteriorating during storage:

Fertile eggs get deteriorated more rapidly than infertile eggs. Eggs when stored at room temperature undergo deteriorative changes. The weakening of the yolk membrane occurs after 2 days storage at 37°C, or after 5 days at 25°C, or 20 days at 2°C. These changes that occur during deteriorating may be grouped as physical and chemical.

Physical Changes:

1. Egg white becomes less viscous and spreads rapidly.
2. The size of the air cell increases.
3. Water passes from the white to the yolk thus increasing the volume and water content of the yolk resulting in breaking of vitellin membrane.

Chemical changes:

1. Loss of water.
2. Loss of carbon dioxide.
3. Change in pH 7.6 to 9-9.7 in egg white.
4. The breakdown of proteins.
5. Increase in the amount of free ammonia.
6. Increase in water soluble inorganic phosphorus.
7. Increase in free fatty acid in yolk fat.
8. Deterioration in the flavor of eggs occurs by the invasion of microorganisms and by the changes that takes place in fat and protein.

Bacterial Decomposition:

An egg ages the porosity of the cell increases making possible the infiltration of bacteria and moulds. The alkalinity of egg white and the lysozyme serve to reduce this spoilage caused by the micro organisms.

7.3. EGG COOKERY:**Effect of heat on the egg proteins:**

Upon heating the egg proteins are denatured and then gradually aggregate to form a three dimensional gel network. The network is stabilized by cross-bonds that include disulphide linkages and hydrogen bonding.

Ovalbumin the main protein in egg white is a globular protein denatured by heat. Egg white coagulated by heat changes from a transparent viscous sol to an opaque white gel, the water of white trapped by the protein. Egg yolk, a thick liquid no longer flows when cooked, it becomes solid with a mealy structure. The range in temperatures over which coagulation takes place varies with the rate of heating. Eggs exposed to heat of high intensity are over coagulated before they can be removed. In undiluted egg white, coagulation may begin near 60°C or 140°F with the white no longer able to flow near 65°C or 149°F. Coagulation of the yolk begins near 65°C and the yolk no longer flows when the temperature nears 70°C or 158°F. Heating on egg much beyond this temperature shrinks and toughens the coagulum of the white.

Factors affecting coagulation of egg protein:

Concentration:

The temperature at which egg proteins coagulate and the time required for coagulation depend in part on the proportion of egg in any mixture. Dilution of egg increases the temperature at which coagulation occurs.

Part of egg used:

Egg yolk proteins require a slightly higher temperature for coagulation than do those of egg white.

Intact or stirred:

The texture of coagulated egg yolk, when it is cooked intact, is crumbly and mealy but solid. When the yolk membrane is ruptured and the stirred yolk is heated, however, the texture of the resulting gel is firm and rubbery. The difference in texture of intact and stirred egg yolk may result from changes that occur in the intricate micro structure of egg yolk with stirring. The tiny discrete granules of the intact yolk may form a highly cross linked protein net work when it is disrupted.

Time and temperature:

The rate of coagulation and the amount of coagulum formed in a definite time increase with increasing temperature. The character of the coagulum formed when egg white is heated at high temperature is firm, as compared with the soft, tender, more evenly coagulated product obtained when coagulation takes place at lower temperature.

The toughness and greater shrinkage of the protein coagulated at a high temperature are the basis for the recommended use of low or moderate temperatures for egg cookery. If eggs are cooked in water, temperature should be 85°C that will produce a texture that is tender yet firm.

Oven temperatures from 300°F to 350°F have been found to be satisfactory for cooking eggs and egg dishes. Plain egg dishes in a pan of water when baking them in the oven helps to protect the egg product from becoming over cooked.

7.3.1. Properties of Egg Proteins:

The extensive use of eggs in cookery is made possible by their protein content. The protein coagulates during heating, thus bringing about thickening as in custards or the binding of pieces of food together as in croquettes. The proteins of the egg are good emulsifying agents. The proteins

form elastic films when beaten, thus incorporating air, which is used as leavening in such products as angel cakes and souffles. The elasticity of the egg protein is also important in products. The egg stretches with expansion of steam, and later coagulates to aid in forming the framework of the popover.

Proteins of an egg: The proteins of the white are ova albumin, ovoglobulin, and ovomucin. There may be small amounts of other proteins and it is also possible that each protein is made up of component fractions. The principal protein of the yolk is ovovitellin. Sell, Olsen, and Kremers separated salted egg yolk into a soluble lipid fraction and an insoluble residue. The latter consisted of sodium chloride and the protein-like material of the yolk. This residue they called lecitho-protein. It composed about 32.5 percent of the yolk. This protein fraction contained nearly one-half the total lecithin of the yolk.

Solubility of the proteins: The albumin of egg forms a sol with water and dilute salt solutions. The globulin forms a sol in dilute salt solutions, but not in pure water. The globulin composes about 6.5 per cent of the total proteins of the egg.

Egg-white proteins belong to the group of hydrophilic colloids. Egg white and water are mutually soluble. Usually the addition of 1 tablespoon of water to an egg white, unless it is very watery, increases its extensibility, and when the egg white is whipped a larger volume is obtained. But with increasing quantities of water a stage is reached at which the egg white loses too much of its rigidity and will no longer retain air in small bubbles, the bubbles being large and floating on the more liquid part.

The ovovitellin of the egg yolk is combined with phosphorus and belongs to the phosphor protein group. It is insoluble in water but is soluble in dilute salt solutions and in dilute alkalies.

Iso electric point of egg proteins: Loeb has reported the iso electric point of egg albumin as pH 4.8. Some investigators give pH 4.7 as the iso electric point. Above the iso electric point the albumin combines with bases to form salts like sodium albuminate; below the isoelectric point it combines with acids to form salts like albumin acetate, citrate, or tartrate. Above the iso electric point the protein is negatively charged; below, it is positively charged. Since the reaction of the egg white is about pH 7.6 to 9, there will probably be few combinations of egg white with alkalies or alkaline salts in food preparation that will increase its alkalinity. Many combinations are made that increase its acidity. For example, the addition of a teaspoon of cream of tartar, a salt with an acid reaction, to a cup of egg whites, proportions often used in angel food cakes, increases the acidity and lowers the pH, often to about 7.5 or 7.0. As the proportion of cream of tartar is increased, the pH is lowered to a greater extent. The addition of fruit juices and fruit pulp to egg whites to make fruit whip, souffles, or similar desserts, increases the acidity. When 1 to 2 teaspoons of lemon juice are added to an egg white the pH is lower than 4.8.

No record could be found in the literature of the iso electric point of ovovitellin. When lemon juice is added to egg yolk, the mixture is thickest at a pH between 4 and 5, as if the greatest tendency to curdle is at this point. This might indicate that the iso electric point of the egg yolk proteins is between pH 4 and 5. This greatest thickening occurs with about 5 cc. of lemon juice to an egg yolk.

The addition of an acid like vinegar or fruit juice to the white and yolk beaten together tends to curdle the mixture. This occurs when the acidity is in the vicinity of the iso electric point. When sufficient acid is added to lower the pH below the iso electric point of the egg proteins, and if the salt formed, such as protein citrate, is soluble, the coagulum dissolves and the mixture becomes smooth. With the exception of salad dressing and a few sauces, there are probably not many instances in which enough acid is added to lower the pH of the food mixture below the iso electric point of the egg protein.

Peptization of egg proteins: Peptization of egg proteins increases the tenderness of some products. Freundlich states that peptization of proteins is frequently brought about by low concentrations of electrolytes; though to accomplish this the electrolyte must be intimately mixed with the substance to be peptized. The hydroxyl, citrate, acetate, and tartrate ions are effective for peptizing egg proteins. For example, when tomato or lemon juice is added to egg in amounts to bring the pH of the egg slightly above or about the isoelectric point of egg albumin, the tenderness of omelets is definitely increased. In some instances peptization of the egg proteins is detrimental. An example of this is the thinning of salad dressings, thickened with only egg yolk, when heated above the temperature at which optimum coagulation occurs. Sugars (sucrose, dextrose, and levulose) through peptization tend to prevent coagulation of egg protein.

Denaturation: Denaturation, by which soluble proteins are rendered insoluble, of egg proteins is brought about in a variety of ways, including the action of acids, salts, heat, mechanical agitation, and radiation. Mechanical agitation or beating of egg white, as well as the tendency of proteins in surfaces to form films, causes partial denaturation of the egg proteins. Sugar tends to prevent this denaturation.

The minimum temperature to be achieved during cooking should be 70°C, and this temperature should be maintained for at least 1 minute. Egg dishes should be consumed immediately after preparation and cooking.

7.4. USES OF EGG PREPARATIONS:

While eggs are widely known as breakfast entrees, they also perform in many other ways for the knowledgeable cook. Their cooking properties are so varied, in fact, that they have been called "the cement that holds the castle of cuisine together."

Eggs can bind ingredients as in meatloaves or croquettes. They can also leaven such baked high rises as souffles and sponge cakes. Their thickening talent is seen in custards and sauces. They emulsify mayonnaise, salad dressings and Hollandaise sauce and are frequently used to coat or glaze breads and cookies. They clarify soups and coffee. In boiled candies and frostings, they retard crystallization. As a finishing touch, they can be hard cooked and used as a garnish.

Egg protein coagulates on heating. The coagulum formed is a smooth and jelly-like mass. It supplies a thickening effect to the products. If the temperature is high, the coagulum is toughened and it shrinks and water comes out of the product. This is called syneresis and it occurs in custards and scrambled egg preparations.

Egg is cooked in its shell, scrambled, poached, fried or used in the preparations of desserts, cakes and other confectioneries. Egg is used in food mixtures to contribute flavor and colour to the products. Cakes and puddings owe their colour and flavour to eggs. In the preparation of mayonnaise

the protein of egg stabilizes the oil in water dispersion. The protein of egg stabilizes the air in liquid dispersion. Egg is also used for thickening various desserts and creams and patties. Since egg is highly perishable the quality has to be judged by internal appearance flavor and external shell appearance.

7.5. CHARACTERISTICS OF EGGS:

The structural components of the egg include the shell and shell membranes (10 percent); the albumen or white (60 percent), including the thick albumen, the outer thin albumen, the inner thin albumen, and the chalazae; and the yolk (30 percent). In a fertilized egg, the yolk supplies the nutrients and the albumen supplies the water necessary for the development of the embryo. In addition, the layers of albumen act as a cushion to protect the embryo from jarring movements, while the chalazae help to maintain the orientation of the embryo within the egg.

The whole egg is a source of high-quality protein (i.e., proteins that contain all the amino acids needed in the human diet). In addition, it is an excellent source of all vitamins (except vitamin C) and contains many essential minerals, including phosphorus and zinc.

All the fats, or lipids, as well as the cholesterol are found in the yolk. Yolk lipids are high in unsaturated fatty acids, with the ratio of unsaturated to saturated fatty acids commonly being 2 to 1. By influencing the diet of the hen, some processors are able to market shell eggs with a higher ratio of unsaturated to saturated fatty acids. Particular emphasis is being given to increasing the highly unsaturated long-chain omega-3 fatty acids by adding fish oil to the hen feed. Omega-3 fatty acids have been shown to play a role both in normal growth and development and in the prevention of many diseases.

The cholesterol content of a whole large egg is approximately 216 milligrams—a substantially lower figure than that reported before the late 1980s, when improved analytical techniques were instituted. Moreover, the egg industry has probably made some progress in lowering cholesterol content through genetic selection and improved diets.

More than 90 percent of all eggs are free of contamination at the time they are laid; contamination with *Salmonella* bacteria and with certain spoilage organisms occurs essentially afterward. Proper washing and sanitizing of eggs eliminates most *Salmonella enteritidis* and spoilage organisms deposited on the shell. The organism salmonella a common cause of gastroenteritis (a form of food poisoning), has been found to be transferred through the hen ovary in fewer than 1 percent of all eggs produced. Ovarian-transferred *S. enteritidis* can be controlled by thorough cooking of eggs (i.e., until there are no runny whites or yolk).

7.5.1. Binding agent:

One of the most recognizable of binding agents, this is for sure an ingredient you already know of. In many baked goods eggs can help "glue" ingredients together or act as a leavening agent, and so in much gluten free recipes you will see higher egg amounts listed in the ingredients compared to their glutenicous equivalents. Eggs are often a great binding agent in light and fluffy cakes. Glutenicous versions that use cake flour instead of all-purpose or bread flour already have

lower gluten content – so some of the glutenicous properties (like elasticity) are really not so important in those cases and eggs work wonderfully

7.5.2. Foaming agent:

Egg white foams are used in baking as a leavening agent. When beaten, egg white can swell to eight times their original volume. The secret to egg whites incredible ability to form a stable foam are the albumen proteins' foam is made up of tiny gas bubbles dispersed throughout a liquid. In beaten egg whites the albumen proteins unfold and align themselves at the liquid-gas interface of the tiny bubbles reinforcing the bubble walls creating a stable foam. The addition of various ingredients can either heighten or hinder the ability of an egg white to form stable foam. Acid, in the form of cream of tartar (tartaric acid) or lemons (citric acid), has a beneficial effect on the stability of egg white foams. This small addition of an acid changed the pH of albumen from 9 to 8 increasing the number of hydrogen ions tenfold lowering the reactivity of the protein molecules and reducing their ability to bond to each other. This prevents the coagulation of the proteins and the collapse of the foam.

7.5.3. Emulsifying agent:

The egg yolk contains an emulsifying agent, lecithin, which acts as a stabilising emulsion between oil and water. This prevents oil and water mixtures from separation. Lecithin attracts oil and water particles and forms a thin layer around them to keep them from dispersing. When making mayonnaise, the egg lecithin surrounds the oil particles, preventing them from joining and discharging oil.

7.6. SUMMARY:

As a functional Egg can be classified food, a hot button for today's consumer. Eggs provide richness, colour, protein and tenderness. Beaten egg whites provide extra volume and air. Most egg replacers on the market will provide instructions for replacing whole eggs and egg whites. Eggs also act as binding and leavening agents.. Figuring out the purpose the eggs serve in a recipe will help determine which type of egg substitute to use. The whole egg is rich source of all nutrients except vitamin C. The protein in egg is considered as a complete protein because of its high biological value and digestibility.

7.7. SELF ASSESSMENT QUESTIONS

1. Describe the composition and nutrient value of whole egg, egg whites, and egg yolks.
2. Describe the structure of an egg.
3. Discuss quality indicators of fresh eggs and describe the grading of fresh eggs.
4. Explain safe handling of eggs and egg products.
5. Identify ways that eggs are preserved and processed.
6. Describe the preparation of eggs and use of eggs in several types of dishes.
7. Describe the coagulation of eggs by heat and by mechanical beating.
8. Explain the reasons for the development of a green color in cooked eggs.

9. Describe egg substitutes and their use in food preparation.

7.8. REFERENCE BOOKS

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Lesson – 8**MEAT COOKERY****8.0 OBJECTIVE:**

- To understand the structure and composition of meats.
- To understand meat inspection and grading practices.
- To Purchase meats appropriate needs.
- To apply various cooking methods to meats.

STRUCTURE**8.1. Introduction****8.2. Post mortem changes****8.3. Changes in cooking****8.4. Fish cookery****8.5. Composition****8.6. Changes in fish****8.7. Preservation and storage****8.8. Summary****8.9. Self Assessment Questions****8.10. Reference Books****8.1. INTRODUCTION:**

Meat is muscle tissue. It is the flesh of domestic animals (cattle, hogs, lamb) and of wild game animals such as such as venison. Meat is a main stay of our diet. People spending more time and money on meat than any other food. It is important to understand meats thoroughly in order to cook well and profitably.

Meat is composed mainly of muscle fibers, which vary in size. Larger fibers indicate a naturally less tender cut of meat and small fibers indicate a tenderer cut of meat. For example, a chuck steak is less tender than filet mignon.

Meat also contains connective tissue. One connective tissue, collagen, hydrolyzes to gelatin during cooking. Elastin, the other connective tissue, does not become more tender during cooking.

The primary nutrient found in meat is protein. Protein is composed of amino acids, which build and maintain all tissues, forms an important part of enzymes, hormones and body fluids, and supplies energy. The body can manufacture some amino acids; others are supplied only by food. A severe deficiency causes loss in strength and appetite and retards growth in children. Excess protein is converted to fat and stored. Other nutrients found in meat include fat, carbohydrates, vitamins, and minerals.

Edible fish are categorized as either fin fish or shell fish. The term fin fish refers to the fishes that have bony skeleton. Shell fish is used to designate both mollusks and crustaceans. Most fin fish come from salt water; however, great lakes and inland water add considerable amounts to the total catch. Edible shell fish are mainly salt water fish. Although fish contains complete proteins and can be alternate for meat in the diet, fish consumption per capita is far lower than that of meat.

Fish come in all shapes and sizes, some are free swimming, while others rest on the bottom of the sea, some are herbivores and others are carnivores, and some lay eggs while others give live birth and parental care to their young.

8.2. Post Mortem Changes in Meat :

Immediately after slaughter, changes occur in the muscle of an animal. These changes, like the changes in milk and eggs can be retarded by method of handling and storage. They are brought about by enzymes and microorganisms, and by chemical and physical means which alter the structure and chemical composition of the meat. Muscle in the living animal are Pliant, soft, gel-like, yet somewhat viscous. After slaughter the muscles pass from this state into a stiff or rigid one known as rigor mortis, or muscle rigor. After some time the muscle again become pliant known as the passing of rigor. With longer storage enzymes and chemical means bring about more extensive changes which produce ripened meat. With bacterial action and still more extensive changes incipient putrefaction occurs. The passage from one stage to another is gradual with no definite dividing zone and is accelerated at higher temperatures and retarded at lower ones.

Meat may be cooked during any of these stages and heat denaturation causes characteristic changes which are part of the post-mortem changes. Means of retarding these changes will be considered before these changes are discussed.

Meat cooked before the onset of rigor is said to be tender. But rigor develops quickly so that this period is short. Concerning the question of tenderness of meat before the onset of rigor, Dr. Trowbridge, who has had many years of experience in meat work, wrote the author, "I doubt if freshly killed meat is ever as tender as the same meat ripened."

Preservation of meat by freezing: Meat may be frozen and then stored at temperatures of -10° to -15°F . In this way the post-mortem changes are nearly inhibited.

Cold storage: The passing of rigor, ripening, and development of putrefaction are delayed by quickly chilling the dressed meat and keeping it at a low temperature just above the freezing point of meat. Moran states that if the dressed meat is chilled slowly more protein is denatured than if it is chilled quickly, and, because bacteria attack denatured protein more rapidly than native protein, quick chilling is one means of increasing the storage life of meat.

Contamination with bacteria and storage life: Another factor affecting the storage life of meat is the initial contamination with bacteria. But with care the initial contamination should be small. Other

things being equal, the smaller the initial load of bacteria the longer the storage life of the meat. Spoilage by bacteria, yeasts, and molds is largely surface, and in general does not extend to a greater depth than 1/4 to 1/2 inch. Hoagland, Microorganisms may enter the meat by penetration from the surface, which is a slow process, and by following the cavities in meat, that is, the blood and lymph vessels.

Bacteria grow and develop very slowly on meat during rigor, as a pH of approximately 5.3 to 5.6 is not a desirable one for their growth. Stansby and Griffith also found that bacteria do not develop rapidly on fish during rigor.

Humidity: Mueller and Richardson have reported that dry air as well as the low temperature is a factor in preventing bacterial growth. Hoagland, McBryde, and Powick found that in a cooler with low humidity the growth of mold on the surface of the meat at 177 days was no greater than in a cooler with higher humidity at 53 days.

Ham, bacon and salt pork are probably the best known of cured pork products. Dried or chipped beef and corned beef are among the more familiar cured-beef products. Beef cuts most often cured are the plates, flanks, and rumps, though from the lower grades the chucks and rounds are often used. Dried beef is cured in a sweet pickle, then dried and smoked. Usually the rounds and sometimes the shoulder clods are used for dried beef.

Cold storage The passing of rigor, ripening, and development of putrefaction are delayed by quickly chilling the dressed meat and keeping it at a low temperature just above the freezing point of meat. protein, quick chilling is one means of increasing the storage life of meat.

Chemically conditioned cold: Moran states that with temperature control alone the storage life of chilled beef is about 35 to 40 days. If, in addition to low temperature control, what is sometimes known as "chemically conditioned cold," i.e., 10 percent of carbon dioxide is used in the storage atmosphere, the storage life of the meat may be extended to 60 or 70 days. The carbon dioxide retards or checks bacterial growth but if too much is used with red meats such as beef and mutton, the surface of the meat turns dark. This is because of the decreased amount of oxygen obtained by the meat when carbon dioxide is increased. For fish a higher percentage of carbon dioxide can be used. Stands by and Griffith have reported that haddock packed in ice and plus an atmosphere of 15 to 40 per cent of carbon dioxide have their storage life doubled over that when packed in ice alone.

8.3. Changes in cooking:

Longer cooking times will affect the final result of the meat, by changing the taste, appearance and texture, producing an unsatisfactory and disappointing final dish. Meats especially, can become dried out from over cooking when using a pressure cooker. This is true of standard pressure cookers using 15psi, and even more using a non standard model using less than 15psi because it takes longer to finish cooking. This also applies to electrics that are notorious for cooking at temps that are too high, and when users of jiggle top pressure cookers let the pressure rise so that the regulator weight is spinning rapidly .temperature. For example; at 160°F (71°C), a roast will be cooked to medium. At this temperature, some of the tougher connective tissue breaks down to gelatin, which helps "lubricate" and tenderize the meat.

Meat may be cooked during any of these stages and heat denaturation causes characteristic changes which are part of the post-mortem changes. Means of retarding these changes will be considered before these changes are discussed.

Meat cooked before the onset of rigor is said to be tender. But rigor develops quickly so that this period is short. Concerning the question of tenderness of meat before the onset of rigor and freshly killed meat is ever as tender as the same meat ripened."Cured meat may be smoked and partially dried on the surface. Actual smoke and not chemical treatment to produce a smoke flavor must be used in establishments under federal growth.

Meat is cooked to sterilize it and for most persons to make it more palatable. It should be cooked in such a way as to increase its tenderness if it is a tough cut, and to keep it tender if it is a tender cut. It is desirable in cooking meat to have maximum tenderness of both fibers and connective tissue so that the meat carves well and cuts easily. Meat cooked so long, or at such a high temperature that the connective tissue is dissolved, is not attractive and the fibers are tough and stringy. As a general rule, it should be cooked in such a way as to retain its nutritive value, i.e., to prevent cooking losses to as great an extent as possible, either dripping losses or destruction of some food constituents by heat. When the drippings are used in gravy or other ways this loss is not a serious one.

The flavor and the tenderness of the cooked meat depend to a great degree upon the quality of the meat before cooking, for cooking cannot make a well-flavored piece of meat from one of poor quality and flavor, nor does it always produce a tender piece of meat. However, the method and length of time of cooking may and often do spoil a good piece of meat, yet the method of cooking may improve a poor piece of meat.

Browning and thoroughly cooking meat develop a different flavor, just as cooking cabbage a long time develops a characteristic flavor. Many persons prefer the development of this flavor.

Coagulation of proteins: The heat renders the soluble proteins of meat insoluble, the extent of denaturation depending on the stage of cookery or temperature reached, the time held at this temperature, the pH of the meat, its salt content, its degree of ripeness, and probably other factors. The higher the temperature reached and the longer the meat is held at this temperature, the greater the denaturation.

Formation of gelatin: After the meat is heated in a moist atmosphere to a definite temperature for a sufficient time the connective tissue dissolves. If the concentration of gelatin in the liquid reaches 1.5 or higher percentages, it forms a jelly when cooled. Connective tissue is composed largely of collagen. Collagen is changed to gelatin more rapidly at higher temperatures. Smith states that the phosphate ion accelerates the rate at which collagen is changed to gelatin at a given temperature. The addition of acid to meat may also increase the rate of hydrolysis of collagen. Juiciness is given as a desirable quality of cooked meat. Meat loses moisture during cooking, even when cooked submerged in water. The higher the interior temperature to which the meat is cooked, if the composition and cooking conditions are standardized, the less moist the meat. Meat that contains a large amount of fat within and around the muscle fibers may seem juicy because of melting of the fat by heat in cooking. The fibers with a high fat content may also have high water content, particularly if part of the fat is in an emulsion that will not break with high temperatures, thus retaining part of the moisture.

Some pieces of meat are apparently far more juicy than others after cooking. It seems rather certain from the results of Hoagland et al, Grass-man, and others, that the increase of amino nitrogen with aging is one factor in bringing this about. The amino acids may not be able to bind as much water as the protein, so that the free water content and apparent juiciness may be increased with increase of amino nitrogen. Sometimes the juiciness seems to be related to the fat

content. How great an influence the method of distribution of the fat within the fiber, the salt content of the fiber, the pH, or the development and maturity of the fiber has upon this point cannot be stated? The tissues of old animals lose their power to bind as much water as tissues from younger animals. Although this may partially explain the better quality of meat from younger animals it does not explain why veal is less juicy than baby beefs. Perhaps, if the water is bound too tightly by the coagulable protein micelles, the dryness is more apparent to the tactile sense.

Child and Fogarty found that approximately 11 per cent more fluid could be pressed from one semitendinosus muscle when heated to an interior temperature of 58°C. than for the other semitendinosus muscle from the same animal heated to 75°C.

Noble, Halliday, and Klaas found: "When subjected to a pressure of 3,800 pounds per square inch, the ribs cooked to 61° C. yielded more juice than those heated to 75°C. and the round more than the corresponding ribs. The larger quantity of juice was found to be richer in solids, total nitrogen, and, in one case, also richer in coagulable nitrogen."

Empery states that for uncooked meat there is a direct relationship between the hydrogen-ion concentration of the muscle fiber and its capacity for holding muscle fluid, but the author knows of no work in which juiciness of cooked meat has been related to pH. Change in color. During the heating of meat, after a temperature of about 50°C. is reached, the color gradually changes from red or pink to a lighter shade and finally, if a sufficiently high temperature is reached, becomes brown or gray. Veal and pork are more gray, beef and lamb develop a browner shade. This color change has been discussed in connection with meat pigments, the oxyhemoglobin being broken down by heat to the brown hematin. The degree of ripeness of the meat affects the temperature at which the color change occurs, ripened meat becoming gray at a lower temperature.

The extreme browning on the surface of meat is accompanied by breakdown of surface proteins and fat, probably with liberation of sulfur and other compounds.

Tenderness is one quality universally desired in cooked meats. Tenderness may be estimated by subjective methods such as the ease of cutting or chewing. At present the most widely used method for comparing the tenderness of meat is the grading chart. The chart developed by the Cooking Committee of the National Project.

8.4. FISH COOKERY:

Principles of cooking fish:

Since fish has little connective tissue, it requires a much shorter cooking time than meat and poultry. Fish should be cooked at moderate temperatures long enough for its delicate flavor to develop, for protein to coagulate and for very small amount of connective tissue present to break down. The flesh of fish is sufficiently cooked when it falls easily into clumps of snowy white flakes when tested with a fork. Cooking fish at high temperature or cooking it too long, causes the muscle protein to shrink leaving the fish tough, dry and lacking in flavour. Fish can also be cooked by coagulating protein with acids such as lemon or lime juice.

Methods of cooking fish:

Fish is usually cooked by dry heat – broiling, baking and frying. Moist heat is also effectively employed to protect the delicate flavor of the fish. Fish such as salmon, mackerel and herring contain some fat and require very little addition of fat in cooking. Some fish like cod, haddock;

halibut and bass, contain very little fat and require added fat during cooking. Fin fish may be poached in water or court bouillon, a highly seasoned stock that enhances the flavor of fish. In order to keep the fish from falling apart while it cooks it is best to tie the fish in cheese cloth or parchment paper before immersing it into the hot water. Shell fish needs only to be plunged into the simmering salt water but care must be taken to keep the water from boiling so that the fish meat remains juicy and tender.

Shell fish cooked in the shell is said to retain its flavor better. Fish that is oven baked enclosed in a sort of oil paper is called "en papillote". The difference in oven temperatures does not affect the palatability. Fish can be baked with butter, garlic and spices. Unlike meat and poultry cooked fish tends to break up easily thus requiring careful handling during cooking and serving. To test if fish is cooked insert a fork into the fleshiest part of the fish. The flesh will flake away if cooked. The flesh loses its translucency and becomes opaque.

8.5. COMPOSITION:

The composition of fish varies reflecting to a large extent its variable fat content. In fish such as cod, haddock, whiting, rock fish and sole, the amount of fat content is less than 1%. In salmon, mackerel and butter fish the fat content is as high as 25%. The protein content of fish is approximately 20% and the mineral content is about 1.5%. The shell fish has less fat and more carbohydrate than fin fish. Like meat, fish contain some glycogen in muscle tissue. In the live fish, glycogen is the source of stored energy. Oysters are notable for their high content of glycogen, on an average of 2-3%.

NUTRITIVE VALUE:

Fish is an excellent source of protein due to its quality and quantity. They contain around 20% protein. The biological value of fish protein is 80%, that is, it has good quality protein compared to any other animal protein. Fishes are not good sources of energy because they are not good source of carbohydrate and fat. Fish contains less amount of fat compared to meat and poultry. The lipid content of both fish and prawns, is very low and varied within a very narrow range of 1-28%.

Fresh water fish contains n-3 poly unsaturated fatty acids. The levels of these fatty acids varied widely from 0.07 to 0.28g/100g edible muscle, most of which was made of eicosapentaenoic acid and docosahexaenoic acid. Commonly consumed fish murrel has the highest content of n-3 PUFA- 0.28g/100g edible muscle. These values are similar to those of marine fish and indicate that both are good sources of n-3 PUFA. Fresh water fish with fat content of about 1.7g% (pearl spot) contains n-3 PUFA of about 0.26g/100g edible muscle, whereas in marine fish (mackerel) with similar fat content (1.8%) the n-3 PUFA content is 0.39g/100g edible muscle. Thus marine fish is relatively rich in n-3 fatty acids. In prawns the n-3 PUFA ranged from 0.2-0.3g/100g edible muscle with total fat content of 1.0-1.8%.

Fish is rich in calcium particularly small fish when eaten with bones. Marine fish or ocean fish are good sources of iodine. Oysters are good sources of copper and iron. Sodium content of fresh water fish is slightly less than meat. Fish liver oils are excellent sources of fat soluble vitamins, Rohu contains vitamin C. Fish are food sources of niacin and vitamin D.

8.6. CHANGES IN FISH

SPOILAGE:

Fish is considered in prime condition for upto three hours from catch, in average condition from three to six hours and on the way to spoilage from the sixth hour.

Microbiological:

While live fish is bacteriologically sterile, there are large number of bacteria on the surface slime and digestive tracts of living fish. When fish is killed, these bacteria multiply rapidly and attack all tissues. Growth of microorganism and enzymes affect of the quality.

Physiological:

Fish struggle when caught and hence all the glycogen stores in the muscle and liver are used up. There is no glycogen left for being converted into lactic acid which helps to increase the pH of the tissues and retard the multiplication of microorganisms.

Biochemical:

The important biochemical change leading to the development of the characteristic fishy off odour is due to the production of trimethylamine by the action of bacterial enzymes on phospholipids and choline present in fish. The fats present in fish are highly unsaturated. By the action of bacterial lipases and lipoxidases, free fatty acids are produced and the fat undergoes oxidative rancidity.

8.7. PRESERVATION AND STORAGE:

Fish spoils quickly and should be used as soon as possible. It should be kept covered in the coldest part of the refrigerator for no longer than 2 days. Prepackaged fish and shellfish can be refrigerated in the original package for a short time. Fish wrapped in butcher paper should be taken out and wrapped in aluminum foil or plastic wrap. Frozen fish maintains good quality when placed in the freezer immediately after purchase. Freezer temperature of 0°F (-18°C) or lower are necessary to prevent loss of colour, texture, flavor and nutritive value. Cured fish is best kept covered in the refrigerators. Open canned fish should be used up immediately or refrigerated.

Cold Storage:

The fishes are packed with crushed ice in suitable containers. This will prevent spoilage for 1-2 days. Fresh fish or dressed fresh fish in good condition will keep well for about a week, if they are packaged with crushed ice and stored at 0°C in a refrigerated room.

The dressed fish or fillets are preserved by coating with salt powder in the ratio 1 part of salt to 3 parts of fish. The salt powder should contain sodium benzoate.

Preservation:

Fish can be preserved by canning, chilling, freezing and curing. Unlike most foods, the enzymes of fish operate at about 5°C, the temperature of the water from which they came. In order to keep fish for any length of time, they must be frozen, canned or cured.

Canning:

In canning, fish is dressed and washed. It is cut into pieces and filled in cans in saline. The cans are double steamed under vacuum. The sealed cans are sterilized at steam pressure at 250°F for 90 minutes. The sterilized cans are cooled in running water, wiped and kept in a cool place (50°F to 60°F). Fishes like salmon, tuna, sardines, mackerel, herring, lobster, crab, clams, shrimp and mussels are canned. Of these, Salmon and tuna are the most popular.

Canned shellfish may become dark or discoloured during storage. This discolouration is thought to be caused by ferrous sulphide formed by the hydrogen sulphide released from the fish and the iron in the can. The use of a special enamel can containing zinc is effective in preventing this discolouration. Shellfish is sometimes dipped in acetic, citric or tartaric acid before it is packed. This increases the acidity of the fish and reduces the possibility of ferrous sulphide formation. However, the colour changes in canned tuna are the result of a lack of vitamins in the flesh. Ascorbic acid and niacin, are effective in returning the flesh to its normal pink colour.

Chilling:

Because, the enzymes that cause spoilage of fish are active at low temperatures and because fish oils become oxidized at fairly low temperature, fish catches subjected to temperatures above freezing are given to fast deterioration. The entire fish catch is usually aboard the fishing vessel by packing in crushed ice or by mechanical refrigeration. The use of antibiotics and other preservatives in the crushed ice retards bacterial action to some extent.

Freezing:

The freezing of fish greatly extends the period of storage and is effective in keeping the fish in a condition similar to that of fresh fish, large fish may be frozen by the sharp freeze, a comparatively slow freeze.

Fin fish are usually frozen as fillets and steaks with or without skin. Fillets of cod, patack, sole, haddock, rorefish and whiting are the most popular. Swordfish, turbot, salmon and halibut are frozen in steak form.

Dressed fresh fish or fillets or steaks are wrapped in moisture proof cellophane. The freezing is done rapidly at -40°F and the frozen fish is maintained at -10°F to 0°F. Fish in the frozen state will keep well for long periods upto 6 months.

Effect of freezing:

Protein denaturation:

The time taken to freeze fish influences the size of the crystals formed and the extent of protein denaturation. Considerable denaturation of the protein takes place during the freezing process, mainly because of loss of moisture from the flesh. As the water freezes in the fish, the salt concentration of the muscle tissue increases. The highly concentrated salt solution that prevails while the water is going into crystallization, denatures the protein making it tough and rubbery. This is an irreversible reaction. Not all denaturation of muscle protein takes place during the freezing process, considerable alteration occurs, while the frozen fish is stored.

Desiccation:

Another effect of freezing is desiccation (drying out). Drying is caused by the transfer of moisture from the surface of the fish to the cold or metal surface on which the fish rest during freezing. It may also be caused by air currents. The air close to the fish in the storage room is warmer than the refrigeration pipes and is able to absorb large amounts of moisture from the fish. As the warm air moves into contact with the refrigeration pipes, its temperature drops and its capacity to hold water is reduced. Desiccation can occur if air pockets are left in the cartons or between the fish and the wrapping. Many quick-freezing processes freeze fish under pressure to eliminate the formation of air pockets.

Another less controllable form of desiccation is caused by the evaporation of water from the frozen fish flesh into air interstices within the muscle fibres. This evaporation may be reduced by covering the fish with dilute brine that fills in the interstices. Frozen fish undergo undesirable oxidation changes. Oxidation can be retarded by packaging the fish so that no air spaces form between the surface of the fish and the wrapping.

Curing:

Fish can be cured by salting, drying, pickling or smoking.

Pickling or smoking:

Fish allowed to remain in the salt solution are said to be pickling, e.g. pickled herring, sprats, mackerel and salmon.

Salting and drying:

Salting and drying of fish are the most important methods of fish preservation. The process of salting and drying includes the following steps.

Cleaning and dressing:

Fish is cleaned and dressed. Dressing is done by splitting the fish open on the ventral side along with the cerebral column with the dorsal side as hinge. Gills and entrails are removed. In the case of large fish, fillets are prepared. Salting is done with the addition of potassium sorbate, sodium benzoate and acid sodium phosphate (0.5%). Salting is carried out at room temperature for 48 hours. Salted fish is washed over with 5% salt solution to remove excess of salt sticking to the surface of the fish.

Drying and packing: The salted fish is dried in the sun or cabinet driers with inlet air temperature at 180°F and outlet air temperature at 110°F to moisture content of about 25%. The dried fish is packed in polythene bags and wrapped in wax paper and packed in wooden boxes.

8.8. SUMMARY

Meat cooking in rural and small urban communities is increasing tremendously. Hence, the cooking of meat attains importance and knowledge of what happens to the meat during cooking gives understanding of why it should be cooked soon after defrosting, if it is defrosted before cooking. Cooking method, changes in cooking. Because meat may account for the largest portion of food cost.

Always check fish for freshness. Smell the fish, look closely at it, and when buying whole fish, touch it. Fresh fish should smell of the sea, but never "fishy." The flesh should be firm and the grain of the fish should be tight. If the flesh looks watery or desiccated, or if there is gapping in the grain, pass it by. Fish should be firm, not mushy. Fish are waterproof on the outside, not on the inside.

8.9. SELF ASSESSMENT QUESTIONS

1. Explain the role of meat in our diet?
2. Discuss the postmortem changes in meat?
3. List the methods of cooking in meat?
4. Describe the storage changes in meat?
5. Write a short note on preservation of fish?
6. Explain changes and composition of fish?
7. Discuss the points remembered while cooking fish?

8.10. REFERENCE BOOKS

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Lesson – 9**STRUCTURE OF VEGETABLE AND FRUIT TISSUES****9.0. OBJECTIVE**

- To understanding of the structure of cell
- Describe the major free sugars which occur in common foods of plant origin

STRUCTURE**9.1 Introduction****9.1.1 Cell****9.2 Starch****9.2.1 Sources for starch****9.2.2 Structural unit****9.2.3 Molecular structure****9.2.3.1 Amylose****9.2.3.2 Amylopectin****9.2.4 Functionality****9.3. Free sugars in fruits and vegetables****9.4. Summary****9.5. Self Assessment Questions****9.6. Reference Books****9.1. INTRODUCTION**

Fruits, vegetables, and other plant tissues either directly or indirectly supply all of man's foods. There are an estimated 270,000 plant species. The number of crops which fit into man's dietary picture is probably between 1,000 and 2,000 species. Some 100 to 200 species are of major importance in world trade, 15 species provide the bulk of world food crops, such as rice, wheat, soybean, peanut, coconut, and banana.

There are a number of different types of vegetables. They are classified as bulbs, roots, and tubers. Vegetable fruits, such as okra, or cucumbers, make up another category or classification of vegetables. Of course, there are also flowers, buds, stems and leafy vegetables. Vegetable seeds are those such as the legumes, coconut, or corn.

However, the important distinction between fruit and vegetables has come to be made on a usage basis. Those plant items that are generally eaten with the main course of a meal are considered to be vegetables. Those that are commonly eaten as dessert are considered fruits. That is the distinction made by the food processor, certain marketing laws and the consuming public, and this distinction will be followed in this document. Vegetables are derived from various parts of plants and it is sometimes useful to associate different vegetables with the parts of the plant they represent since this provides clues to some of the characteristics we may expect in these items. A classification of vegetables based on morphological features is seen in Table 2.1.

TABLE 2.1 Classification of Vegetables*

Category	Examples
Earth vegetables roots	sweet potatoes, carrots
Modified stems tubers	Potatoes
Modified buds bulbs	onions, garlic
Herbage vegetables	
Leaves	cabbage, spinach, lettuce
Petioles (leaf stalk)	celery, rhubarb
flower buds	cauliflower, artichokes
sprouts, shoots (young stems)	asparagus, bamboo shoots
Fruit vegetables	
Legumes	peas, green beans
Cereals	sweet corn
vine fruits	squash, cucumber
berry fruits	tomato, egg plant
tree fruits	avocado, breadfruit

Source: Feinberg (1973)

Fruit as a dessert item, is the mature ovaries of plants with their seeds. The edible portion of most fruit is the fleshy part of the pericarp or vessel surrounding the seeds. Fruit in general is acidic and sugary. They commonly are grouped into several major divisions, depending principally upon botanical structure, chemical composition and climatic requirements.

Berries are fruit which are generally small and quite fragile. Grapes are also physically fragile and grow in clusters. Melons, on the other hand, are large and have a tough outer rind. Drupes (stone fruit) contain single pits and include such items as apricots, cherries, peaches and plums. Pomes contain many pits, and are represented by apples, quince and pears. Citrus fruit like oranges, grapefruit and lemons are high in citric acid. Tropical and subtropical fruits include

bananas, dates, figs, pineapples, mangoes, and others which require warm climates, but exclude the separate group of citrus fruits. The compositions of representative vegetables and fruits in comparison with a few of the cereal grains are seen in Table 2.

TABLE 2 Typical percentage composition of foods from plant origin Percentage Composition- Edible Portion

Food	Carbo- hydrate	Protein	Fat	Ash	Water
Cereals					
wheat flour, white	73.9	10.5	1.9	1.7	12
rice, milled, white	78.9	6.7	0.7	0.7	13
maize, whole grain	72.9	9.5	4.3	1.3	12
Earth vegetables					
potatoes, white	18.9	2.0	0.1	1.0	78
sweet potatoes	27.3	1.3	0.4	1.0	70
Vegetables					
Carrots	9.1	1.1	0.2	1.0	88.6
Radishes	4.2	1.1	0.1	0.9	93.7
Asparagus	4.1	2.1	0.2	0.7	92.9
beans, snap, green	7.6	2.4	0.2	0.7	89.1
peas, fresh	17.0	6.7	0.4	0.9	75.0
Lettuce	2.8	1.3	0.2	0.9	94.8
Fruit					
Banana	24.0	1.3	0.4	0.8	73.5
Orange	11.3	0.9	0.2	0.5	87.1
Apple	15.0	0.3	0.4	0.3	84.0
Strawberries	8.3	0.8	0.5	0.5	89.9

Source: Anon. (1960)

Compositions of vegetables and fruit not only vary for a given kind in according to botanical variety, cultivation practices, and weather, but change with the degree of maturity prior to harvest, and the condition of ripeness, which is progressive after harvest and is further influenced by storage conditions. Nevertheless, some generalisations can be made. Most fresh vegetables and fruit are high in water content, low in protein, and low in fat. In these cases water contents will generally be greater than 70% and frequently greater than 85%.

Commonly protein content will not be greater than 3.5% or fat content greater than 0.5%. Exceptions exist in the case of dates and raisins which are substantially lower in moisture but cannot be considered fresh in the same sense as other fruit. Legumes such as peas and certain beans are higher in protein; a few vegetables such as sweet corn which are slightly higher in fat and avocados which are substantially higher in fat.

Vegetables and fruit are important sources of both digestible and indigestible carbohydrates. The digestible carbohydrates are present largely in the form of sugars and starches while indigestible cellulose provides roughage which is important to normal digestion. Fruit and vegetables are also important sources of minerals and certain vitamins, especially vitamins A and C. The precursors of vitamin A, including beta-carotene and certain other carotenoids, are to be found particularly in the yellow-orange fruit and vegetables and in the green leafy vegetables.

Citrus fruit are excellent sources of vitamin C, as are green leafy vegetables and tomatoes. Potatoes also provide an important source of vitamin C for the diets of many countries. This is not so much due to the level of vitamin C in potatoes which is not especially high but rather to the large quantities of potatoes consumed.

Fruit and vegetables have many similarities with respect to their compositions, methods of cultivation and harvesting, storage properties and processing. In fact, many vegetables may be considered fruit in the true botanical sense. Botanically, fruits are those portions of the plant which house seeds. Therefore such items as tomatoes, cucumbers, eggplant, peppers, and others would be classified as fruits on this basis.

In discussing the composition of fruits and vegetables, one is interested in both the tissue structure and in the components which make up this structure. One of the major structural components of fruits and vegetables is cellulose. Scanning electron micrograph allows us to view the extracted cellulose in crystalline form. It is a polymer of glucose and is the major structural component. Cellulose is not the only structural material; however, the fundamental type of cells are parenchyma or ground cells. There are several different categories of tissues. All cells have a cell wall. The cell wall consists of very thin primary cell wall and a hydroxyproline-containing membrane. This cell wall contains much of the cellulose. Additionally, there are other polymers, such as the pectic substances, lignin, and sometimes even leucoanthocyanins (pigments).

The understanding of the structure of a particular plant cell is not only important for texture elucidation. It will also assist with a greater awareness of color and of flavor.

Leafy vegetables are generally high in water and low in carbohydrates, proteins and fats. They frequently contain the mechanism for photosynthesis.

- **Spinach:** Leaves of *Spinacia oleracea*.
- **Lettuce:** Leaves of the plant *Lactuca sativa*.
- **Mustard Greens:** is the leaves of the mustard plant used in salads or cooked as a vegetable. The mustards are of the CRUCIFERAE family which gets its name from the characteristic cross-shaped flowers, and of the genus BRASSICA.
- **Cabbage:** The Cabbage is one of the innumerable forms of the species *Brassica oleracea* (Crucifer Family), these characterized by a more or less compact head formed by the leaves.

Seeds, a mature ovula, vary in water content and are a source of carbohydrates and proteins. They may be "fresh" and high in water or "dried" and relatively low in water content.

Tubers are generally higher in carbohydrates and lower in water content than stem, flower or leafy vegetables. Tubers are an enlarged underground stems.

Potatoes: Potatoes are a vegetable. The tuber of a plant belonging to the order Solanaceae. The potato (*Solanum tuberosum*) furnishes a high amount of starch.

Fruits are the fleshy part of the plant which surrounds the seed. It may be eaten either, botanically or culturally, as a fruit or as a vegetable.

Cantaloup: cantaloupes and muskmelons are names used interchangeably to refer to both the netted and smooth type of melon. These melons are oval and approximately 5 inches or more in diameter, with yellow or golden (not green) background color.

Eggplant: The eggplant (aubergine) is native to Asia, having been cultivated in China from 600BC.

Squash: is an edible fruit of the gourd family, the flesh of which is cooked and eaten as a vegetable.

Peas (snow peas): Another name, sugar peas, is more accurately descriptive because these tender pods are as sweet as sugar when young, which is when they should be eaten. Their Cantonese name is a corruption of Holland (hoh laan), and this may explain their origins. They look similar to green garden peas, except that they are flatter. Snow peas develop a large, fleshy shell long before their peas develop. When they are fully developed, it is necessary to remove the string that runs along the top before cooking.

Stems are plant portions generally high in water and fiber. They have relatively little other nutritive value.

Asparagus: is called in Britian sometimes "Sparrow-grass" a term with no meaning. The plant is one of the lily tribe, and, although cultivated in gardens for table use, is not unfrequently met with growing wild along the sea-shore.

Bulbs are generally higher in carbohydrates and lower in water content than stems, flowers or leafy vegetables. Bulbs are enlargements above the roots.

- **Onion:** Belonging to the Liliaceae family, onions are characterized by layered crisp flesh, usually white but in some types a red-purple. When raw they have a pungent odor and strong flavor, which becomes almost sweet when cooked.

- **Garlic:** Bulb of *Allium sativum* (Lily family) with pungent odor when crushed. This is due to diallyl thiosulphinate, ammonia and pyruvic acid liberated from an odorless precursor, alliin (allyl-cysteine sulphoxide) by the enzyme alliinase.

Although broccoli, cauliflower and artichokes are generally listed as the edible flowers, naturalists are exploring edible decorative flowers. Flowers are generally high in water and low in carbohydrates.

- **Artichokes:** there are two kinds of vegetables known by this name — the Green or Globe artichoke (*Cynara Scolymus*), the flower of which resembles that of a thistle, and provides the edible part; and the Jerusalem artichoke, which is a species of sunflower, with edible, tuberous roots (*Cynara Scolymus*), the flower of which resembles that of a thistle.

• **Broccoli:** is a plant of the cabbage family related to the cauliflower, bearing heads of green or purplish flower buds. The flower stalk and head are eaten as a vegetable.

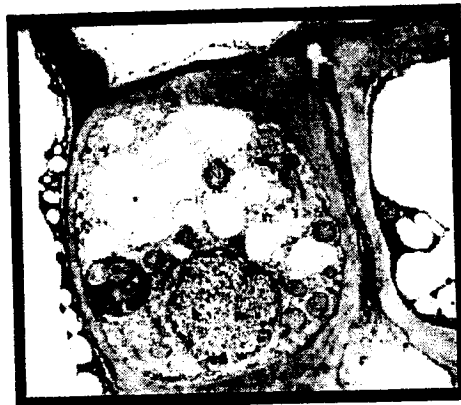
Roots are generally higher in carbohydrates and lower in water content than stem, flower or leafy vegetables. Roots are the part of a plant which grows downward into the soil and furnishes nourishment by absorbing nutrients.

• **Carrot:** The Carrot (*Daucus Carota*) is a native of the warmer parts of Europe and western Asia, but was used as a food crop in such places as China, Japan, and India as early as the thirteenth century.

The understanding of the structure of a particular plant cell is not only important for texture elucidation. It will also assist with a greater awareness of color and of flavor.

- cell wall
- chloroplasts
- chromoplasts
- cytoplasm This is the living part of the cell. Generally, it is at least immediately inside the cell wall. The plastids, nucleus, and mitochondria are located within this cytoplasm.
- leucoplasts/amyloplasts
- pectic substances
- plasmamembrane
- middle lamella
- nucleus
- vacuole

As can be seen in the transmission electron micrograph below, within the cell wall there is the cytoplasm which is simply a jelly-like colloid of living matter. In this cytoplasm are plastids, mitochondria, and a nucleus. Plastids consist of chloroplasts, chromoplasts, and leucoplasts. Also, in the cell are the mitochondria and nucleus, which are the predominant metabolic organizing units of the cell. The cell also contains a vacuole which is, essentially, the garbage can of the cell for waste substances containing compounds such as sugars, acids, and soluble pigments and tannins. In addition to parenchyma cells, there are dermal tissues (shown in the cabbage leaf) and vascular tissues. Parenchyma tissue occurs in abundance in the potato.



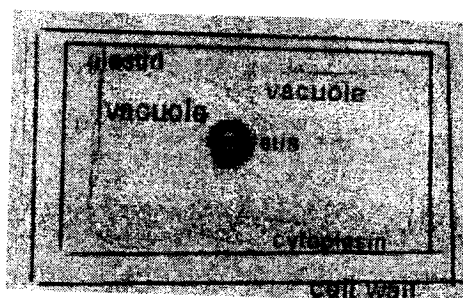
9.1.1 Cell

Plant cell structure depends upon the role and function of the cell. Regardless of the cell's function, there are a number of commonalities between different cells. The cell wall consists of a primary wall and a secondary wall. The primary walls of two cells are joined together by a common layer called the middle lamella. The cell wall and middle lamella's chief components are cellulose, hemicellulose and pectic substances. The pectic substances in the middle lamella are hydrolyzed from an insoluble macromolecule to smaller pectic substances during the maturation and ripening process.

Pectic substances, large macromolecules primarily of (1- \rightarrow 4)-alpha-D-galacturonic acid, are the glue or cementing substances of plant cells. The polymers are located in the cell wall or middle lamella. These polygalacturonic macromolecules are found both between the cells and within the cellulose, hemicellulose, and lignin matrix of the cell wall. During maturation of the plant the largest of the polymers, protopectin, is hydrolyzed by pectinases to smaller polymers. An example of such a change, determined through texture changes, is observed during the ripening of an apple. The unripe apple, which is generally firm and hard, has the pectic cementing substance, protopectin dominate. As the apple ripens, pectinases hydrolyze the protopectin to pectinic substances dominating in a ripe apple and pectic acids dominating in an over ripe apple. A vacuole is contained within plant cells. Its size is somewhat dependent upon the cells function. The vacuole is composed of water with soluble substances dissolved within it. These may include sugars, acids, volatile esters, aldehydes, ketones, and water soluble pigments depending upon the particular fruit or vegetable:

Energy conversion in the cell is carried out by the chloroplasts and mitochondria. The leucoplasts store starch which is used for energy. The mitochondria are small spheres, rods, or filaments that produce energy for the cell through cellular respiration. They contain fats, proteins and enzymes. The nucleus of the cell is imbedded within the cytoplasm. This is the nerve center of the cell. It controls reproduction and protein synthesis. Both the nucleus and mitochondria are needed for the continued life of the cell.

The cell can be diagrammed as follows:



9.2 STARCH

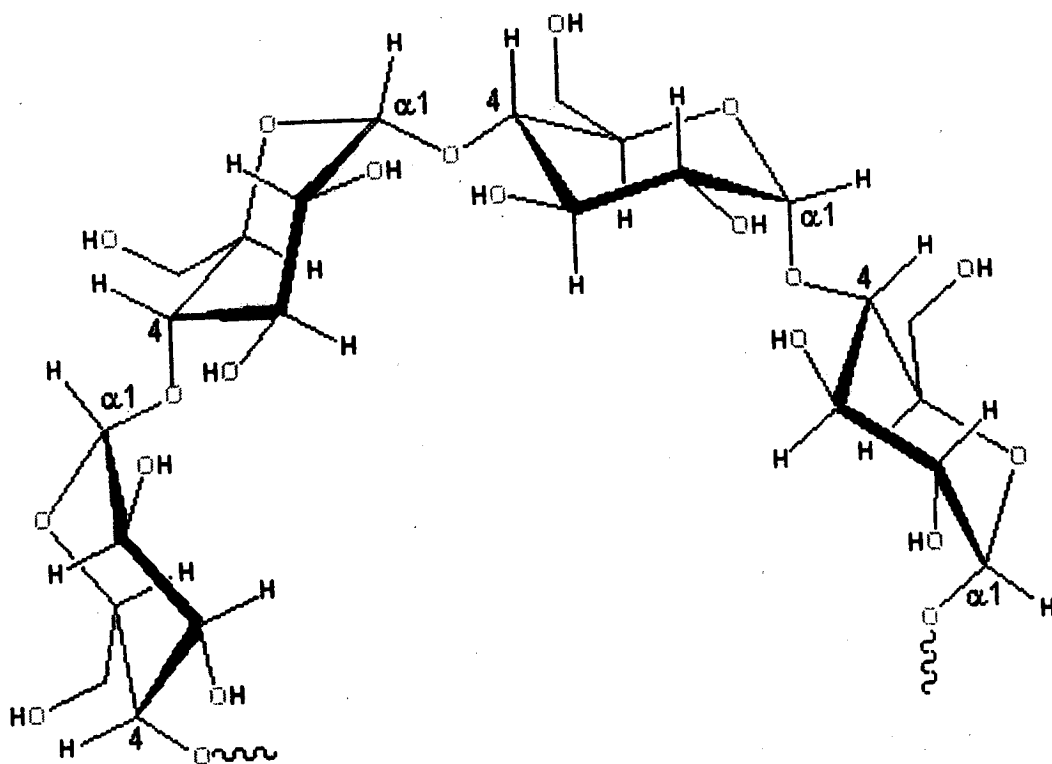
9.2.1: Sources for starch

Starch is the major carbohydrate reserve in plant tubers and seed endosperm where it is found as granules each typically containing several million amylopectin molecules accompanied by a much larger number of smaller amylose molecules. By far the largest source of starch is corn (maize) with other commonly used sources being wheat, potato, tapioca and rice. Amylopectin (without amylose) can be isolated from 'waxy' maize starch whereas amylose (without amylopectin)

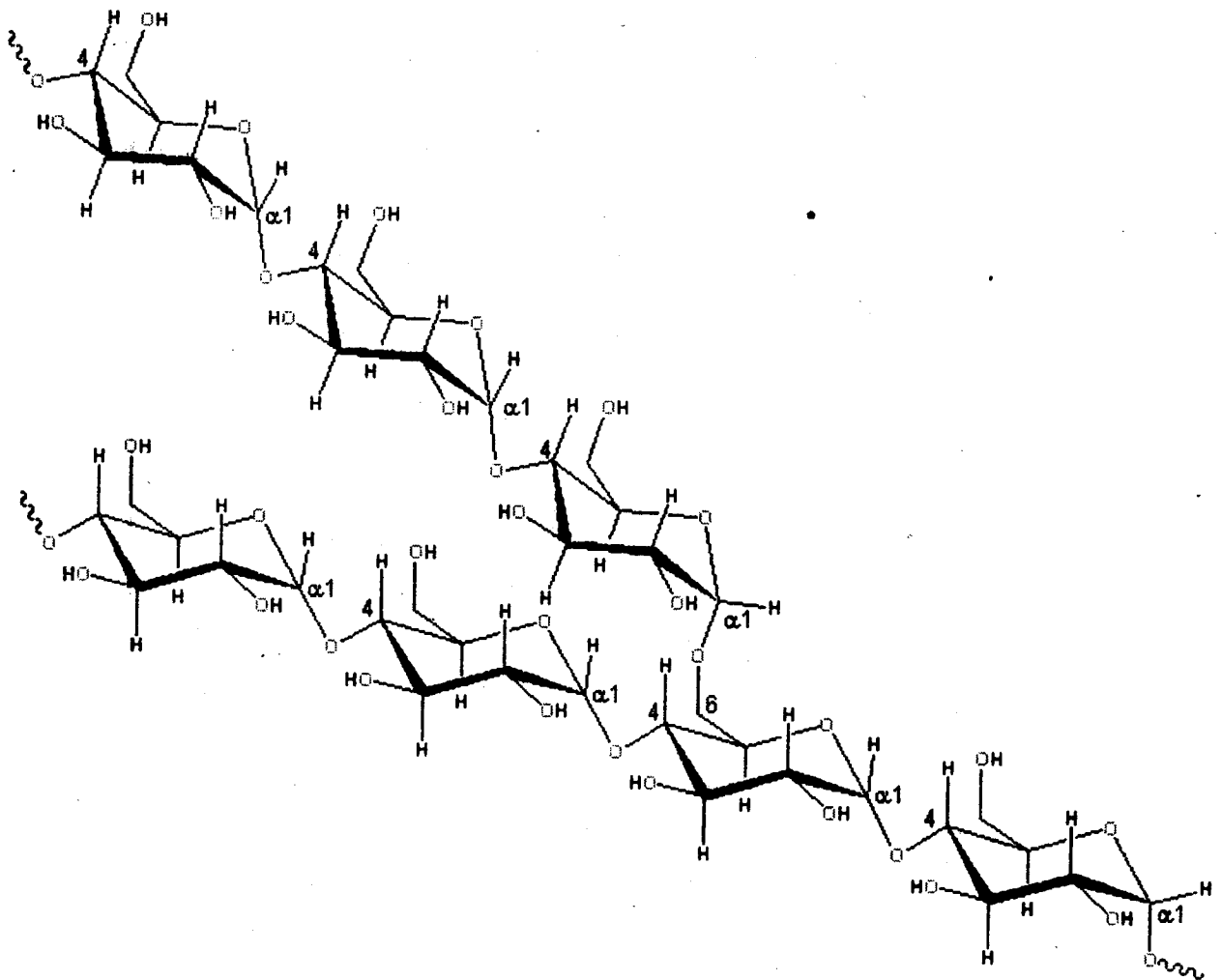
is best isolated after specifically hydrolyzing the amylopectin with pullulanase. Genetic modification of starch crops has recently led to the development of starches with improved and targeted functionality.

9.2.2: Structural unit

Starch consists of two types of molecules, amylose (normally 20-30%) and amylopectin (normally 70-80%). Both consist of polymers of α -D-glucose units in the 4C_1 conformation. In amylose these are linked $-(1\rightarrow4)-$, with the ring oxygen atoms all on the same side, whereas in amylopectin about one residue in every twenty or so is also linked $-(1\rightarrow6)-$ forming branch-points. The relative proportions of amylose to amylopectin and $-(1\rightarrow6)-$ branch-points both depend on the source of the starch, for example, amylomaizes contain over 50% amylose whereas 'waxy' maize has almost none (~3%).



Representative partial structure of amylose



9.2.3: Molecular structure

Amylose and amylopectin are inherently incompatible molecules; amylose having lower molecular weight with a relatively extended shape whereas amylopectin has huge but compact molecules. Determination of the molecular weight distribution of starch molecules presents several problems. The presence of amylose tends to reduce the crystallinity of the amylopectin and influence the ease of water penetration into the granules. Most of their structure consists of α -(1 \rightarrow 4)-D-glucose units. Although the α -(1 \rightarrow 4) links are capable of relatively free rotation around the (δ) phi and (θ) psi torsions, hydrogen bonding between the O3' and O2 oxygen atoms of sequential residues tends to encourage a helical conformation. These helical structures are relatively stiff and may present contiguous hydrophobic surfaces.

9.2.3.1: Amylose

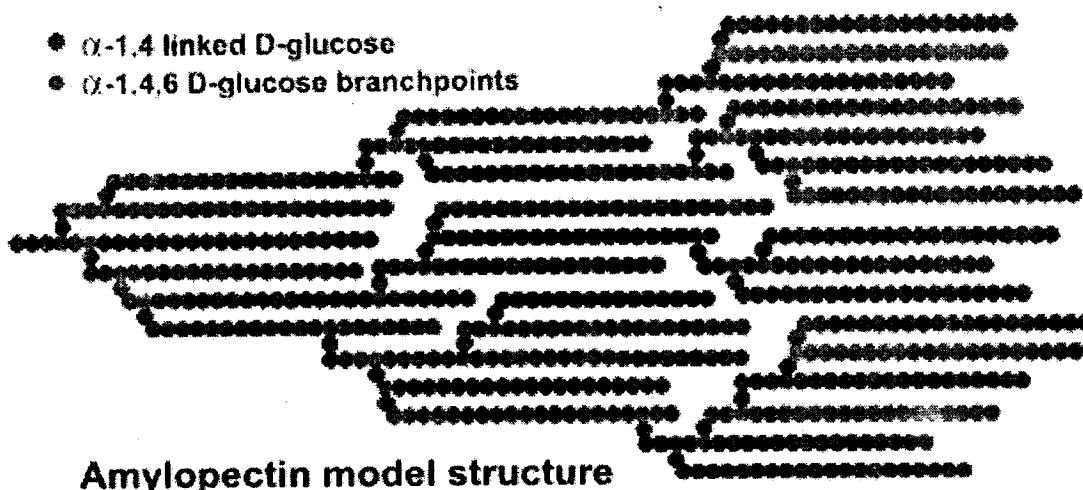
Amylose molecules consist of single mostly-unbranched chains with 500-20,000 α -(1 \rightarrow 4)-D-glucose units dependent on source (a very few α -1 \rightarrow 6 branches and linked phosphate groups may be found, but these have little influence on the molecule's behavior). Amylose can form an extended shape (hydrodynamic radius 7-22 nm) but generally tends to wind up into a rather stiff left-handed

single helix or form even stiffer parallel left-handed double helical junction zones. Single helical amylose has hydrogen-bonding O2 and O6 atoms on outside surface of the helix with only the ring oxygen pointing inwards. Hydrogen bonding between aligned chains causes retrogradation and releases some of the bound water (syneresis). The aligned chains may then form double stranded crystallites that are resistant to amylases. These possess extensive inter- and intra-strand hydrogen bonding, resulting in a fairly hydrophobic structure of low solubility. The amylose content of starches is thus the major cause of resistant starch formation.

Single helix amylose behaves similarly to the cyclodextrins by possessing a relatively hydrophobic inner surface that holds a spiral of water molecules, which are relatively easily lost to be replaced by hydrophobic lipid or aroma molecules. It is also responsible for the characteristic binding of amylose to chains of charged iodine molecules (for example, the polyiodides; chains of I_3^- and I_5^- forming structures such as I_9^{3-} and I_{15}^{3-} ; note that neutral I_2 molecules may give polyiodides in aqueous solution and there is no interaction with I_2 molecules except under strictly anhydrous conditions) where each turn of the helix holds about two iodine atoms and a blue color is produced due to donor-acceptor interaction between water and the electron deficient polyiodides.

9.2.3.2: Amylopectin

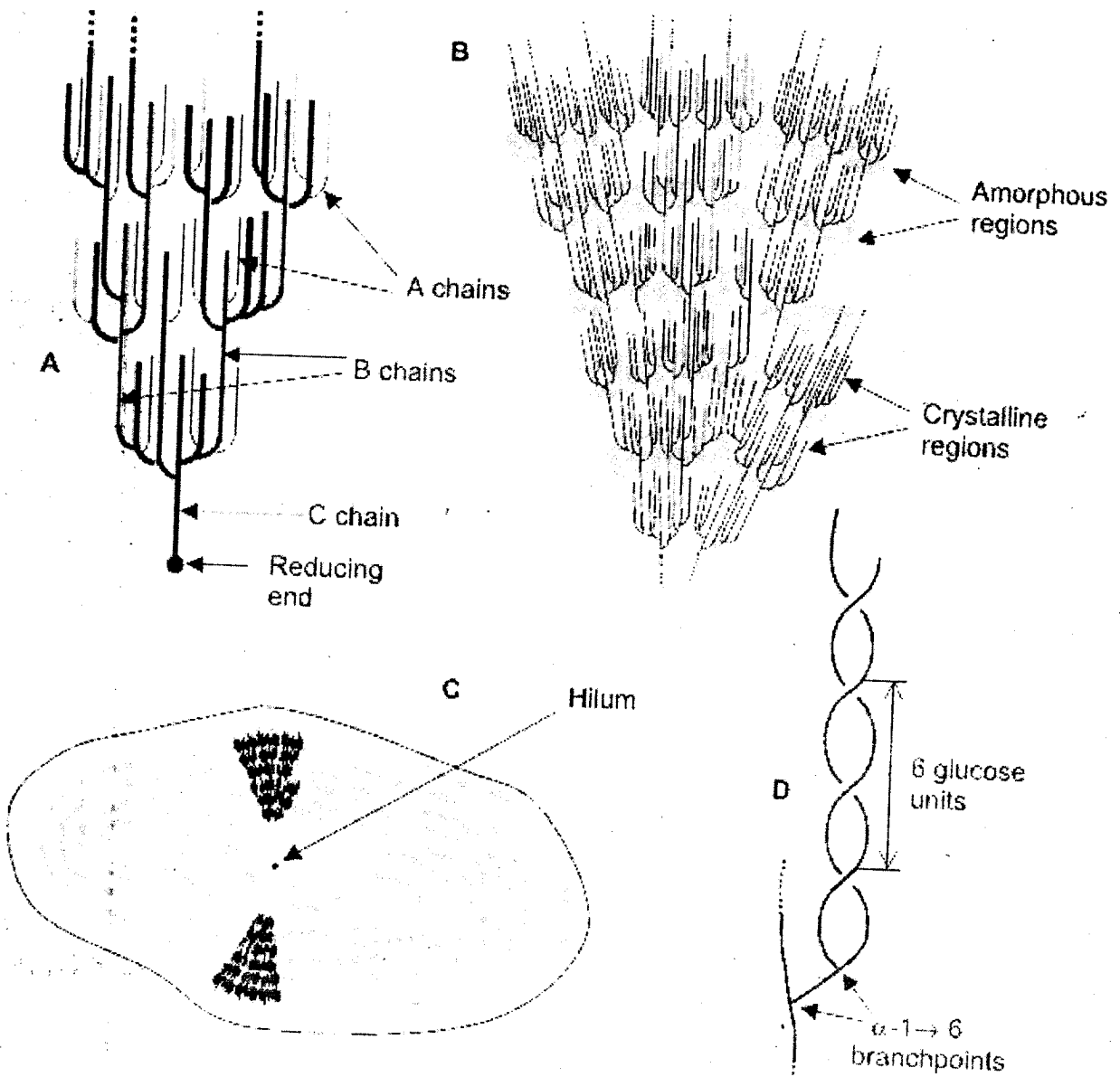
Amylopectin is formed by non-random α -1 \rightarrow 6 branching of the amylose-type α -(1 \rightarrow 4)-D-glucose structure. This branching is determined by branching enzymes that leave each chain with up to 30 glucose residues. Each amylopectin molecule contains a million or so residues, about 5% of which form the branch points. There are usually slightly more 'outer' unbranched chains (called A-chains) than 'inner' branched chains (called B-chains). There is only one chain (called the C-chain) containing the single reducing group.

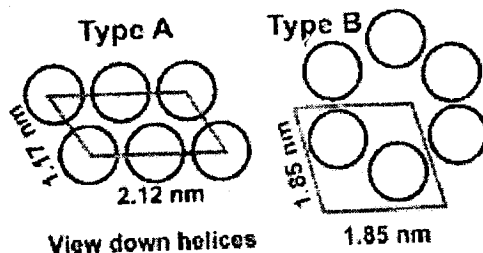


A-chains generally consist of between 13-23 residues. There are two main fractions of long and short internal B-chains with the longer chains (greater than about 23-35 residues) connecting between clusters and the shorter chains similar in length to the terminal A-chains.

Each amylopectin molecule contains up to two million glucose residues in a compact structure with hydrodynamic radius 21-75 nm (waxy maize amylopectin >300 nm). The molecules are

oriented radially in the starch granule and as the radius increases so does the number of branches required to fill up the space, with the consequent formation of concentric regions of alternating amorphous and crystalline structure. In the diagram below: A - shows the essential features of amylopectin. B - shows the organization of the amorphous and crystalline regions (or domains) of the structure generating the concentric layers that contribute to the "growth rings" that are visible by light microscopy. C - shows the orientation of the amylopectin molecules in a cross section of an idealized entire granule. D - shows the likely double helix structure taken up by neighboring chains and giving rise to the extensive degree of crystallinity in granule. There is some debate over the form of the crystalline structure but it appears most likely that it consists of parallel left-handed helices with six residues per turn. An alternative arrangement of interconnecting clusters has been described for some amylopectins.





Some amylopectin (for example, from potato) has phosphate groups attached to some hydroxyl groups, which increase its hydrophilicity and swelling power. Amylopectin double-helical chains can either form the more open hydrated **Type B** hexagonal crystallites or the denser **Type A** crystallites, with staggered monoclinic packing, dependent on the plant source of the granules. **Type A**, with unbroken chain lengths of about 23-29 glucose units is found in most cereals.

Type B, with slightly longer unbroken chain lengths of about 30-44 glucose units is found in banana, some tubers such as potato and high amylose cereal starches. There is also a **type C** structure, which is a combination of types A and B and found in peas and beans. Starch granule architecture has been recently described.

9.2.4: Functionality

Starch is a versatile and cheap, and has many uses as thickener, water binder, emulsion stabilizer and gelling agent. Its form and functionality have recently been reviewed. Starch is often used as an inherent natural ingredient but it is also added for its functionality. It is naturally found tightly and radially packed into dehydrated granules (about one water per glucose) with origin-specific shape and size (maize, 2-30 μm ; wheat, 1-45 μm ; potato, 5-100 μm). The size distribution determines its swelling functionality with granules being generally either larger and lenticular (lens-like, **A**-starch) or smaller and spherical (**B**-starch) with less swelling power^a. Granules contain 'blocklets' of amylopectin containing both crystalline (~30%) and amorphous areas. As they absorb water, they swell, lose crystallinity and leach amylose. The higher the amylose content, the lower is the swelling power and the smaller is the gel strength for the same starch concentration. To a certain extent, however, a smaller swelling power due to high amylose content can be counteracted by a larger granule size. Although the properties of starch are naturally inconsistent, being dependent on the vagaries of agriculture, there are several suppliers of consistently uniform starches as functional ingredients.

Of the two components of starch, amylose has the most useful functions as a hydrocolloid. Its extended conformation causes the high viscosity of water-soluble starch and varies relatively little with temperature. The extended loosely helical chains possess a relatively hydrophobic inner surface that is not able to hold water well and more hydrophobic molecules such as lipids and aroma compounds can easily replace this. Amylose forms useful gels and films. Its association and crystallization (retrogradation) on cooling and storage decreases storage stability causing shrinkage and the release of water (syneresis). Increasing amylose concentration decreases gel stickiness but increases gel firmness. Retrogradation is affected by lipid content, amylose/amylopectin ratio, chain length of amylose and amylopectin, and solid concentration. Amylopectin interferes with the interaction between amylose chains (and retrogradation) and its solution can lead to an initial loss in viscosity and followed by a more slimy consistency. Mixing with κ -carrageenan, alginate, xanthan gum and low molecular weight sugars can also reduce

retrogradation. At high concentrations, starch gels are both pseudoplastic and thixotropic with greater storage stability. Their water binding ability (high but relatively weak) can provide body and texture to foodstuffs and is encouraging its use as a fat replacement.

A significant proportion of starch in the normal diet escapes degradation in the stomach and small intestine and is labeled 'resistant starch', but this portion is difficult to measure and depends on a number of factors including the form of starch and the method of cooking prior to consumption. Nevertheless resistant starch serves as a primary source of substrate for colonic microflora, and may have several important physiological roles. Resistant starch has been categorized as physically inaccessible (RS_1), (raw) ungelatinized starch (for example, in banana; RS_2^b), thermally stable retrograded starch (for example, as found in bread, especially stale bread, mainly amylose; RS_3) and chemically modified starch (RS_4). Resistant starch should be considered a dietary fiber. Although not exactly quantifiable due to its heterogeneous nature, some is determined by the official Association of Official Agricultural Chemists (AOAC) method. Starch with structure intermediate between the more crystalline resistant starch (for example, RS_3 in staled bread) and more amorphous rapidly digestible starch (for example, in boiled potato) is slowly digestible starch (for example, in boiled millet). Slowly digestible starch gives reduced postprandial blood glucose peaks and is therefore useful in the diabetic diet.

Many functional derivatives of starch are marketed including cross-linked, oxidized, acetylated, hydroxypropylated and partially hydrolyzed material. For example, partially hydrolyzed (that is, about two bonds hydrolyzed out of eleven) starch (dextrin) is used in sauces to control viscosity.

9.3 FREE SUGARS IN FRUITS AND VEGETABLES

The carbohydrates are especially prominent constituents of plants and usually form over one-half of the total plant substance. They serve not only as a source of available energy but also as reserve food and as structural materials. They are one of the main groups of food substances (carbohydrates, proteins, and fats) to be synthesized in the plant from simple organic substances. The empirical composition of carbohydrates may be expressed by the formula $C_nH_{2n}O_n$. With regard to their specific chemical properties, carbohydrates may contain a potential aldehyde, -CHO, or ketone, C=O, group.

In general, the substances belonging to this class of compounds may be divided into three broad groups: monosaccharides, oligosaccharides, and polysaccharides.

Monosaccharides have five carbon atoms (pentoses) or six carbon atoms (hexoses) and have a sweet taste. The second group of carbohydrates, oligosaccharides, is made up of two or more monosaccharide units linked to one another through a glycosidic bond. These are the disaccharides, trisaccharides, tetrasaccharides, etc., and may or may not have reducing properties. No sharp line of distinction can be drawn between the oligosaccharides and the third group of carbohydrates, the polysaccharides, which represent large aggregates of monosaccharide units (starch, cellulose, pectin, etc.).

The main function of carbohydrates upon ingestion by an animal organism is that of a fuel. They are metabolized to other products with the release of carbon dioxide, water, and energy. In addition, certain products of carbohydrate metabolism aid in the breakdown of many food stuffs, acting as catalysts in biological oxidations. Carbohydrates can also be used as a starting material

for the biological synthesis of other types of compounds in the body, such as fatty acids and certain amino acids. Regardless of the form in which a carbohydrate happens to be ingested, it must be transformed into a monosaccharide for absorption and metabolism, thus emphasizing the significance of monosaccharides in food stuffs.

9.4. SUMMARY

In spite of the increasing awareness of the specific carbohydrate role as human food, however, many problems in this field are far from being solved owing to chemical and structural complexity of the sugars. The types of sugar and their concentration in foods are only known approximately and in general terms. The free hexose and pentose content of many foods is generally reported only as "total reducing sugars," and the oligosaccharide content of foods is usually reported as "nonreducing sugar" calculated to be sucrose. It is now apparent that the "nonreducing sugar" fraction of foods may have, as the major sugar present, higher molecular weight and more complex homologues of sucrose such as raffinose, stachyose, and verbascose.

9.5. SELF ASSESSMENT QUESTIONS

1. What are the free sugars present in fruits and vegetables?

9.6. REFERENCEBOOKS

Fruits and vegetables, www.dcpn.nci.nih.gov

Dr. D. JALAJA KUMARI

Lesson – 10**PECTIN SUBSTANCES****10.0 OBJECTIVE:**

- To understanding of the classification of pectin
- Describe the sources of cellulose in fruits and vegetables
- Know the effect of alkalies, acids and calcium on the structural part of fruits and vegetable

STRUCTURE**10.1 Introduction****10.2 Nomenclature of the pectic substances****10.3 Function of pectic substances in plant life****10.4 Sources of pectin in plants****10.4.1 Protopectin****10.4.2 Pectic acid****10.5. Extraction of and preparation of juice for jelly****10.6. Cellulose****10.6.1 Effects of alkalies, acids, and calcium on the structural or woody part of fruits and vegetables****10.6.1.1 Pickles****10.6.1.2 Crisping pickles****10.6.2 The effect of sugar on the firmness of fruit****10.7. Summary****10.8. Self Assessment Questions****10.9. Reference Books****10.1 INTRODUCTION**

In plant biology, pectin consists of a complex set of polysaccharides that are present in most primary cell walls and are particularly abundant in the non-woody parts of terrestrial plants. Pectin is present not only throughout primary cell walls but also in the middle lamella between plant cells, where it helps to bind cells together.

The amount, structure and chemical composition of pectin differs among plants, within a plant over time, and in various parts of a plant. Pectin is an important cell wall polysaccharide that allows primary cell wall extension and plant growth. During fruit ripening, pectin is broken down by the enzymes pectinase and pectinesterase, in which process the fruit becomes softer as the middle lamellae break down and cells become separated from each other. A similar process of cell separation caused by the breakdown of pectin occurs in the abscission zone of the petioles of deciduous plants at leaf fall.

Pectin is a natural part of the human diet, but does not contribute significantly to nutrition. The daily intake of pectin from fruits and vegetables can be estimated to be around 5 g (assuming consumption of approximately 500 g fruits and vegetables per day).

In human digestion, pectin binds to cholesterol in the gastrointestinal tract and slows glucose absorption by trapping carbohydrates. Pectin is thus a soluble dietary fiber.

Consumption of pectin has been shown to reduce blood cholesterol levels. The mechanism appears to be an increase of viscosity in the intestinal tract, leading to a reduced absorption of cholesterol from bile or food. In the large intestine and colon, microorganisms degrade pectin and liberate short-chain fatty acids that have positive influence on health (prebiotic effect).

10.2 NOMENCLATURE OF THE PECTIC SUBSTANCES:

The different names used in the literature for pectin and its related compounds have been numerous. To avoid confusion, the Committee on the Nomenclature of the Pectic Substances (Dore, Chairman) have proposed dividing these into three groups: (1) protopectin, (2) pectin, and (3) pectic acid. The chemical identity of the various pectic substances is not definitely settled, but a great deal of investigational work is being done at the present time.

10.3 FUNCTION OF PECTIC SUBSTANCES IN PLANT LIFE:

The pectic substances play an important role in plant life. Dore states that the primary function of the pectic substances is the cementing together of the individual cells that compose the plant.

10.4 SOURCES OF PECTIN IN PLANTS:

The pectic substances are found in the leaves, bark, roots, tubers, stalks, and fruits of plants. The pectic compounds occur in two places in the plant cell - in the middle lamella, where they serve as cementing material, and as thickened places on the cell wall. These two sources may yield slightly different substances. In fruits the pectin is usually found in the pulp and not in the juice, though there are some exceptions. For example, currant juice often contains pectin. The skins and cores of fruit like apples contain large proportions of pectin. Hence, apples and crab-apples are cut into small pieces, but not peeled or cored, for making jelly. Some of the root stocks, such as sugar beets, carrots, rutabagas, and turnips, contain appreciable amounts of pectin.

The amount of pectin not only varies in different fruits, but also in the same fruit at various stages of ripeness and in the same fruit in different years or seasons.

10.4.1 Protopectin Protopectin has been called pectose and pectinogen. It is the water-insoluble pectic substance in plants. It may be rendered soluble by the enzyme protopectinase or by treatment with acid and other reagents. The soluble substances thus formed are designated as pectins.

Sucharipa has presented evidence that the protopectin is combined with cellulose. In the plant, the separation of the pectin from the cellulose is brought about by hydrolysis by the enzyme protopectinase.

The protopectin is the precursor of pectin. As the fruit ripens, pectin increases while the protopectin decreases. Protopectin is also converted to pectin by boiling with dilute acid. Since fruit juices contain acid, some protopectin is changed to pectin when the fruit is boiled. This is the reason why cooked fruit juices are better for jelly than uncooked ones.

According to Sucharipa the pectins may be classified into (1) free pectins, which are removable from the plant by water solution, and (2) hydrolysis pectins, which result from treating protopectin with hydrolyzing agents.

10.4.2 Pectic acid In fruit, protopectin is changed to pectin by enzymes of the fruit. With still further ripening, pectic acid is formed from pectin by the enzyme pectase. These changes are gradual, but the larger portion of the pectic acid is formed when the fruit is ripe and when decay begins. In the presence of pectase and calcium, barium, or strontium salts, pectic acid may form a gel.

In fruits the rate at which softening takes place depends largely upon the temperature. Haller has shown this for a number of varieties of apples in storage. The rate "at 40°F was found to be slightly more than double that at 32°, whereas that at 50° was slightly less than double that at 40°, and that at 60° nearly double the rate at 50°."

Protopectin and pectic acid do not form jellies. Protopectin and pectic acid do not form jelly when cooked with sugar and a fruit juice containing acid, although pectin forms a jelly under these conditions. Since over-ripe fruit contains a larger proportion of pectic acid and a smaller percentage of pectin, this furnishes the explanation for the fact that many jelly makers have long known, that juice from partially ripe fruit makes a better jelly than juice from over-ripe fruit.

Cooked extracted fruit juice is better for jelly. Fruit juice extracted raw or without cooking will seldom make jelly, or it yields a jelly of poor quality. Since the protopectin is not soluble in the juice of the fruit, if the juice is extracted raw it remains with the pulp of the fruit. If cooked, some of the protopectin is changed to pectin. Goldthwaite has reported experiments with apple and some other fruit juices extracted raw. Either no jelly was obtained or it had a poor texture.

10.5. EXTRACTION OF AND PREPARATION OF JUICE FOR JELLY:

Hard fruits like apples and crab-apples are cut into small pieces or ground with a food chopper, barely covered with water, and cooked. Soft berries need little water added, 1/4 cup to a pound of fruit often being used. Currants that are not too ripe should have a larger proportion of water. Gooseberries, if green, because of their very high acid and pectin content and the character of the pectin, can be completely covered with water, and sometimes will need additional water. Ripe gooseberries require the same proportion of water used for other berries. After cooking, the juice is drained without squeezing from the pulp by placing the cooked material in a cloth bag. Fruits that are very rich in pectin may have two or three extractions made. These second and third extractions

need to be boiled down more than the first extraction to concentrate the pectin. Second and third extractions also do not have as much of the fruit flavor as the first one.

Apple juice sometimes contains starch, particularly that from under-ripe fruit, which renders the juice cloudy. Askew states that starch formation begins near the periphery and progresses toward the core; but as the fruit matures the core area is cleared of starch first, the area near the skin last. Commercially, diastase can be added to convert the starch to sugar and thus clear the juice.

Grape juice contains tartaric acid, which often crystallizes in long needle-like crystals in the jelly. It can be removed partially from the juice by putting the juice in a refrigerator (the colder the better, but it is less soluble at lower temperatures), over night, or for a few days, and then straining the crystals from the juice.

10.6. CELLULOSE

Cellulose forms the structural, fiber, or woody part of the plant. Other substances such as pectic substances may occur in combination with cellulose. In the young plants or the new growth of older plants the cell walls are at first yielding. As they mature, they grow more resistant and may change physically and chemically, their function becoming more specialized with the occurring changes. In tree trunks some cell walls become woody or lignified. Doree and Barton-Wright state that the stone cells distributed throughout the flesh and particularly near the core of pears are lignified cellulose.

Cellulose is a carbohydrate. It is found in plants in several forms. There is no unanimity of opinion regarding its definition, although the cotton fiber is always taken as a standard cellulose product.

Hemicellulose, wood cellulose, and gelatinized cellulose are names given to different forms of cellulose. Probably each group includes several products. Schorger defines hemicellulose as "A polysaccharide soluble in dilute alkalis and convertible into simple sugars by heating with dilute acids at atmospheric pressure." He adds that a hemicellulose in the natural state should be insoluble in boiling water.

10.6.1 Effects of alkalis, acids, and calcium on the structural or woody part of fruits and vegetables:

Ammonia and sodium bicarbonate added to the water in which vegetables are boiled, or ammonia or ammonium carbonate added to water in which vegetables are steamed, causes them to soften in a shorter time than if these substances had not been added. With longer cooking the vegetable becomes mushy and disintegrates. The disintegration begins with the surface layer of the food, and its depth depends on the length of time of cooking and the size of the piece of food.

If vinegar is added to the water in which vegetables are cooked the effect is opposite from that of sodium bicarbonate: a firmer and more solid texture is obtained and the vegetable requires longer to cook. In cooking vegetables like cabbage and spinach the amount of calcium and magnesium salts found in the water seems to have little effect upon the texture or the length of time for cooking.

The pulp and white part of the rind of watermelon as well as the pulp of muskmelon or cantaloupe, and perhaps other foods, can be made very firm and brittle or woody if soaked in

saturated calcium hydroxide (lime) water. The longer they are soaked the harder and firmer they become if the water is kept saturated with lime. Five to six hours' soaking is usually sufficient to produce enough firmness to prevent shriveling when cooked in syrups for preserves or pickle. The melon pulp may be cooked in water until transparent and tender, then put in lime water to harden, and finally cooked in a syrup. Or cooking first in only water does not prevent hardening of the pulp by calcium. The few times that cucumbers have been soaked in lime water either slight or no hardening occurred. But other calcium compounds such as calcium chloride do produce hardening in pickles.

10.6.1.1 Pickles: The inside of the cucumber is free of bacteria, but the brine into which the cucumbers are placed contains several thousand bacteria per cubic centimeter. There are many different kinds of bacteria present in the beginning but with the strength of brine maintained most of them die. However, a few kinds that thrive in the brine survive. Fresh brine contains no food for bacteria. But with placing of the pickles in brine, or the formation of brine by adding dry salt to cucumbers, small amounts of sugar and other bacterial food are dissolved from the cucumbers as they shrink. Hence bacteria that can tolerate salt grow and decompose the sugar. The resulting decomposition products of the sugar are acid and gas. The gas produces froth. The acid, probably mostly lactic, is very important, for the keeping of the pickles depends upon it. The concentration of the acid is rather high when frothing ceases, varying from 0.6 to 1.2 per cent. The acid is a fairly good disinfectant and practically all bacteria in the brine are killed.

In addition to bacteria, yeasts are present in the brine; but because they need oxygen they grow principally on the surface. The scum yeast feed on the acid of the brine and decompose it, thus decreasing the quantity of acid in the tank or container. If scum grows long enough, all the acid is destroyed and then the pickles become slippery, soft, and mushy. It is better not to stir the pickles too much after they are in the brine, for the acid tends to stay at the bottom of the container and the yeasts grow at the surface.

There are two periods when the acid is low, and these stages are the periods of greatest danger in fermenting pickles. The first stage is before fermentation has started and no or little acid has been formed; the second is after the acid has been used up by scum yeast, for spoilage only occurs when the acidity of the brine is sufficiently low. The slipperiness and softness are caused by so-called potato bacteria, which resist the salt well but do not tolerate acid. Because oxygen is necessary for their growth and the bacteria only grow at the surface, the pickles protruding from the brine become soft. These potato bacteria can cause great loss and damage before a concentration of acid great enough to delay their growth is formed. A single potato bacterium, if all conditions are favorable, produces from 10 to 100 million new bacteria in 24 hours.

Hence, to prevent spoilage all pickles should be kept under the brine. Some acid or vinegar can be added with the brine to prevent spoilage. It has been interesting to see that this has been advocated for commercial practise since Rahn's work was published. Other methods of preventing growth of the yeast are to keep the container in the sunlight or irradiate with ultra-violet light, both of which are not practical in the home. After fermentation is complete, that is, after frothing has ceased oil paraffin may be used over the surface of the brine. Since the oil is rather difficult to wash from the pickles, paraffin is preferable.

10.6.1.2 Crisping pickles: Calcium chloride is used to make pickles crisp or firm. It is used either in the last soaking water, when the brine is being removed, or added directly to the sweetened vinegar. The proportion used is one pound per barrel of pickles.

The hardening may come from the calcium combining with the cellulose or it may combine with acid of the pickle or melon or be deposited as calcium salts in the food. Some factors other than the ones mentioned may cause the hardening.

10.6.2 The effect of sugar on the firmness of fruit: The effect of sugar of course varies somewhat with the amount used in proportion to the quantity of fruit. Osmosis occurs when a syrup has greater sugar concentration than that of the fruit to which it is added. The vapor pressure of the syrup solution is lower than that of the fruit so that water passes from the fruit to the syrup. This transfer from a region of high concentration to a low one is called osmosis. If a membrane separates the regions of high and low concentrations it is dependent upon the membrane whether all the dissolved constituents of a solution can pass through the membrane. With a semi-permeable membrane only the water can pass through the membrane. Without discussing the possible role of the membrane in osmosis or the osmotic pressure that may be produced, it is sufficient for the purpose here to state that as the permeability of the membrane increases larger and larger ions or molecules dissolved in the water may pass through the membrane. The skin and cell walls of the fruit serve as membranes. These membranes in the different fruits seem to have a greater or a lesser permeability to sugar.

When cooked in a syrup some fruits tend to keep their shape, some become mushy, some shrivel, and others tend to collapse or flatten out. For instance, sweet apples tend to stay whole whether cooked in syrup or in water, whereas sour apples have a greater tendency to break up during cooking. In general, the fruits tend to stay whole better if cooked in a syrup. For purees the fruit is cooked in water and the sugar added later. Cooking seems in most instances to increase the permeability of the fruit membranes to sugar. Some apples, some plums, and most berries can be cooked directly in the syrup without noticeable toughening of the fruit. Peaches, apricots, most apples, and most plums absorb sugar satisfactorily. Lathrop states that the firm texture of the cherry skin and of the peach and blackberry flesh retards penetration of the sugar during cooking. On the other hand, a fruit like Keifer pears is dehydrated if cooked directly in a syrup and becomes shriveled, tough, hard, and rubbery. It is necessary to soften the fruit by cooking and increase its permeability to sugar before the sugar is added. It is of course possible that many changes other than increasing the permeability of the fruit to sugar occur when the fruit is cooked in syrup. Later work has shown that fruit like Keifer pears and quinces can be cooked by adding the sugar directly to them without preliminary cooking. But it is necessary to start with an excess of thin syrup and cook slowly to evaporate the excess liquid, as the sugar penetrates the fruit. So long a time is required that the method is not practical. The fruit becomes more transparent in appearance. It may be that the sugar has some effect on the cellulose.

In fruits like strawberries and seeded sour cherries, and particularly if they are heated rapidly in a sugar syrup, flattening occurs. If a large number of cell walls are broken the fruit becomes mushy. Time is required for sugar to pass through the cell walls of fruits. If osmosis has not progressed far enough, i.e., if the concentration of the sugar within the berry is not as great as in the syrup surrounding it, the berry floats when canned.

In pickling, shriveling can be prevented by heating the pickling material slightly and increasing the concentration of the sugar gradually, allowing about 24 hours or more to elapse before the next addition of sugar. But fermentation is more likely to occur when preserves are treated this way. It is a good practise to add the sugar directly to fruits like strawberries and cherries and let them stand over night. The fruit loses water, shrinks somewhat, and becomes slightly tougher. When heated slowly, and if necessary removed from the heat for a few minutes before boiling commences, there is time for the sugar to penetrate into the interior of the berry, the fruit is plump and will not

float when placed in the container. In the commercially vacuum-processed berries, floating in the can is prevented by adding the berries, to which part of the sugar has previously been added, to a hot syrup, but further heating is not continued until the berries have stood for a few minutes. By producing a vacuum, the greater pressure within the berry tends to puff it up; by breaking the vacuum, flattening occurs. In this way the process of osmosis is helped.

Strawberries and the sour cherries develop a strong flavor when boiled for a long time. Hence time must be allowed for the sugar to penetrate into the fruit before the boiling point is reached. Boiling should be rapid, and the quantity of fruit used in a batch small. The popularity of sun preserves for certain fruits is due to osmosis being slow and complete. If the fruit is heated the heating period is very short, so that strong flavors are not developed, less sugar is inverted and caramelized, and the aromatic substances are not lost to such an extent as in long cooking.

Since strawberries usually contain about 90% water, it seems a better practise to add the sugar directly to the berries, for not as long a time is required to cook the berries to the concentration desired. When water is added to the sugar to make a syrup it is necessary to evaporate the water used in the syrup as well as a part of that contained in the fruit. Increasing the proportion of sugar to fruit also lessens the time required to reach a definite concentration of the syrup, so that the preserves do not develop as strong a flavor. When 1 1/2 pounds of sugar are used with a pound of strawberries only a short time of cooking is required for the syrup to reach a temperature of 103°C, which gives a syrup containing 60 per cent of sugar.

10.7. SUMMARY

The frame work of fruit is made of cellulose which forms the walls of the plant cells and in which large amounts of water are held. Pectic substances are found in cell walls and between the cells. They act as a cementing substance and bind cells together.

10.8. SELF ASSESSMENT QUESTIONS

1. Explain the function of pectin substance in fruits and vegetables

10.9. REFERENCE BOOKS

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Dr. D. JALAJA KUMARI

Lesson -11**PLANT PIGMENTS****11.0 OBJECTIVE:**

- To understand the classification of plant pigments
- Describe the uses of plant pigments

STRUCTURE**11.1 Introduction****11.2 Solubility of chlorophyll****11.3 Composition of chlorophyll****11.3.1 Reactions of chlorophyll with alkalies****11.3.2 Reaction of chlorophyll with acids****11.3.3 The effect of heat upon chlorophyll****11.3.4 Replacing magnesium in chlorophyll products****11.4 Carotinoids****11.5 Flavones and Flavonols****11.6 Anthocyanins****11.7 Color changes of fruit juices****11.8 Fruit colors and punch****11.8.1 Violet colorations in canned fruits****11.8.2 Color changes of red vegetables****11.9 Metals and anthocyan pigments****11.10 Tannins****11.10.1 Reactions of the tannins****11.10.2 Astringent qualities due to tannins****11.10.3 Persimmons contain a very large amount of tannin****11.10.4 Blue or purple discoloration in English walnuts****11.10.5 Tannins and discolorations in canned goods**

11.10.6 Other discolorations with tannins

11.11 Tea

11.12 Summary

11.13 Self Assessment Questions

11.14. Reference Books

11.1 INTRODUCTION

Chlorophyll, the green pigment of plants, plays an important role in their synthesis of carbohydrates. The cells of the mesophyll of the leaf contain chloroplasts or chlorophyll-corpuscles, the nucleus, other substances, and the cell liquid with its dissolved materials. The chloroplasts contain four pigments, two green ones, chlorophyll a and chlorophyll b, and two yellow ones, carotene and xanthophyll.

11.2 SOLUBILITY OF CHLOROPHYLL:

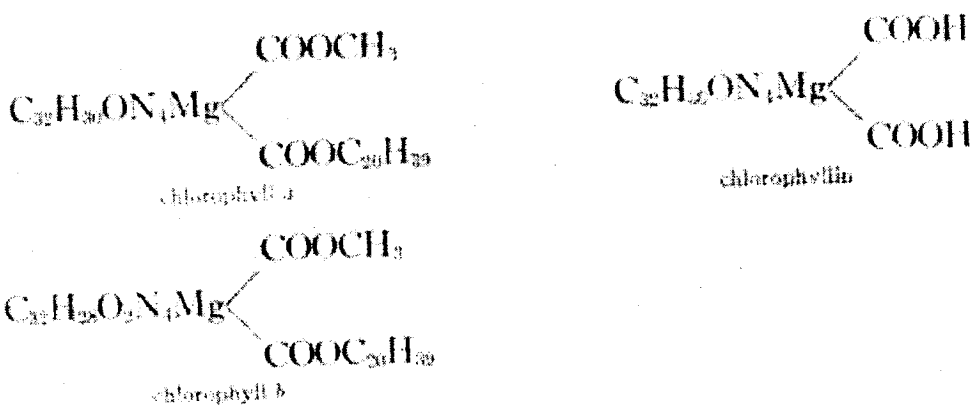
Chlorophyll is not soluble in water. Very little green color is found in the water in which green vegetables have been cooked. Pure isolated chlorophyll is soluble in acetone, ether and benzene. In extracting the pigment from thoroughly dry leaves it is necessary to add about 20 per cent of water to the acetone or other solvent. One explanation for this is that chlorophyll is in the colloidal state in the leaf, and the mineral constituents of the leaf, dissolved in the water, peptize it, rendering it soluble. Onslow states that "the condition of chlorophyll is altered by plunging into boiling water. The pigment is then much more soluble, in ether, etc., even when the leaves are subsequently dried. It is supposed that the chlorophyll has diffused out from the plastids, and is in true solution in the accompanying waxy substances which have become liquid owing to change in temperature."

When green vegetables are dropped into boiling water a change takes place nearly instantly, the green color being intensified. Various explanations have been offered for the phenomenon. One is that the hot water has melted waxy constituents of the leaf so the chlorophyll escapes from the cell more readily or may become more soluble. Or the hot water may have dissolved salts or other substances in contact with the chlorophyll so that it diffuses more readily.

For peas, Kohman states that one factor in the intensification of the green color is the removal of air from the pea when it is dropped in the boiling water. The outer skin of the pea is transparent, the space beneath this being impregnated with air which is removed when the peas are blanched. That this change in color is caused by removal of the air can be shown by subjecting the peas to an adequate vacuum under cold water and releasing the vacuum while the peas are still under the water.

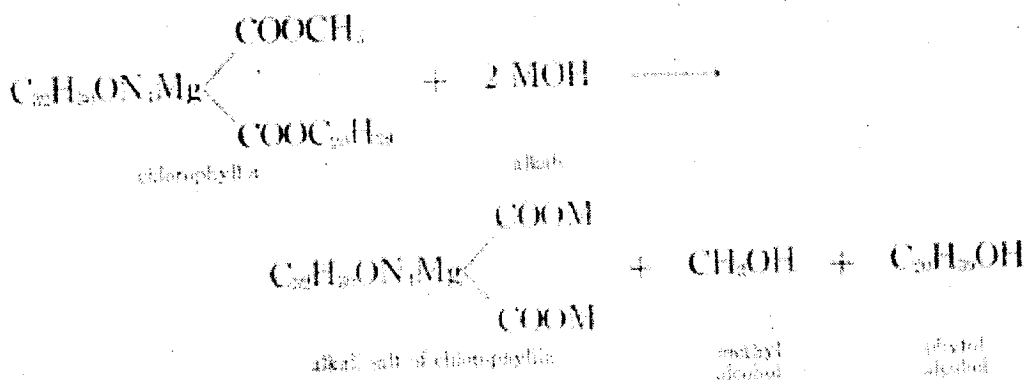
11.3 COMPOSITION OF CHLOROPHYLL:

Willstatter, whose work gave us the formula for and the chemical reactions of chlorophyll, reports that it exists in two forms, depending upon the degree of oxidation in the plant cells: form (a) and form (b). The former exists in the proportion of three to one of the latter.



Chlorophyll contains 2.7 per cent of the metal magnesium. It contains two ester groups, one of methyl alcohol (COOCH₃) and one of phytol alcohol (COOC₂₀H₃₉).

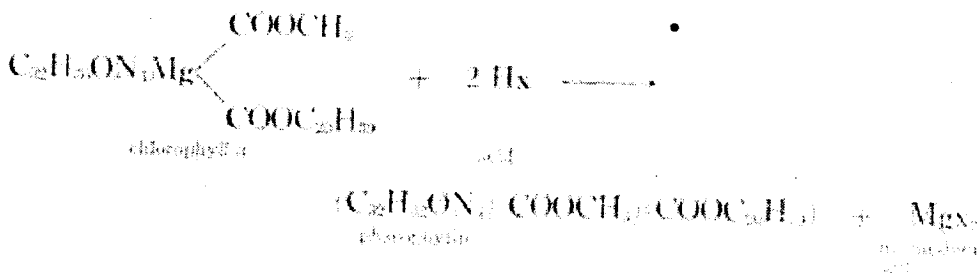
11.3.1 Reactions of chlorophyll with alkalis: Chlorophyll is a neutral substance but gives characteristic reactions when treated with alkalis or acids. Will-statter designates the parent substance of chlorophyll as chlorophyllin. The reaction of chlorophyllin with methyl and phytol alcohols gives the ester chlorophyll. Chlorophyll, when treated in the cold with alkalis, gives alkaline salts of chlorophyllin. The color change is first brown, followed by a return of the green, but it is no longer fluorescent. When chlorophyll is saponified with hot alcoholic alkalis, isochlorophyllins are formed, which are fluorescent.



When the green-colored vegetables are cooked in water with an alkaline reaction, or in water to which a small amount of soda is added, they develop a bright, intense green color.

11.3.2 Reaction of chlorophyll with acids: Chlorophyll reacts with acids to give an olive-colored product, without fluorescence, called phaeophytin. The magnesium of the chlorophyll is replaced by hydrogen. From phaeophytin, Willstatter has obtained two decomposition groups: the first,

designated as phytochlorins, are olive green and derived from chlorophyll a; the second, the phytorhodins, are red and derived from chlorophyll.



11.3.3 The effect of heat upon chlorophyll: The chlorophyll is changed to the olive-green color by two means, (1) by hydrogen ions or an acid reaction and (2) by heat. As previously given, the hydroxyl ions, or an alkaline reaction, produces chlorophyll salts with bright green color. In general, the more acid the reaction, the more rapid is this change in color when the vegetable is heated; or, vice versa, the more alkaline the reaction, the more slowly the chlorophyll changes to olive-green. Thus in order that the bright green color be retained in cooking green vegetables, they should be cooked for as short a time as possible and contact with acids should be avoided as far as possible. It is also possible that other ions than the hydrogen and hydroxyl ions may affect the stability of the chlorophyll, for some vegetables with nearly the same pH, cooked in water from the same source, and with other conditions standardized are more stable to heat than others.

In cooking certain procedures may aid in decreasing the acidity of the cooking water. The vegetables contain both volatile and non-volatile acids, which in the plant are prevented from uniting with the chlorophyll but are liberated when the plant tissues are heated. If the cooking vessel is not covered, the volatile acids may escape with the steam, thus decreasing the acidity.

It has been found that the highest percentage of these volatile acids passes off during the first few minutes of cooking. Hence, if the cooking vessel needs to be covered for a part of the time, it is preferable to have the uncovered period the first few minutes.

Certain water, such as hard water, softened water, or water from many streams, is alkaline in reaction. Rain water, snow, oricewater is usually about neutral. If the cooking water contains alkaline salts, these salts may neutralize the non-volatile acids, and if there is a slight excess of alkaline salts the green color is intensified. To a certain extent the intensification depends upon the quantity of water used, for the larger quantity of water contains a greater quantity of alkaline salts. If the water is only slightly alkaline the plant acids may not all be neutralized and the olive-green color may develop. If the water is very alkaline and considerable water is used, not enough volatile and non-volatile acids will be liberated to neutralize the alkalinity of the water, the cover can be kept on during cooking, and the product will be bright green. With longer cooking the heat may have more effect upon the chlorophyll than the alkaline salts of the water. Canned spinach, asparagus, peas, and string beans have a deep olive-green color due to the retention of the plant acids during processing and to the high temperature at which they are processed. Green vegetables like cabbage, Brussels sprouts, and spinach cooked in milk may remain a bright green color. Owing to the ease with which milk scorches and boils over there is usually less tendency to cook the vegetables too long when milk is used.

Heat decomposes chlorophyll, an olive-green color being produced. The extent of decomposition depends upon the time of heating and the temperature reached. With a very short cooking period little destruction may occur, but with a longer time all the chlorophyll may be decomposed. At lower temperatures the change is less rapid and at higher temperatures more rapid. Thus in a pressure cooker the change is rapid, since the temperature is high and acidity is not decreased because the volatile acids are retained. Increasing the alkalinity by using alkaline water or adding soda retards the color change by heat. However, the addition of soda is not advisable, because it softens the cellulose rapidly so that the vegetable with slight over-cooking becomes mushy or even slimy and the destruction of some of the vitamins is hastened.

The cooking of green vegetables that contain enough acid to taste sour, like sorrel, sour grass, and dock, always produces this olive-green color no matter how cooked or for how short a time. Their acid content is too high to be neutralized by the alkaline salts of water or the addition of baking soda in small amounts. Green fruits like gooseberries, green grapes, and green plums develop an olive-green color when cooked. If the fruits are mature they may also contain yellow pigments that modify the color to a certain extent.

If acid is to be added as a seasoning to green vegetables it is preferable to add it when served, for there will not be so long a time for the acid to react on the chlorophyll and less brown color will develop. When vegetables are cooked with added acid, the softening of the vegetable is prevented to a slight extent.

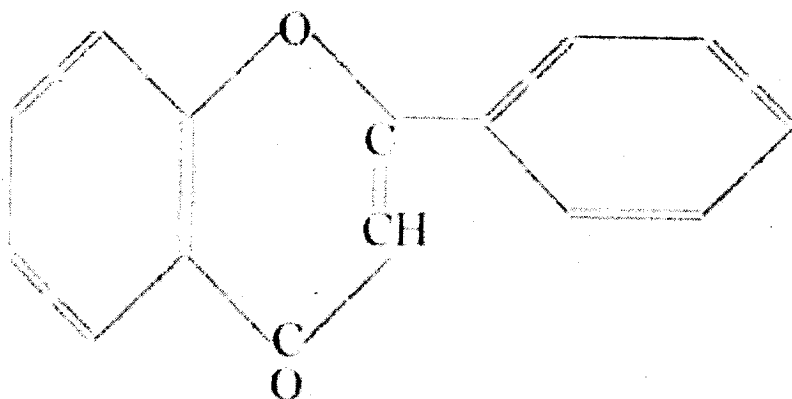
11.3.4 Replacing magnesium in chlorophyll products: It is very difficult to replace the magnesium of the magnesium-free chlorophyll products. It can be done chemically by using a very reactive substance, magnesium methyl iodide, but this is impracticable to use in cooking processes. However, Will-statter states that the acetate salts of some metals such as copper, iron, and zinc will combine with phaeophytin and give very bright green-colored products. This is such a good test for small quantities of these metals that it is necessary in isolating chlorophyll to be extremely careful that it does not come in contact with them.

11.4 CAROTINOIDS:

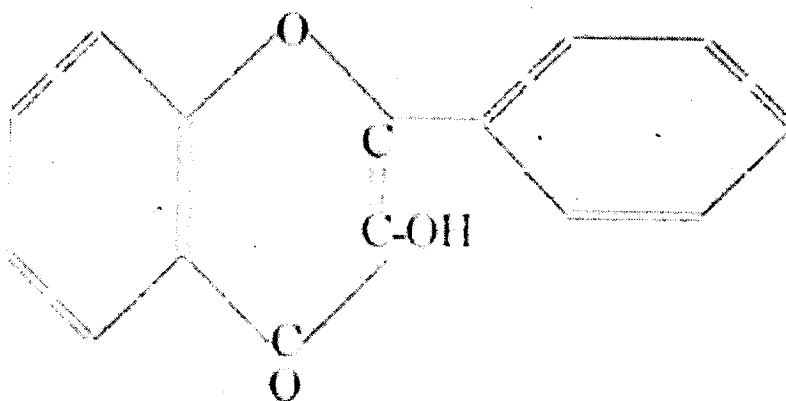
Carotinoids is a term applied to the pigments giving yellow and orange coloring to fruits and flowers, carotene, $C_{40}H_{56}$, and xanthophyll, $C_{40}H_{56}O_2$. The carotinoids are not soluble in water, and the pigments are not affected, to any great extent, by the concentration of acids or alkalies used in food preparation. The darkening produced by the action of alkalies by caramelization of the sugar in vegetables, like carrots, must not be confused with a change in pigment color. Carotene is easily oxidized when exposed to air. Xanthophyll can also be oxidized in the same way. One of the characteristics of the carotinoids is the intensity of their coloring. The red pigment found in tomatoes is lycopin, an isomer of carotene.

11.5 FLAVONES AND FLAVONOLS:

Flavones and flavonols are amphoteric pigments found in vegetables and petals of flowers. They are also found in the cell sap of the epidermis and underlying tissue of plants. Onslow gives the following formulas:



Flavone



Flavonol

As they occur in nature they often have other or additional hydrogen atoms replaced by hydroxyl groups. The position of the hydroxyl groups markedly influences the intensity of color, the color usually being deeper if two hydroxyl groups are in the ortho position to each other. The flavone and flavonol pigments are yellow in color. In plants they often occur as glucosides, one or more of the hydroxyl groups being combined with the sugar, and then the color is less intense. They give an intense yellow color with alkalies. Sometimes the quantity of them found in white vegetables is so minute that they are not visible. Adding an alkali or holding them over ammonia vapor intensifies the color and they become visible. The color changes of the flavones cannot be observed so readily in the yellow, red, or green vegetables.

Rice cooked in alkaline water usually has a yellow tinge, and sometimes it is rather deep in hue or has a green tint. Rice from the same source as that cooked in alkaline water, but cooked in distilled water, has a snowy white appearance.

The cooking of cauliflower, white cabbage, and particularly white onions in alkaline water often causes the yellow color to develop. Some white onions cooked in the hard water at Ames have developed nearly a sulfur yellow in color, whereas portions of the same onions cooked in distilled water remained white, or retained their natural yellow tinge.

Potatoes must often contain flavones, as they sometimes develop a yellow or green color in alkaline water. Mashed potatoes that have a strong alkaline taste may be improved in flavor by adding a very small amount of cream of tartar.

Flavones and flavonols with iron salts turn green and then brown. This may explain some color changes that occur when foods are cooked in chipped enamel utensils having an iron base.

11.6 ANTHOCYANINS:

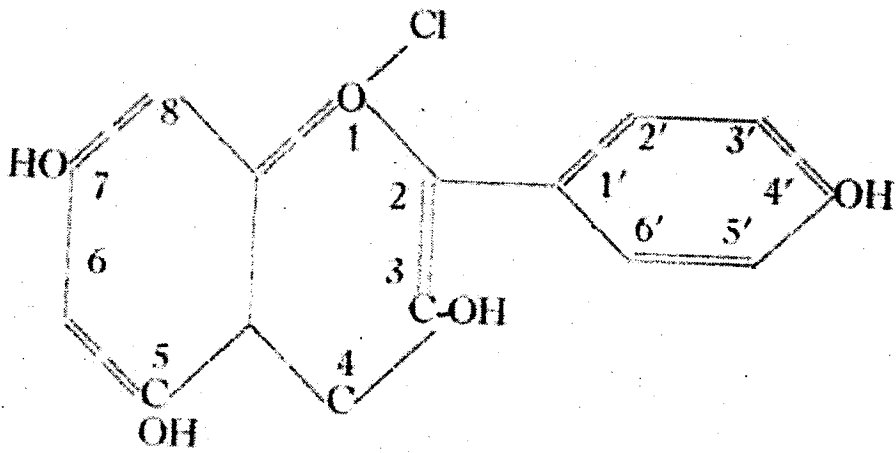
The anthocyanins include a group of pigments that, like sugars, have similar composition and properties yet have individual differences. As a rule they occur as glucosides in different parts of the plant and are known as anthocyanins in this combination. When the glucoside is hydrolyzed by boiling with dilute acid the non-glucosidal pigment portion is called anthocyanidin. The anthocyanins are soluble in water. Onslow states that occasionally they crystallize from the cell sap. Most but not all of the anthocyanins are soluble in alcohol. The anthocyan pigments give the blue, purple, violet, and red shades to different parts of the plant. They are very widely distributed. Onslow states that the plant that does not produce them is the exception rather than the rule. They occur in apples, cherries, currants, grapes, blueberries, red and black raspberries, in some varieties of peaches and plums, and in red cabbage, radishes, beets, and other fruits and vegetables.

All the anthocyanins so far isolated have fallen into one of three groups. They are illustrated as the chlorides. The number of hydroxy groups attached to the side benzene ring is made the basis of the classification. The glucosides of these anthocyanidins are called pelargonins, cyanins, and delphinins.

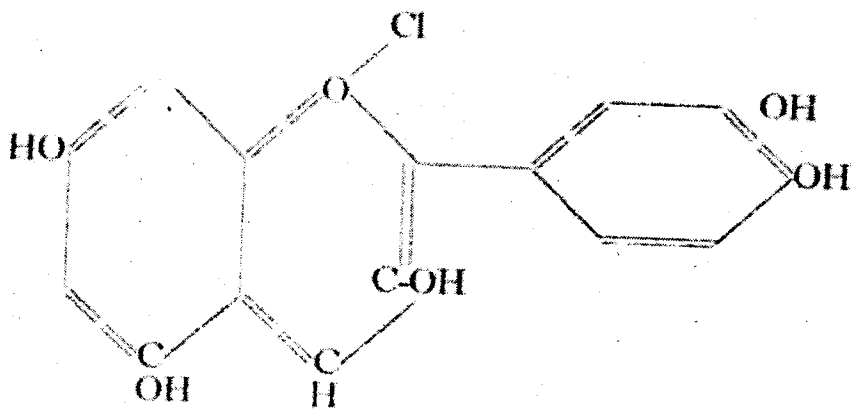
One of the reactions that the anthocyanins have in common is their color changes. Onslow states that the pigment should be pure to test the color reactions, for in the plant the pigment is found with other substances that may modify the reaction. In an acid solution, pure anthocyanins are usually red; in an alkaline one they are violet or blue, but if flavones or flavonols are present, a green color is obtained through the mixture of the blue and yellow. Yet the solutions of many fruit juices show typical color changes. In ordinary solutions of plant pigments they become green, then yellow, and sometimes brown upon the addition of alkali. If the alkali is very weak, or with salts with a weak alkaline reaction, a blue color may form and the green may never develop, or the blue may be intermediate between the red and the green.

11.7 COLOR CHANGES OF FRUIT JUICES:

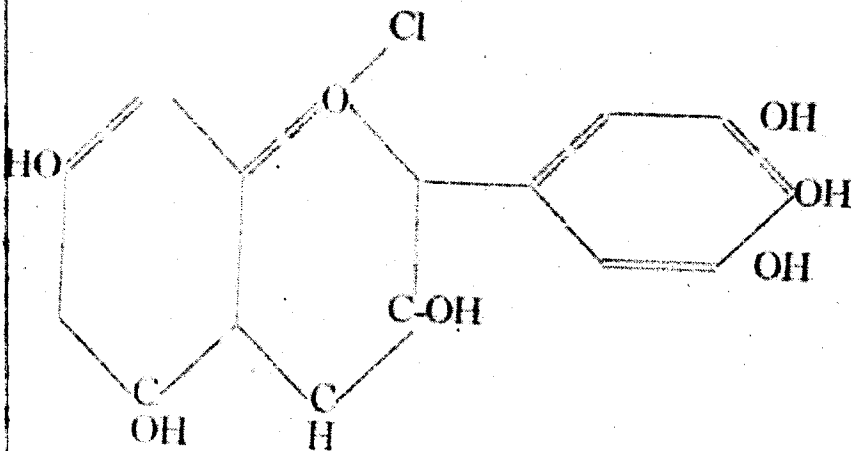
Pratt and Swartout state that the solutions of many fruit pigments act as indicators; that the solutions are easily prepared and stable; that the liquid indicators can be used in titrating acids, but not bases, for in a solution no more than moderately alkaline they soon decompose, all of them producing a brown color which does not change when acid is added. They found that apricots, peaches, pears, persimmons, and tomatoes failed to yield pigments that could be used as indicators. It is interesting that the pigment of cactus holds its red color even in a distinctly alkaline medium. They also state that "the pigment of red beets remained red through the acid range and into the alkaline range at least as far as pH 13.0." In their conclusion they recommend that the greatest usefulness of the indicators is in test papers.



Pelargonidin chloride



Cyaninidin chloride



Delphinidin chloride

11.8 FRUIT COLORS AND PUNCH:

Combinations of fruit juices for punch can yield beautiful, clear colors, or ugly, muddy ones. If a red color is desired, use red- or blue-colored juices and keep the reaction acid by the addition of lemon juice. For a purple shade, choose fruit juices nearly neutral in reaction and do not add lemon juice. A blue color can usually be intensified by the addition of canned pineapple juice. (See the following paragraph.) Alkaline water may or may not give a bluish tinge to red fruit juices, depending on the alkalinity of the water and the acidity of the juice. Orange juice should be added to red or blue fruit juices only when a brownish or magenta shade is desired, for often this combination is not attractive. From the colors produced, or unless very small proportions of one color are used, the red and yellow, blue and yellow, or green and yellow combinations should be avoided.

Table 1: The pH Range with Color Changes of Fruit Juices (Pratt and Swartout)

Fruit source	Color change	pH range
Apples	Red to yellowish-green	6.2-7.2
Blackberries	Red to dark grayish-blue	6.0-7.4
Blueberries	Reddish-purple to greenish-purple	6.2-7.2
Cactus	Red to faint purple	9.0-12.0
Cactus	Faint purple to reddish-brown	12.0-13.0
Cherries	Red to bluish-purple	6.0-7.2
Grapes	Red to purple	5.0-6.6
Grapes	Purple to green	6.6-7.6
Plums	Red to yellowish-green	6.2-7.2
Pomegranates	Red to purple	6.0-6.8
Pomegranates	Purple to green	6.8-7.6
Strawberries	Red to yellowish-green	6.2-7.2

The Color of Fruit Juices in Neutral, Acid, and Alkaline Mediums (Pratt and Swartout)

Fruit source	Neutral tint	Acid tint	Alkaline tint
Apples	Grayish-purple	Red	Green
Blackberries	Purple	Red	Bluish-green
Blueberries	Purple	Red	Blue
Cherries	Reddish-purple	Red	Bluish-green
Cranberries	Faint purple	Red	Light green
Grapes	Purple	Red	Bluish-green
Plums	Faint purple	Red	Light green
Pomegranates	Purple	Red	Bluish-green
Strawberries	Reddish-purple	Red	Light green

The color change obtained by the addition of canned pineapple juice to grape, wild grape, blackberry, raspberry, or loganberry juices cannot be explained on the basis of acidity alone. Even if these juices have had a large quantity of lemon juice added they usually turn blue or the original blue shade is intensified and particularly after the juices have been mixed and left standing a short time. Tin salts from the canned pineapple may be one cause for the color change. In addition, proteins, tannins, and ferric salts may play a role in causing color changes. Also many of the salts of the anthocyanins have characteristic colors which are independent of mild changes in acidity. Many organic substances also have characteristic color changes.

11.8.1 VIOLET COLORATIONS IN CANNED FRUITS: Culpepper and Caldwell have reported the cause of violet coloration of some fruits canned in tin containers. The red anthocyan pigments have the property of combining with tin, forming salts that are violet colored. The salts are formed when the material containing the pigment is heated with tin. They find that "the amount of the violet compound formed is determined by the amount of pigment present, and by the degree of acidity of the medium, low acidity favoring its formation, high acidity depressing or suppressing it." The addition of an alkali intensifies the violet color; the addition of acid restores the original red color. The violet color is deepened by standing in the air after opening the can.

11.8.2 COLOR CHANGES OF RED VEGETABLES: Clark gives in his list of indicators that red cabbage extract is red at pH 2.4 and green at pH 4.5. However, the results in this laboratory have not agreed with those of Clark. In general there is lack of agreement in reports of pH at which the pigment of red cabbage turns blue. There are probably two reasons for this. The anthocyanins combine with metals to form salts, the particular metal influencing the color reactions. Also the color developed at a given pH may depend upon the time of exposure at that pH. The cabbage itself, when cooked in water or juice pressed from the cabbage, shows changes at varying reactions, which have varied slightly at different times. This is probably due to other constituents and their concentration in addition to the red cabbage coloring. Temperature and time of standing before the determinations were made also affect the pH.

Usually at a pH of 2.4 to about 4.0 the color is red, showing gradual changes through blue-red, purple or violet, red-blue, and finally blue. These changes occur over a rather wide range of pH, the blue developing at pH 6 or above. The green color develops with greater alkalinity at about pH 7 to 9. With still higher concentrations of alkali a yellow or brown color develops.

If red cabbage is served raw with a salad dressing containing acid it is bright red or blue-red in color. If cooked in distilled water, it is violet or violet-blue in color, but often becomes blue after standing a few minutes. With a slightly alkaline water the color is blue, for the plant acids lower the pH of the water. If the water is distinctly alkaline the color becomes green if cooked about 15 minutes or longer. The addition of a little soda to distilled water, Experiment 17B, 5, gives a green color unless the cooking period is exceptionally short. The red vegetables tend to retain their color better when cooked in milk than when cooked in water. Red onions show the same color changes as red cabbage, but the colors are often muddy. Red cabbage shows color changes in handling it. When the cut edges of the cabbage come in contact with the hands or knife they turn blue. Hands and knives washed in hard water or with soap may have salts with an alkaline reaction on their surface, but the anthocyanins can also form compounds with metallic ions.

Beets do not develop the blue or green color, although the color often contains a considerable amount of blue or purple. Sometimes they turn from red to yellow when cooked. If the cooked beets are placed in acid, the red color is often restored after a short time. Blair states that beets contain two pigments, one being scarlet the other purple. The scarlet pigment is stable to heat, but

the purple one fades. The scarlet pigment is stable even in the alkaline range as far as pH 9 or, according to Pratt and Swartout, even at pH 13.0. The color of canned or cooked beets depends upon the proportion of the two pigments present in the beets. This is probably an explanation of why cooked beets vary so much in color, even when cooked under the same conditions of acidity, temperature, and time. Beets have been produced in which the scarlet pigment has been increased and which do not lose color when canned at high temperatures.

11.9 METALS AND ANTHOCYAN PIGMENTS:

The tin salts of the anthocyanins have been mentioned, but the iron salts are even better known. In general, the iron salts of anthocyanins are blue. It is known that juice from blue hydrangeas contains a higher percentage of iron than that from pink hydrangeas even at the same pH. Some anthocyanins may not combine with iron or other modifications may occur which prevent or are necessary for the development of the blue color, for if some anthocyanins are treated with iron salts the color fades or remains red. Other metals which may combine with the anthocyanins are aluminum, zinc, and lead. Aluminum produces about the same colors as iron, although less intense. It seems reasonable to expect that, if certain salts are present in the vegetable in high concentration or are furnished by the cooking water or the cooking utensil, they will modify colors obtained at a given pH in cooking. Also, the blue color that develops on the cut surface of red cabbage in a short time after cutting with a metal knife may possibly be due to formation of anthocyanin salts with the metal.

Lathrop states that both iron and tin are "injurious to fruit pigments. The compounds of the pigments with the metals become quickly oxidized on exposure to air, with a marked increase in intensity of discoloration. Tin turns grapes, cherries, raspberries, and blackberries a deep purple and strawberries a pale red. Iron produces dull brownish discolorations. Copper and aluminum are far less injurious and are therefore used wherever fruit must come in contact with metal. Copper being somewhat injurious to the color of grape, aluminum is usually used with grape."

The application of this knowledge comes in cooking fruits, preserves, and jellies. Since tin cooking utensils are seldom used in household cooking, this metal would be injurious to color of fruits when used in taking seeds from berries with tin colanders, or when such fruits are canned in un-lacquered tin. Iron might affect the color of fruits, if such fruits are cooked in utensils from which the enamel has been chipped.

11.10 TANNINS

The term tannin is sometimes used to denote a whole group of substances having certain characteristics in common. Sometimes it is used to denote a particular substance, i.e., gallic or digallic acid. The former is the meaning used in the following paragraphs.

The tannins are widely distributed in the higher plants. Some plants are very rich in them; others contain very little. The amount in the plant will vary with different years and growing conditions. The tannins are found throughout the plant, but the woody part, the stems, and rootstocks are likely to contain larger amounts. They are found in many fruits, especially during the immature or green stages, and in the seeds of several plants. Lathrop states that stemming of grapes prior to heating for juice extraction is advisable to get rid of astringent tannin of the stems which would be detrimental to flavor.

To some extent the tannin content of fruit is not only dependent upon environmental influences, but upon inherited characteristics. The New York Experiment Station has reported a variety of peach called Sunbeam, which does not turn brown when pared. Kertesz reports its tannin content as very low, 0.0076 per cent.

11.10.1 Reactions of the tannins: Thatcher states that chemically the "Tannins are either free phenol-acids, or, more commonly, glucosides of these acids." The structure of the tannins is very similar to that of the anthocyan pigments. They are divided into two general classes, known as the pyro-gallol tannins and the catechol tannins. Thatcher has reported the following characteristic reactions.

	Pyrogallol Variety	Catechol Variety
Ferric salts.....	Dark blue	Greenish black
Bromine water.....	No precipitate	Yellow or brown precipitate
Leather.....	Produces bloom	No bloom
Concentrated sulfuric acid..	Yellow or brown	Red or Pink
Lime water.....	Gray or blue precipitate	Pink or brown precipitate

Haas and Hill summarize the properties of the tannins under eight headings. Only five will be given here.

1. Tannins are mostly uncrystallizable colloidal substances with astringent properties.
2. They give blackish-blue or blackish-green colors with ferric salts, a fact made use of in the manufacture of ink.
3. In alkaline solution the tannins and many of their derivatives readily absorb oxygen becoming dark in color.
4. They precipitate gelatin from solution and form insoluble compounds with gelatin-yielding tissues, a property which enables them to convert hide into leather.
5. They are precipitated from solution by many metallic salts such as copper or lead acetates, or stannous chloride.

11.10.2 Astringent qualities due to tannins: The astringent properties give a slightly bitter taste to some foods, the degree depending on the amount of tannins present. Thatcher states that "Tannins are of frequent occurrence in green fruits imparting to them their characteristic taste. They nearly always disappear as the fruit ripens." Two explanations are suggested for the disappearance of the tannins in ripening fruit. The anthocyan pigments may be derived from the tannins, so that as the fruit colors the tannins disappear; or the tannins may be changed into an insoluble form and therefore are not so apparent to the taste.

11.10.3 Persimmons contain a very large amount of tannin: Green persimmons have a bitter, astringent, puckery taste, that is not easily forgotten, once they have been tasted. Gore's work has shown that most of the tannin of persimmons is enclosed in cells, which he terms giant tannin cells. By artificial processing in carbon dioxide, or by ripening, the membrane containing the tannins becomes hard and insoluble so that the astringent taste is not evident.

11.10.4 Blue or purple discoloration in English walnuts: English walnuts are more astringent than other nuts and often develop color changes that are unattractive when combined with other foods. When they are combined with apples in a salad they often develop a blackish blue or purple color. This may come from having prepared the apples with an iron knife, the acid and enzyme of the fruit acting on the iron to produce ferric salts. When this small amount of ferric salt comes in contact with the tannin of the nut and particularly with the skin the purplish color develops. In nut bread, English walnuts often produce a dark color.

Tannins may produce a gray shade in sugar. Zerban has found that the color of dark greenish cane juice, which produces a sugar with a gray shade, may be due to tannins, oxidizing enzymes, and iron. When the cane is crushed the acid of the juice forms some ferrous salts with the iron of the roller. Oxidizing enzymes of the juice oxidize the ferrous salts to ferric ones and they combine with the tannins of the juice. A similar change occurs when fruits are pared with iron knives and especially when the juice is left to stand on the knife and it darkens.

11.10.5 Tannins and discolorations in canned goods: Kohman has reported that the discoloration, a darkening in color, often found in spots in canned sweet potatoes is due to tannins. The tannin combines with the iron of the can to produce the dark color. Oxygen is necessary to oxidize the ferrous iron to ferric, so that, unless oxygen is found in the can, either through not exhausting all of the air in processing or to a leak in the can, the discoloration does not occur.

Salsify probably contains large amounts of tannic substances. It turns dark when peeled even if put under water unless a little vinegar is added to the water to acidify it. Salsify or oyster plant and sometimes other vegetables such as carrots stain the fingers when they are pared. This may be due in part to tannins. Lemon juice is effective in removing or lightening such stains because of its acidity.

11.10.6 Other discolorations with tannins: Brownish or black discolorations of vegetables in vinegar have been caused by the tannin of the vinegar combining with the iron of the food. The use of a tannin-free vinegar does away with this difficulty. Greenish black spots in chocolate ice cream were traced to the tannin supplied by the chocolate or cocoa and the iron from rusty spots in the can. In green-colored beer the iron came from exposed pipes, the tannin from the hops.

According to Atwater, cherry juice, now commercially marketed, when mixed with gelatin for a molded dessert, sometimes gave a gummy, purplish precipitate. The precipitate was caused from combination of the tannin of the juice with the protein, gelatin; the purplish color came from combination with metals.

11.11 TEA

Black tea is darker than green tea because of oxidation of tannins in the leaf during drying and fermentation. It is also less astringent than green tea because the tannins are in a less soluble form.

Tannins also give precipitates of calcium, magnesium, and iron tannates, when these minerals are present in the water. The film on coffee or tea is from these tannates. When lemon or orange is added to tea, the film usually disappears, for in acid the tannins often lose the darker color acquired in an alkaline medium.

Tannins lower the surface tension of water, and the water in which vegetables containing tannins are cooked is apt to froth or foam.

11.12 SUMMARY

The attractiveness of fruits and vegetables depends to a large extent on their colors. In many cases these colors are the result of anthocyanin pigmentation. Carotenoids are not involved very often as the major pigment, but they are important in several well-known examples such as lycopene in tomatoes, and carotene in carrots and sweet potatoes. Chlorophyll, of course, is the pigment in green vegetables. The color-producing pigments are concentrated in the skin or rind of a number of fruits and vegetables, including the anthocyanins of apples, plums, and pears, and the carotenoids of oranges and bananas. In other examples, the pigments are distributed throughout the fruit or vegetable (e.g., anthocyanins in raspberries and carotenoids in carrots). The ripening of most fruits and some vegetables is characterized by a rapid decrease in chlorophyll levels coupled with a rapid increase in pigment levels. It is generally assumed that the same type of anthocyanin reactions responsible for flower colours are also important in some fruit and vegetable colours.

11.13 SELF ASSESSMENT QUESTIONS

1. Explain the effect of cooking acid and alkali in water soluble pigments of fruits and vegetables?
2. Classify the pigments present in fruits and vegetables. Write a short a short note on each pigment?

11.14. REFERENCE BOOKS

1. Chichester, C.O, The Chemistry of plant pigments, Academic Press, New York, 1972.
2. Goodwin, T.W. Biochemistry of Carotenoids, Vols I & II, Academic press, New York, 1980, 84.
3. Michael Eskin, N.A. Plant pigments, Flavor and Texture, Academic press, New York, 1979.

Dr. D. JALAJA KUMARI

PLANT ENZYMES

12.0 OBJECTIVE:

- To know the important enzymes and their sources
- Describe the plant enzyme mechanism of functions
- To understand the type and prevention of browning reaction

Products

12.9.2.2.1 Water activity (aw)

12.9.2.2.2 pH

12.9.2.2.3 Temperature

12.10 Summary

12.11 Self Assessment Questions

12.12. Reference Books

The best way to obtain plant enzymes is from raw fruits, vegetables, and plant-based enzyme supplements. The plant-based supplements are commonly obtained from fungal sources but can be obtained from other sources as well. They are said to be more effective than animal-sourced supplements because they are able to work both in the stomach and small intestine. Furthermore, the body is able to produce its own enzymes from amino acid chains, also known as polypeptides.

When it comes to plant versus human enzymes, plant enzymes seem to be a better choice. This is because plant enzymes are able to work in the acidic environment of the stomach as well as in the more alkaline environment in the small intestine. Human enzymes are able to work only in the small intestine. Therefore, plant enzymes can begin the digestive process much sooner, speeding up the digestive process. Another difference between the two enzymes is that plant enzymes can help the body to absorb nutrients in a weak digestive system, which human enzymes are not able to do in many cases.

12.3 PAPAIN:

Indigenous to the tropical climes of America, the papaya plant is now found in all tropical regions across the world. The papaya plant is normally small size and belongs to the Carica papaya or the Caricaceae family. The plant has a non-timbered trunk that is hollow and bears large, long stalked and extremely lobed leaves. The papaya plant does not have any intervening or dominant branches, its fruits have smooth exterior that openly resembles the cantaloupe groups of fruits or melons. The ripened papaya fruit is yellowish-orange in color and extremely delicious. The full grown, but unripe papaya fruits give out a milky sap or latex when low cuts are made on them. This white milky substance is a useful medication and is collected and dried as crude papain. While most of the papain is collected by making incisions in the unripe papaya fruits, some quantity (approximately two per cent) of this important ingredient is also obtained from the plant's leaves.

Papain is also often known as the vegetable pepsin. This milky ingredient of raw papaya fruits is a blend of proteolytic enzymes that have multifarious activities. Papain not only hydrolyzes proteins, but also does the same with small peptides (linear molecules of amino acids), amides (organic or inorganic derivatives of ammonia) as well as a number of esters. The other elements of crude papain cause the hydrolysis of carbohydrates as well as fats in the body. Owing to its wide range of functions, early herbal medicine practitioners used papain to treat various types of digestive disorders, especially those related to the intake of protein-rich diets. In addition, the papain enzymes as well as the papaya leaves are also used as a vermifuge to throw out worms from the intestines. This is particularly effective in dispelling tapeworms from the body. Presently, tablets prepared from papain containing 10 mg to 50 mg of the enzyme are readily available in the market to treat digestive disorders.

As mentioned earlier, papain found in the papaya plant's whitish sap or latex is basically an enzyme that helps to break up proteins. The pure form of papain is in great demand as a substance that softens meat. This is owing to pure papain's capability to assimilate approximately 35 times its own weight in slender meat. In herbal medicine, physicians recommend papain for people who have problems digesting proteins and also split blood clots following any surgery. In addition to these, presently doctors as well as scientists are examining the effectiveness of a sister enzyme of papain known as chymopapain in contracting broken or slithered spinal discs.

Interesting to note that papain is present in all parts of the papaya plant in small quantities. However, the maximum concentration of the enzyme can be found in the plant's leaves as well as the skin of the full grown, but unripe fruits. It may be mentioned here that only the pure form of the milk-like enzyme or latex is worth harvesting as the process is done manually and is time consuming. Despite the fact that large orchard of the papaya plant is found almost everywhere in southern Mexico and Central America, where the species is believed to have its origin, and the plant is cultivated in almost all the tropical climatic zones across the world, the latex is commercially collected only in a few places like Zaire in central Africa.

Papain forms an important ingredient in the manufacture of face creams, ointments, cleansers and other similar substances with the belief that the enzyme will apply its assimilating effect on freckles or brown spot on the skin as well as other blotches caused by the sun. It is also thought that lotions, creams and cleansers formulated with papain will provide a normal mitigating result while sanitization of the makeup facial pores. Notwithstanding all these, the most popular use of papain to any housewife is the enzyme's capability to tenderize meat. In fact, most supermarkets today sell the enzyme mixed with salt that acts as a stimulator and a carbohydrate that functions as a dispersing agent. When added to meat before cooking, the enzyme makes it tender by predigesting some amount of the animal protein. The enzyme is particularly effective while cooking the tough beef meat as it helps in softening fibrous animal protein present in the meat. In addition to its tenderizing effect on meat, papain may also be used to make beer chill proof and elucidate fruit juices, but these aspects of the enzyme may be discussed elsewhere later.

Here is a word of caution for those who are habituated to drinking tea prepared from the papaya leaves to aid in their digestive process. According to the French herbal physicians, it is necessary to first put the papaya leaves in a fermentation process much like in the case of the black tea. Once the leaves are fermented, it makes the extraction of the active elements easier by boiling water and also brews a more plentiful beverage than that could be acquired from the usual papaya leaves. However, the bad news is that papain is somewhat unbalanced in the company of digestive juices and hence its effectiveness as a vermifuge to throw out intestinal worms or as a digestive aid is quite questionable. Thus, even after studying the proof substantiating the hypothetical efficiency of papaya, the German health authorities have come to the conclusion that the plant's usefulness still remains unverified. As a consequence, the German health authorities have not approved or recommended the use of the plant or its fruit for remedial use.

12.3.1 Parts used:

Fruit, latex, leaves, flowers, seeds.

12.4 USES

Papaya is basically an agent that helps in the digestive process. The leaves of the tree as well as the fruit, both ripe and raw, are used medicinally to aid digestion. It is interesting to note the unripe papaya fruit is medicinally more advantageous. The milky white sap produced by the trunk of the papaya tree is also a useful remedy and is applied externally to accelerate the curing of abrasions, ulcers, boils, warts and cancerous growth. The papaya seeds are also useful as when ingested they help in throwing out worms from the body. The latex or the white sap produced by the papaya tree trunk is also effectual in this manner, but comparatively more aggressive. On the other hand, an infusion prepared with the flowers of the plant may be used to stimulate menstruation. The decoction prepared by boiling the ripe fruit in water is useful for curing enduring diarrhea and dysentery among children. While the raw papaya contains a white milk

substance called papain, the ripe fruit is moderately laxative and helps in the movement of bowels. The leaves of the papaya tree are useful too as they are often used for dressing wounds and injuries.

12.5 HABITAT AND CULTIVATION

Papaya is native to the tropical regions of South America, but is now cultivated commercially in all tropical climates across the globe.

12.6 CONSTITUENTS

Chemical analysis of the papaya has found that the fruit encloses proteolytic enzymes such as papain and chymopapain. In addition, the fruit also contains hints of an alkaloid called carpaine. Papain is a milky white sticky substance that flows from the raw fruit when it is cut. The substance is highly useful as a medication and is known to be an enzyme that dissolves protein. Regular ingestion of papain helps in the digestion process.

12.7 PAPAYA SKIN TREATMENT

Papaya, a fruit that appears similar to a melon, contains an enzyme which assists in getting rid of dried out scaly skin. However, it is advisable that you should never allow the papaya to remain on your face for an extended period, as this fruit has a propensity to dehydrate the skin.

Just a wedge of papaya is enough for this treatment. Slice out a wedge from a ripened papaya and keep the remaining fruit for consumption. Get rid of the seeds, dig out the pulp of the fruit and pound it. Apply the smooth pulp over your face evenly and after a few minutes, clean up your face using a washcloth. Subsequently, splash some cool water on your face for a refreshing experience.

12.8 MECHANISM, BIOLOGICAL IMPORTANCE AND FUNCTIONS

12.8.1 Mechanism of Functions

The mechanism in which the function of papain is made possible is through the cysteine-25 portion of the triad in the active site that attacks the carbonyl carbon in the backbone of the peptide chain freeing the amino terminal portion. As this occurs throughout the peptide chains of the protein, the protein breaks apart. The mechanism by which it breaks peptide bonds involves deprotonation of Cys-25 by His-159. Asparagine-175 helps to orient the imidazole ring of His-159 to allow this deprotonation to take place. Although far apart within the chain, these three amino acids are in close proximity due to the folding structure. It is through these three amino acids working together in the active site that provides this enzyme with its unique functions. Cys-25 then performs a nucleophilic attack on the carbonyl carbon of a peptide backbone. In the active site of papain, Cys -25 and His -159 are thought to be catalytically active as a thiolate-imidazolium ion pair.

Papain can be efficiently inhibited by peptidyl or non-peptidyl N-nitrosoanilines. The inactivation is due to the formation of a stable S-NO bond in the active site (S-nitroso- Cys25) of papain.

12.8.2 Papain in Medical Uses

Papain acts as a debris-removing agent, with no harmful effect on sound tissues because of the enzyme's specificity, acting only on the tissues, which lack the α_1 -antitrypsin plasminic antiprotease that inhibits proteolysis in healthy tissues (Flindt, 1979). The mechanism of biochemical removal of caries involves cleavage of polypeptide chains and/or hydrolysis of collagen crosslinkages. These cross-linkages give stability to the collagen fibrils, which become weaker and thus more prone to be removed when exposed to the papain gel. Papain-based gel has also been reported as a potential useful in biochemical excavation procedures for dentin.

Papain has advantages for being used for chemomechanical dental caries removal since it does not interfere in the bond strength of restorative materials to dentin. Papain enzyme has a long history of being used to treat sports injuries, other causes of trauma and allergies. Fortunately papain has a proven track record in managing all of these conditions with clinical evidence of significant benefits for use of papain protease enzyme in cases of sports injury. It has previously been reported that minor injuries healed faster with papain proteases than with placebos. Furthermore, athletes using papain protease supplements were able to cut recovery time from 8.4 days to 3.9 days. Papain also has been successfully used to overcome the allergies associated with leaky gut syndrome, hypochlorhydria (insufficient stomach acid) and intestinal symbiodis like gluten intolerance. Papain has previously been reported to have significant analgesic and anti-inflammatory activity against symptoms of acute allergic sinusitis like headache and toothache pain without side effects.

12.8.3 Industrial Uses and Pharmaceutical Preparations

Papain is used in meat tenderizers; the major meat proteins responsible for tenderness are the myofibrillar proteins and the connective tissue proteins. Protease enzymes are used to modify these proteins and papain has been extensively used as a common ingredient in the brewery and in the meat and meat processing. Papain importance as tenderizers in the food industry is similar to collagenases, which have application in the fur and hide tanning to ensure uniform dyeing of leather. Papain also can act as a clarifying agent in many food industry processes. As a protein digestant, papain is used in combating dyspepsia and other digestive disorders and disturbances of the gastrointestinal tract (Huet *et al.*, 2006). Papain has for quite a long time been used in pharmaceutical preparations of diverse food manufacturing applications as the production of high quality kunafa and other popular local sweets and pastries. Papain has been reported to improve meltability and stretchability of Nabulsi cheese with outstanding fibrous structure enhancing superiority in the application in kunafa, pizza and pastries (Abu-Alruz *et al.*, 2009). Also as pharmaceutical products in gel based a proteolytic cysteine enzyme, papain presents antifungal, antibacterial and anti-inflammatory properties.

12.9 BROWNING REACTIONS

Browning of foods can be either non-enzymatic (caramelization or maillard reaction) or enzymatic.

12.9.1 Enzymatic browning

Enzymatic browning is a chemical process which occurs in fruits and vegetables by the enzyme polyphenoloxidase, which results in brown pigments. Enzymatic browning can be observed in fruits (apricots, pears, bananas, grapes), vegetables (potatoes, mushrooms, lettuce) and also in seafood (shrimps, spiny lobsters and crabs).

Enzymatic browning is detrimental to quality, particularly in post-harvest storage of fresh fruits, juices and some shellfish. Enzymatic browning may be responsible for up to 50% of all losses during fruit and vegetables production.

On the other hand enzymatic browning is essential for the colour and taste of tea, coffee and chocolate.

- **Polyphenols**
- **Polyphenoloxidase**
- **Prevention**

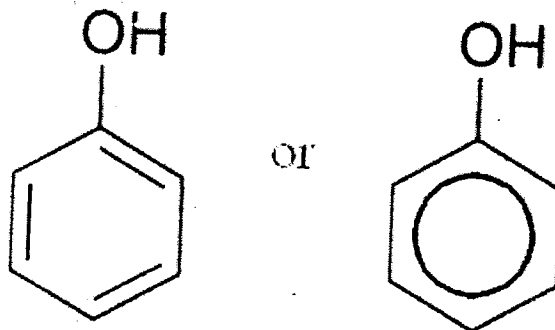
12.9.1.1 Polyphenols – main components in enzymatic browning

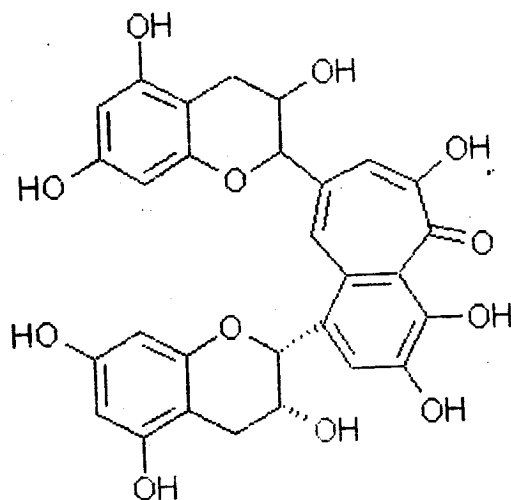
Polyphenols, also called phenolic compounds, are group of chemical substances present in plants (fruits, vegetables) which play an important role during enzymatic browning, because they are substrates for the browning-enzymes.

Phenolic compounds are responsible for the colour of many plants, such as apples, they are part of the taste and flavour of beverages (apple juice, tea), and are important anti-oxidants in plants.

Polyphenols are normally complex organic substances, which contain more than one phenol group (carbolic acid):

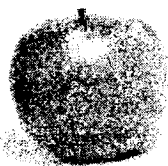
Structure 1: Phenol





Structure 2: Theaflavin, a polyphenol in tea (Source)

Polyphenols can be divided into many different sub categories, such as anthocyanins (colours in fruits), flavonoids (catechins, tannins in tea and wine) and non-flavonoids components (gallic acid in tea leaves). Flavonoids are formed in plants from the aromatic amino acids phenylalanine and tyrosine.



The colour of apples is due to polyphenols

During food processing and storage many polyphenols are unstable due to the fact that they undergo chemical and biochemical reactions. The most important is enzymatic oxidation causing browning of vegetables, fruits. This reaction mostly occurs after cutting or other mechanical treatment of product due to breaking cells.

Table 2: An overview of known polyphenols involved in browning

Apple	chlorogenic acid (flesh), catechol, catechin (peel), caffeic acid, 3,4-dihydroxyphenylalanine (DOPA), 3,4-dihydroxy benzoic acid, <i>p</i> -cresol, 4-methyl catechol, leucocyanidin, <i>p</i> -coumaric acid, flavonol glycosides
Apricot	isochlorogenic acid, caffeic acid, 4-methyl catechol, chlorogenic acid, catechin, epicatechin, pyrogallol, catechol, flavonols, <i>p</i> -coumaric acid derivatives
Avocado	4-methyl catechol, dopamine, pyrogallol, catechol, chlorogenic acid, caffeic acid, DOPA
Banana	3,4-dihydroxyphenylethylamine (Dopamine), leucodelphinidin, leucocyanidin
Cacao	catechins, leucoanthocyanidins, anthocyanins, complex tannins
Coffee beans	chlorogenic acid, caffeic acid
Eggplant	chlorogenic acid, caffeic acid, coumaric acid, cinnamic acid derivatives
Grape	catechin, chlorogenic acid, catechol, caffeic acid, DOPA, tannins, flavonols, protocatechuic acid, resorcinol, hydroquinone, phenol
Lettuce	tyrosine, caffeic acid, chlorogenic acid derivatives
Lobster	Tyrosine
Mango	dopamine-HCl, 4-methyl catechol, caffeic acid, catechol, catechin, chlorogenic acid, tyrosine, DOPA, <i>p</i> -cresol
Mushroom	tyrosine, catechol, DOPA, dopamine, adrenaline, noradrenaline
Peach	chlorogenic acid, pyrogallol, 4-methyl catechol, catechol, caffeic acid, gallic acid, catechin, dopamine
Pear	chlorogenic acid, catechol, catechin, caffeic acid, DOPA, 3,4-dihydroxy benzoic acid, <i>p</i> -cresol
Plum	chlorogenic acid, catechin, caffeic acid, catechol, DOPA
Potato	chlorogenic acid, caffeic acid, catechol, DOPA, <i>p</i> -cresol, <i>p</i> -hydroxyphenyl propionic acid, <i>p</i> -hydroxyphenyl pyruvic acid, <i>m</i> -cresol
Shrimp	Tyrosine
Sweet potato	chlorogenic acid, caffeic acid, caffeylamide
Tea	flavanols, catechins, tannins, cinnamic acid derivatives

12.9.1.2 Polyphenoloxidase (PPO, phenolase)

Polyphenoloxidases are a class of enzymes that were first discovered in mushrooms and are widely distributed in nature. They appear to reside in the plastids and chloroplasts of plants, although freely existing in the cytoplasm of senescing or ripening plants. Polyphenoloxidase is thought to play an important role in the resistance of plants to microbial and viral infections and to adverse climatic conditions.

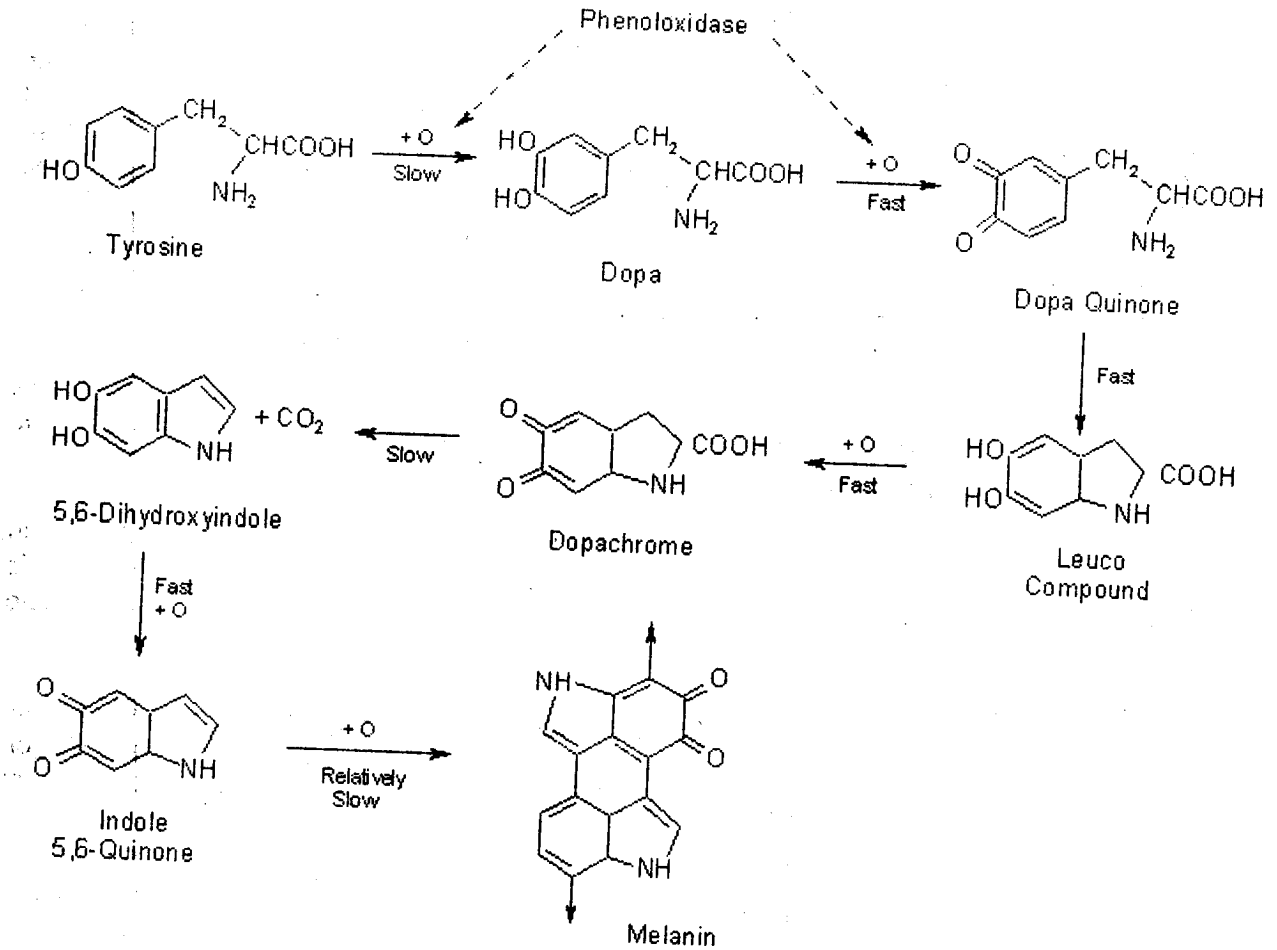
Polyphenoloxidase also occurs in animals and is thought to increase disease resistance in insects and crustaceans.

In the presence of oxygen from air, the enzyme catalyzes the first steps in the biochemical conversion of phenolics to produce quinones, which undergo further polymerization to yield dark, insoluble polymers referred to as melanins.

These melanins form barriers and have antimicrobial properties which prevent the spread of infection or bruising in plant tissues. Plants, which exhibit comparably high resistance to climatic stress, have been shown to possess relatively higher polyphenoloxidase levels than susceptible varieties.

Polyphenoloxidase catalyses two basic reactions: hydroxylation and oxidation. Both reactions utilize molecular oxygen (air) as a co-substrate. The reaction is not only dependent on the presence of air, but also on the pH (acidity). The reaction does not occur at acid (pH <5) or alkaline (pH >8) conditions.

An example of the formation of melanins from a simple polyphenol, tyrosine, is shown in the figure below:



Structure 3: Formation of melanins from tyrosine Source

12.9.1.3 Prevention of enzymatic browning

The control of browning is one of the most important issues in the food industry, as colour is a significant attribute of food which influences consumer decision and brown foods (especially fruits) are seen as spoiled.

Several methods can be applied to avoid enzymatic browning, based on inactivating the enzyme (heat) or by removing essential components (most often oxygen) from the product.

12.9.1.3.1 Blanching

Blanching is a short heat treatment to destroy or inactivate enzymes before freezing of products (mainly vegetables). Enzyme activity may discolour or toughen vegetables during freezing, which results in quality loss. Blanching brightens the colour, softens the texture, but has little effect on nutrient content or flavour as it is a relatively short process.

The blanching temperature depends on the type of enzyme which occurs in the product, but is generally between 70 and 100 °C, sometimes higher when more resistant enzymes are to be inactivated. Table 2 below gives an indication of the temperature needed to inactivate some important enzymes.

Table 3: Inactivation temperatures of some enzymes

Enzyme	effect	inactivation temp. ° C
Lipolytic acyl hydrolase	rancidity	~ 75
Lipoxygenase	rancidity	~ 80
Polyphenoloxidase	browning	~100
Peroxidase	deterioration	~135

12.9.1.3.1a: Types of blanching

- blanching in steam/boiling water;

Steam or boiling water blanching is a type of heat treatment for controlling enzymatic browning in canned or frozen fruits and vegetables. It is scalding the vegetables or food in water or steam for a short period of time. The steam blanching is 1.5 times longer than boiling water blanching.

- microwave blanching;

Microwave blanching may not be effective, since research shows that some enzymes may not be inactivated. This could result in off-flavours and loss of texture and colour.

12.9.1.3.2 Refrigeration

Refrigeration and chilling are used to prevent spoilage of vegetables and fruits during distribution and retailing. Chilling is applied often for broccoli, berries, spinach, peas, bananas, mangoes, avocados, tomatoes. At temperatures below 7 °C the polyphenoloxidase enzyme activity is inhibited, but the enzyme is not inactivated. Therefore the temperature should be well controlled.

12.9.1.3.3 Freezing

Like refrigeration, freezing inhibits, but not inactivates the enzyme. After thawing, the enzyme activity will resume.

12.9.1.3.4 Change pH

The enzyme activity is pH dependent. Lowering of the pH to 4.0 by the addition of citric, ascorbic or other acids inhibits the enzyme activity. During home-preparation of vegetables or fruits lemon juice or vinegar is often sprinkled on the fruit to prevent browning.

12.9.1.3.5 Dehydration

Dehydration is caused by the removing water molecules from the product. The PPO enzyme needs sufficient water to be active. By drying the enzyme is inhibited, but not destroyed.

To avoid flavour and quality loss, dehydration should not involve heat.

Common methods for dehydration are:

- Freezing-drying when moisture is removed by sublimation (the change from solid to gas). Products are frozen and slowly dehydrated under vacuum.
- Lowering water activity by adding water-binding chemicals. The most commonly used substances are salt (sodium chloride), sucrose, and other sugars, glycerol, propylene glycol and syrups or honey.

12.9.1.3.6 Irradiation

Irradiation, or as it is sometimes called "cold pasteurization", is a process in which food is submitted to ionized radiation in order to kill bacteria and reduce the enzyme activity. Irradiation is often applied in meats, seafood, fruits, vegetables, and cereal grains for long-term preservation.

Several types of irradiation methods are used in food processing: gamma rays, X-rays and accelerated electrons (electron beams). Disadvantages of radiation are loss of nutrients and (low) consumer acceptance. Irradiation is thus rarely used.

12.9.1.3.7 High pressure treatment

High pressure treatment also called High Pressure Processing (HPP) is a technique of food processing where food is subjected to elevated pressures (500-700 atmosphere) to achieve microbial and enzyme inactivation.

High pressure processing causes minimal changes in foods. Compared to thermal processing, HPP results in foods with fresher taste, and better appearance, texture and nutrition. High pressure processing without heat eliminates thermally induced cooked off-flavours. The technology is especially beneficial for heat-sensitive products, but still very expensive.

12.9.1.3.8 Addition of inhibitors

Inhibitions can act in three ways:

1. Inactivation towards the enzyme (acting directly on the enzyme)
2. Inactivation towards substrate (removing the substrate like oxygen or phenolic compounds)
3. Inactivation towards the product (changing the product composition)

Large amount of inhibitors are applied in food processing depending on the type of product and process. The most important inhibitors are shown in table 4.

12.9.1.3.9 Ultrafiltration

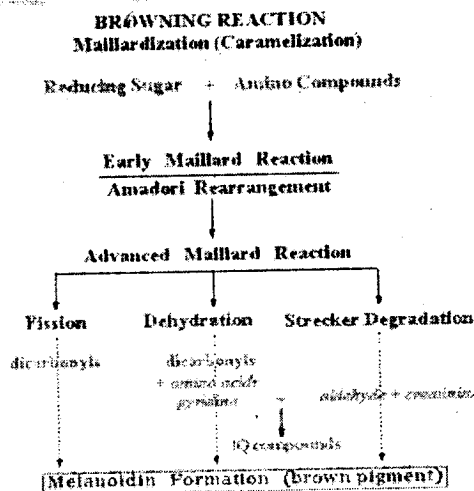
Ultrafiltration is a membrane separation process, driven by a pressure gradient. The membrane separates liquid components according to their size and structure. In the food industry this technique is for example applied for white wine and fruit juices. Ultrafiltration is able to remove larger molecules like polyphenoloxidase, but not lower-molecular-weight components like polyphenols.

Table 4: Inhibitors of enzymatic browning

Category	Example of Inhibitor	Mode of action
Reducing agents	Sulphiting ascorbic acid and analogs cysteine glutathione	removal of oxygen
Chelating agents	Phosphates EDTA organic acids	removal of metals (most PPO enzymes contain metal atoms)
Acidulants	Citric phosphoric acid	acid reducing pH
Enzyme inhibitors	aromatic carboxylic peptides substituted resorcinols	acids react with enzymes

12.9.1.3.10 Ultrasonication

Ultrasonication is an advanced method to inactivate enzymes. Ultrasonic sound waves are able to destroy large molecules by liberating highly reactive radicals from water. It is not yet applied on a large scale.



Treatment with supercritical carbon dioxide (SC-CO₂)

Supercritical carbon dioxide (fluid carbon dioxide at high pressure) treatment is mostly applied to destroying micro-organisms but can also be applied for enzyme inactivation, especially for inactivation of PPO in shrimps, lobsters and potatoes. Inactivation of the enzyme is a result of a decrease in pH caused by production of carbonic acid from carbon dioxide.

12.9.2 Maillard Reaction

Maillard reaction is a non-enzymatic browning reaction, caused by the condensation of an amino group and a reducing compound, resulting complex changes in biological and food system. This reaction was described for the first time by Louis Maillard in 1912. Maillard reaction occurs when virtually all foods are heated, and also occurs during storage. Most of the effect of Maillard reaction, including the caramel aromas and golden brown colors, are desirable. Nevertheless, some of the effect of Maillard reaction, including foods darkness and off-flavor development, are undesirable.

12.9.2.1 Maillard Reaction Products

12.9.2.1.1 Aroma and Flavor

Maillard-derived aromas are extremely complex and many components are formed in trace amounts by side-reactions and obscure pathways. The deoxyosones are considered to be primary source of aroma volatile compounds. Deoxyosones undergo cyclization/dehydration to produce flavor important furan derivatives and different types of furans are formed depending in one structure. The aroma profile also varies with the temperature and time of heating. At any given temperature-time combination, a unique aroma, which is not likely to be reproduced at any other combination of heating conditions, is produced.

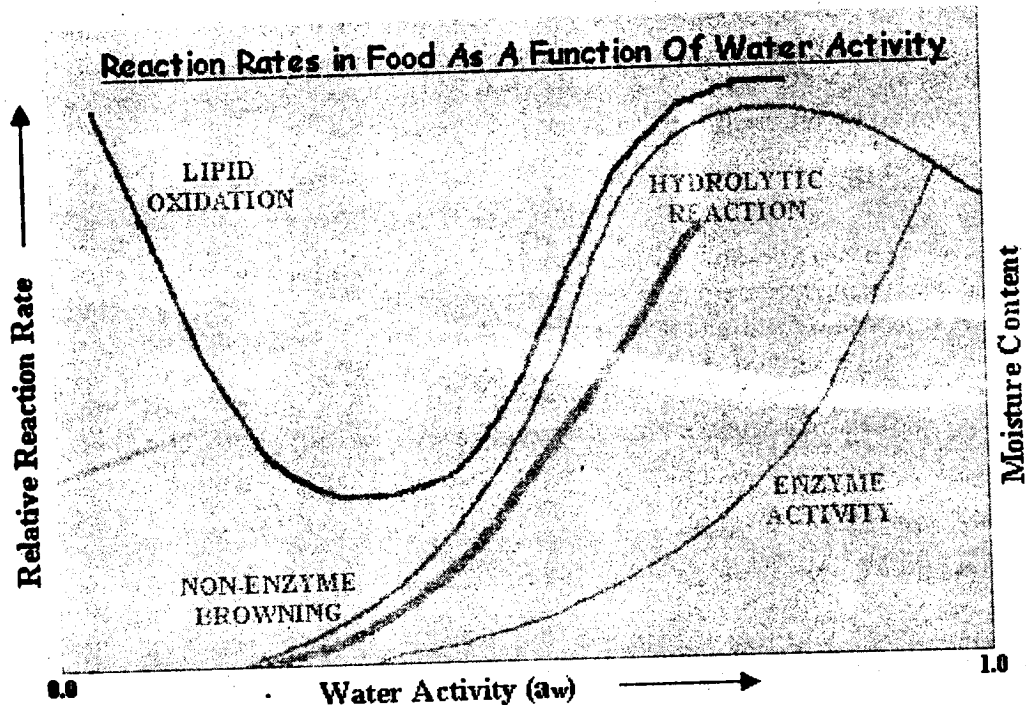
12.9.2.1.2 Color

The development of color is an extremely important feature of the Maillard reaction but relatively little is known about the chemical nature of the compounds responsible. There are both good and bad sides of the Maillard reaction for color development. Color development in meats and bread baking is desirable while the browning of dry milk or dehydrated products is undesirable.

12.9.2.2 Controlling Factors of the Maillard Reaction Products

12.9.2.2.1 Water activity (a_w)

Water is produced during Maillard reaction, thus the reaction occurs less readily in foods with a high a_w values while, at low a_w , the mobility of reactants is limited, despite their presence at increased concentrations.

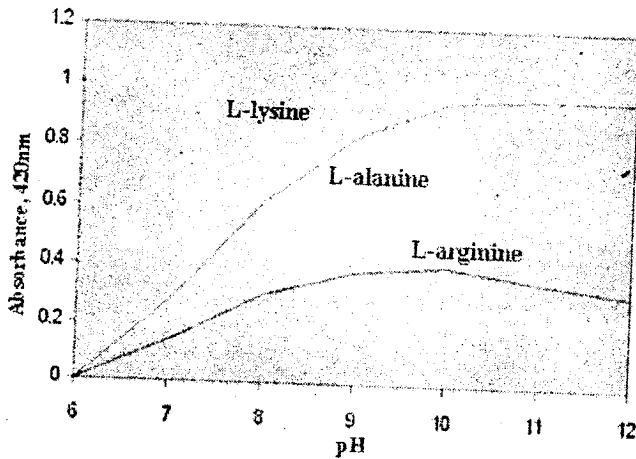


As the figure shown, in practice the Maillard reaction occurs most rapidly at intermediate a_w values (0.5-0.8), and a_w is of most significance to the reaction in dried and intermediate-moisture foods (IMFs), which have a_w values in this range. However, a_w values for maximum browning are affected by other components of the system: humectants, such as glycerol, can lower the a_w value for maximum browning.

12.9.2.2.2 pH

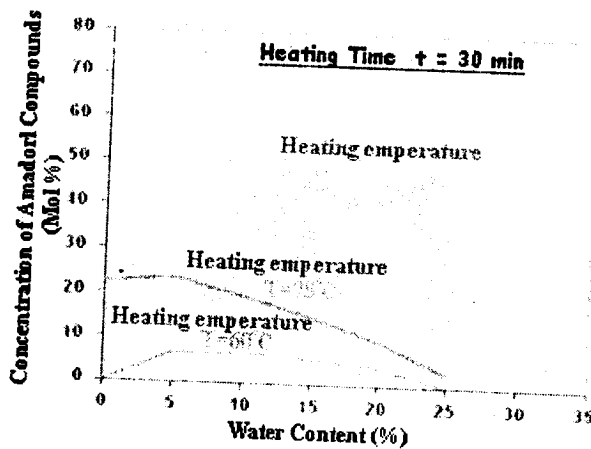
Since the reaction itself has a strong influence on pH it is hard to evaluate the pH influence. However, reactions take place by all pathways, with the pH of the system influencing the ratio of products formed and the rate of color formation can be reduced by decreasing the pH. The most desirable meaty and pot-roasted aroma was obtained at pH 4.7, but pH had a less dramatic effect on aroma than did temperature, time or water content.

The figure is "effect of pH on Maillard browning of L-lysine, L-alanine, and L-arginine heated with D-glucose at 121°C for 10 min". Under weakly alkaline conditions, and with a strongly basic secondary amino components, the 2,3-enolization pathway is favored.



12.9.2.2.3 Temperature

The temperature dependence of chemical reaction is often expressed as the activation energy (E_a). Activation temperature data for the Maillard reaction have been reported within a wide range 10-160KJ/mole, depending on, what effect of the reaction has been measured. The activation energy is also highly dependent on pH. The temperature dependence of the Maillard reaction is also influenced by the participating reactants. So it is difficult to isolate the effect of temperature as a single variable.



12.10 SUMMARY

Browning of foods during processing and storage, especially during manufacture of fruit and vegetable products decreases the sensory properties of products due to associated changes in colour, flavor and softening besides nutritional properties. Therefore, its control is essential to preserve the quality of the food.

12.11 SELF ASSESSMENT QUESTIONS

1. What are the changes that occur during ripening of fruits?
2. Explain the enzymatic browning in vegetables and fruits and four methods of preventing it?

12.12. REFERENCE BOOKS

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అధ్యాపకుల, విద్యార్థుల సలహాలు, సూచనలు :

అధ్యాపకులు, విద్యార్థులు ఈ స్టడీ మెటీరియల్ కు సంబంధించిన సలహాలు, సూచనలు, ముద్రణ దోషాలు తెలియపరచినచో, పునర్ముద్రణలో తగు చర్యలు తీసుకొనగలము. తెలియపరచవలసిన చిరునామా : డిప్యూటీ డైరెక్టర్, దూరవిద్యా కేంద్రం, ఆచార్య నాగార్జున విశ్వవిద్యాలయం, నాగార్జున నగర్ - 522 510.

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