UNIT 9: CHEMICAL, PHYSICAL AND NUTRITIONAL ALTERATIONS OCCURING IN FOODS DURING PROCESSING AND STORAGE

Structure

9.1 INTRODUCTION

In the first block of this course, we have talked about the major constituents, that is, carbohydrates, proteins, lipids and their physico-chemical characteristics. We have also acquired detailed knowledge about vitamins, minerals, enzymes, pigments and flavours, where we had primarily focused on the structure, occurrence of these in the food in their natural form and their application in the food industry. As you are aware that food is a perishable commodity it undergoes various physical, chemical and microbial changes; that might be undesirable. Hence, to prevent such changes and to ensure its future use and availability all round the year, it must be processed and stored using scientific techniques. We will learn about food processing in Units 10, 11 and 12 of this course. Now in this unit, we shall direct our attention to the alterations occurring in the constituents of food during processing and storage. The knowledge gained regarding the chemical composition and physico-chemical properties of food in the earlier units would be useful here for interpreting the changes, which occur during processing and storage.

Objectives

After going through this unit, you will be able to:

- understand the need of food processing
- identify specific changes in a particular food due to various types of processing
- discriminate between favourable and unfavourable reactions during processing and storage in different groups of food and
- have an idea and think about optimization of process parameters to regulate chemical, physical and nutritional alternations according to the need

9.2 FOOD PROCESSING IN PERSPECTIVE

In the present scenario, food processing is very essential in order to achieve food security and in providing safe food to the people.

Food preservation, as you are aware, is *the process in which the perishable food materials are given a suitable physical or chemical treatment to prevent their wastage, spoilage and to retain their nutritive value for long periods*. Food processing can result in several advantages, some of which are substantial. These include:

- increased shelf-life
- decreased hazards from microbial pathogen
- decreased spoilage (microbial, enzymatic)
- inactivation of anti-nutritional factors
- ensured round the year availability of seasonal foods
- perishable foods can be transported to far-off distances from the site of production
- increased availability of convenience (e.g. Ready-to-serve beverages, Instant mixes) foods and

- increased variety of foods, some with enhanced sensory properties and nutritional attributes.

The above mentioned points highlight the importance of food processing. While processing food, you may have realized that many desirable changes occur, which include development of pleasing colours and flavors, improvement of texture and improvement of the functionality of food or ingredients. However, a number of undesirable changes may also occur during food processing which are generally product and process-specific like, damage to colour and flavour, damage to the nutritional properties and/or the development of toxic constituents etc.

Based upon the knowledge acquired about various changes (physical, chemical and nutritional), which may occur during food processing, it is necessary to optimize the process parameters so as to get a wholesome food product. In the subsequent sections in this unit, we shall look at various alterations occurring in different foods, during processing.

9.3 ALTERATIONS OCCURRING IN FRUITS AND VEGETABLES

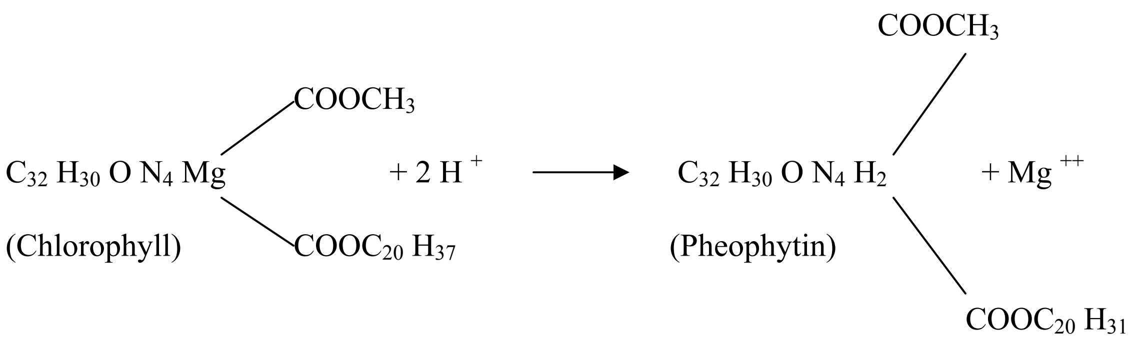
You may already be aware that fruits and vegetables vary greatly in their chemical composition. However, some generalizations are possible. Fruits and vegetables have high water content, with a range from approximately 70 per cent for pears and bananas to 91 per cent for cabbage. The amount of protein and lipids in fruits and vegetables is usually very low, though both are good sources of vitamins particularly vitamins A and C. Part of the carbohydrate in fresh fruits and vegetables is present as cellulose and pectic substances in the cell wall. Starch is present in almost all fruits and vegetables, although it may decrease on ripening. Glucose, fructose and sucrose are widely distributed whose content vary considerably in various fruits and vegetables. Further, we have also seen that carotenoids, chlorophylls, anthoxanthins and anthocyanins are the chief pigments present in fruits and vegetables.

The detailed chemical changes that occur when fruits and vegetables are boiled in water or steamed, canned, dried or frozen, are still for the most part unknown. However, certain fruits and vegetables like apples, peaches, potato etc. turn brown when cut and exposed to air. This is a result of numerous enzymatic reactions that occur in fruit and vegetables on processing. These reactions may result in changes in the appearance, texture, flavour and colour of the fruits and vegetables. You may recall reading about these changes earlier in Unit 2.

Further, as a result of changes in the cell wall and intercellular structure, all fruits and vegetables undergo softening when cooked, no matter by what method. The changes occur in pectic substances, cellulose, starch and intercellular air. Cellulose, pectin and hemicellulose, as you have learnt earlier, are the major polysaccharide components in the cell wall of all plant foods. There has been a rapid progress in understanding the physical and chemical properties of polysaccharides in recent years. Studies on the role of cell wall components in food texture have been done, particularly on pectic substances. Alterations in pigments, formation of acids and release of low molecular weight sulfur compounds have been reported as the major changes during processing of fruits and vegetables. In a study, reactivation of a pectinesterase has been found in cucumber slices. When fresh cucumber slices were blanched for 3 minutes at 81^{o} C, enzyme activity could not be detected. However, when the blanched slices were stored in a pH 3.7, brine containing 0.6% acetic acid, 2.5% sodium chloride (NaCl), and 200 ppm sulphur dioxide (SO_2), about 20% of the activity present in the fresh tissue was regained during the first month of storage.

In processing fruits and vegetables, loss of carotenoids into cooking or canning water is very slight. However, carotenoids undergo oxidation when exposed to air, so that drying of fruits or vegetables which contain these pigments, a problem is sometimes encountered. For example, carrots and apricots show loss of pigment on drying. Anti-oxidants partially protect the pigment from deterioration, as it is reasoned that the degradation of the pigment might be associated with the oxidative changes in the fat.

Chlorophyll, the pigment responsible for giving bright green colour to the vegetables, is very unstable and undergoes changes in colour which are often considered to be undesirable. Have you ever noticed the colour change in spinach when boiled in water? Yes, the green colour of the spinach turns to olive green and then to brown when the leaves are cooked for long. Basically, chlorophyll changes to olive green colour and then to brown when the food is heated and the reaction is faster in acid solutions. When a vegetable becomes olive green on cooking, the chlorophyll gets converted to *pheophytin* (a derivative of chlorophyll). The reaction can be written schematically as indicated below. Hence, special care must be taken to produce food products from plant sources to retain a bright, attractive green colour.



Dehydration is one of the ancient food processing techniques. *Dehydration means to completely remove water under controlled conditions, in such a way that minimal changes occur in the food item.* We will read about the technique later in unit 11. Here, let us focus on the changes occurring in fruits/vegetables during the process of dehydration. Vegetable dehydration reduces the natural water content below the level critical for the growth of microorganisms (12-15%), without being detrimental to important nutrients. Also, it is aimed at preserving flavour, aroma and appearance, and the ability to regain the original shape or appearance on reconstitution with water. However, the dehydration process is also accompanied by significant alterations. These include:

First, there is a concentration of major ingredients such as proteins, carbohydrates and minerals. This occurs along with some chemical changes. Fats undergo oxidative degradation and, although present in low amounts in vegetables, this oxidation often diminishes odor and flavour. Amino compounds and carbohydrates interact in a Maillard reaction (you would recall reading about the Maillard reaction in Unit 2), resulting in a darker colour and development of new aroma substances. Vitamin levels may also decrease sharply. The original volatile aroma and flavour compounds are lost to a great extent during processing depending upon the severity of the processing conditions.

Dried fruits are exceptionally rich in calories and they supply significant amounts of minerals. Of the vitamins found in fruits, β-Carotene and the vitamins of B-group are not significantly altered. Vitamin C is lost to a great extent. Sulfite treatment destroys vitamin B_1, however, fruit colour and vitamin C can be retained and stabilized.

Freezing is another ancient technique of food processing, which allows the transportation of perishable food items for long distances from production to consumption centres. *Freezing* refers to *freeze the available water of the food/food product and maintain it at -18^oC or below*. Freezing is mainly done for vegetables using conventional freezing techniques by indirect cold-transfer in plate or air freezers. We will learn more about freezing in Unit 11 later, but now we shall look at the changes/alterations occurring in fruits and vegetables, caused by freezing as a processing technique.

Freezing preserves vegetable and nutrients to a great extent. Vitamin A and β-Carotene are well preserved in spinach, peas and beans, or are moderately lost (asparagus) after proper blanching, freezing and deep freeze storage and even after thawing to room temperature. Losses in the vitamin B-group depend mostly on the conditions of the primary processing steps (washing, blanching). The other steps have no significant effect on B-vitamins. Leaching of vitamin C by water or steam is detrimental. It is generally preserved during freezing and thawing. Careful blanching and low temperature storage are critical for vitamin C preservation.

Uncontrolled freezing can result in the disruption of texture, denaturation of proteins and many other physical and chemical changes. Irreversible textural changes can occur in deep frozen vegetables. Typical symptoms are softening, ductile stickiness, or looseness or flaccidity (a flabby softness, as in beans, cucumbers carrots); build up of a sticky, ductile, gum-like structure (asparagus) or pasty, soggy structure (celery, kohlrabi) or hull hardening (peas).

Pickled vegetables are produced by spontaneous lactic acid fermentation. Fermentation improves the digestibility and wholesomeness of the product. The acidic pH of the medium stabilizes vitamin C. Pickled vegetables also develop a typical aroma, which is desirable.

Canning, which involves heat sterilization, is one of the most important processes in vegetable preservation. As compared to other foods, vegetable sterilization processes is carried out at towards a higher temperature and shorter time (HTST sterilization). In this way, the products retain a better quality in terms of texture, aroma and colour.

Check Your Progress Exercise 1

1. Fill in the blanks:

a) Fresh fruits contain carbohydrates as …………… and ……. …………… .

b) The component that is present in both fruits and vegetables and decreases on ripening is ………………… .

c) The chief pigments present in fruits and vegetables are chlorophylls, carotenoids, …………………and ………………… .

d) Cooking of fruits and vegetables results in changes in cellulose…………………, ……………… and ………………………… .

e) The enzyme present in cucumber that is activated during first month of storage is……………………

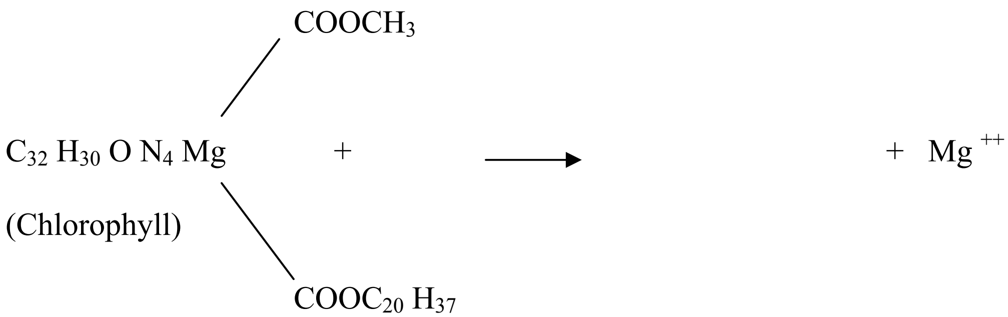
2. Mention the changes that occur in fruits and vegetables during the following processes.

a) Dehydration --
----

b) Freezing --

----

3. Complete the following reaction:



9.4 ALTERATIONS OCCURRING IN MILK AND MILK PRODUCTS

In the dairy industry, milk is commonly given heat treatment for a wide variety of purposes. Depending on the heating temperature, this procedure may cause several changes in milk, such as salt precipitation, due to the formation of insoluble complexes, protein denaturation and interactions among milk components. Heating milk at near boiling point causes a film or skin to form on the surface. This skin is mainly due to calcium caseinate but the other constituents in milk are also present in it.

Have you ever noticed what changes take place in milk if you heat it above its boiling point? Autoclaving milk, wherein temperature of around 121^{o}C is achieved, causes browning. The brown colour is due to the heat effecting an interaction between the casein (or amino acids) and the sugar. The process employed to heat milk also affects the changes in physico-chemical properties of milk. Research has shown that changes in certain physical and chemical properties of ultra-heated milk (95^{o}C to 145^{o}C) were much more severe when the milk was heated by indirect as compared to direct (steam injection) process. Increased browning and a greater amount of whey protein denaturation were particularly noticeable in ultra heated milk.

Apart from the above mentioned alterations, certain flavor changes also occur in milk, depending on the temperature and duration of heating. Heating milk to high temperatures causes a cooked flavor to appear. In the holding method of pasteurization (62^oC for 30 minutes) or the high-temperature short-time (HTST), 71^oC for 15 minutes methods - very little cooked flavor is noticed, but at higher temperatures or longer periods of heating, cooked flavor becomes more apparent. The flavor appears at 70^oC on momentary heating. This cooked flavor has been shown to be due to the production of *sulfhydryls* (compounds with a -SH group, found in many plant and animal enzymes) by high temperatures. Sulfhydryl compounds are readily oxidized and delay the oxidation of fat in milk or cream heated to high temperatures. Oxidized flavors in milk do not usually appear until the sulfhydryls are oxidized and the cooked flavor has disappeared.

Freezing the milk also alters its composition and properties to a great extent. Let us learn about these changes. As the milk freezes, it becomes very uneven in the composition of the frozen and other solids, while the liquid portion becomes concentrated with the milk solids, so much so that milk never freezes solid entirely. Freezing alters the physical condition of milk to the extent that it never returns to its original state. It causes the fat globules to lose their complete emulsion structure, to clump and become distorted and irregular in shape and size. The casein is also affected by freezing. It is partly broken from its existence in milk as calcium caseinate and gets precipitated as flakes. This condition, together with some free fat particles, gives the thawed-out milk an unnatural appearance. The flavor is also affected, being rather watery to the taste.

The caseinate micelles of milk, which are quite stable to heat, may be destabilized by freezing. On frozen storage of milk, the stability of the caseinate progressively decreases and may lead to complete coagulation.

Casein is an important example of protein, which can be boiled without apparent change in stability. The exceptional stability of casein makes it possible to boil, sterilize and concentrate milk, without coagulation.

Now we will have a look at the factors that have a bearing on viscosity. Low temperatures and aging induce clumping of the fat globules of milk, which increases the viscosity. Mechanical agitation of whole milk decreases the viscosity, because the fat globule clumps are partially broken up, while in the case of skim milk, it has no effect due to the presence of small amount of fats.

Homogenized milk will not be affected, as the fat globules are already broken up. Homogenization increases the viscosity of whole milk but slightly decreases that of skim milk. This process breaks up the fat globule into much smaller ones and thereby provides a larger surface area. A film of protein is adsorbed on the surface of the globules and this surface being much larger than in the non-homogenized milk, a much greater adsorption takes place, which causes a higher viscosity. Skim milk, some of the protein particles may be broken and therefore, the viscosity will be reduced.

Pasteurization temperatures slightly lowers the viscosity through breaking the clumps of fat globules, but when subjected to high heat, or high pressure, the viscosity is increased due to the denaturation of proteins.

9.5 ALTERATIONS OCCURRING IN MEAT AND POULTRY

Meat, as you already know, is rich in proteins and contains most of the essential amino acids. It is also rich in minerals such as copper and iron; vitamins such as A, B_1, B_2 and B_3. Its fat content varies from 5-40% with the type, breed, feed and age of the animal. Meats are rich in saturated fatty acids (SFA).A brief account of the effect of thermal treatment of meat products can be included. The intrinsic changes, which the muscles undergo in becoming meat, have not generally been considered, although it is increasingly recognized that their nature and extent may well determine the behavior of the meat.

It is important to point out that over-effective chilling of hot carcasses can lead to toughness. If the temperature of the meat (muscles) can be reduced to -10 to -15^{o}C, whilst they are still in the early pre-rigor condition (pH about 6.0-6.4), there is a tendency for shortening and thereby, toughness on subsequent cooking. This phenomenon is referred to as *"cold-shortening".* The tendency of cold shortening is greater when closer the temperature attained by the pre-rigor muscle is close to the freezing temperature.

The effect of irradiation on nutrients in meats and poultry has been the subject of considerable attention by researchers because they have been used as an argument against the approval and commercial application of this process. Most unreasonable aspect in this controversy is the consistent emphasis made on the detrimental effects of irradiation on food nutrients, including those in meat and poultry that has been reported to a large extent by the extrapolation of data gathered from the studies in which the selected, isolated nutrients were irradiated in model systems.

In terms of amino acid composition, high radiation doses such as those needed for sterilization (e.g. 25-27Kgy), do not change the content of cystine, methionine and tryptophan in beef, despite the fact that these amino acids are highly susceptible to damage by other processes. Data provided by Taub et. al. (1979) on the comparative effects of various processing techniques, including irradiation, on the amino acid content of beef are presented in Table No. 2.

Various studies have been conducted which indicate the effect of processing on vitamins especially, thiamine. In one study, which compared the effects of ionizing radiation and of conventional thermal processing on the thiamine content of enzyme–inactivated ground pork, concluded that sterilization by conventional thermal processing caused thiamine losses in pork were comparable to or greater than those caused by radiation sterilization.

Another study examined the combined effect of irradiation, storage and cooking on the thiamine content of minced pork. The pork was treated at 1Kgy while packaged in polyethylene bags at ambient temperature, followed by storage at 0^oC for 8 months, with or without heating for 10 minutes at 100^oC or 30 min at 200^oC before irradiation. The following results were obtained. Thiamine losses in unheated pork immediately after irradiation were 5%, whereas losses during refrigerated storage at 0^oC were no different from those in the non-irradiated samples. Heating pork at 100^oC for 10 minutes before irradiation had little additional effect on thiamine losses exhibited by unheated, irradiated samples.

Check Your Progress Exercise 2

1. State whether the following statements are True or False. Correct the false statements.

a) Low temperature and aging are the factors that lower the viscosity of milk.

----

b) Autoclaving milk has no effect on milk.

----

c) Heating milk to high temperatures gives it a cooked flavour.

----

d) An important milk protein, casein, on boiling remains stable.

----

e) The surface tension of milk is independent of fats and proteins.

----

f) High radiation doses have no effect on amino acid composition of meat.

----

g) Radiation sterilization leads to increased thiamin losses in pork than conventional thermal processing.

----

h) Thiamin losses were similar in refrigeration at 0^oC and in non-irradiated samples of minced pork.

----

2. Fill in the blanks:

a) The major component of the film formed on heated milk is -------------------- .

b) ……………… delay oxidation of fat in milk or cream heated to high temperature.

c) On frozen storage, the stability of caseinate progressively-------------------------- .

d) ………… increases surface tension of milk while ………………… decreases it.

e) Mechanical agitation greatly affects the viscosity of …….milk but has no effect on ……… milk.

3. Give reasons:

a) Browning caused in heated milk--

----

b) Cooked flavour in milk---

----

c) Freezing alters properties of milk---

----

4. What do you understand by the term 'cold shortening'?

……………………………………………………………………………………

……………………………………………………………………………………

9.6 ALTERATIONS OCCURRING IN FISH

The skeletal muscle of fish consists of short fibers arranged between sheets of connective tissue. The connective tissue in the fish muscle is less than that in mammalian tissue and the fibers are comparatively shorter. The tissue has different physical properties which results in a more tender texture of fish compared with meat. The myofibrils of fish muscles have a striated appearance similar to that of a mammalian muscle and contains the same major proteins, myosin, actin, actomyosin and tropomyosin.

Fish actomyosin has been found to be quite labile and easily changed during processing and storage. During frozen storage, the actomyosin becomes progressively less soluble and the flesh becomes increasingly tougher. Fish proteins are particularly susceptible to destabilization during freezing and frozen storage. After freezing, the fish may become tough, rubbery and lose moisture.

Studies on the effect of heat processing on fish indicate that the dietary value of protein seems not to be significantly affected by exposure to canning time/temperature processes. Infact, some proteinaceous components that would otherwise be plate-waste, like salmon and sardine bones, are softened enough to become edible. The heat denaturation of protein causes water losses varying from 9 to 28%, dependent on the severity of the process/pre-process, species, pH and other physiological factors.

Textural changes due to heat processing are also inevitable and may be advantageous to a limited degree. Excessive protein denaturation and the accompanying decrease in the water-holding capacity of the structural components yield a product with a dry and chewy mouth-feel. However, the oily-fleshed fish exhibit less of these effects, due to the restrictive effects of the lipids on water migration. Choice of raw material is important in this context, with less fresh fish losing more water and therefore, showing greater textural deterioration after processing.

We have already studied about browning in the section of fruits and vegetables. Can you recall which components were responsible for the reaction? Well, yes, sugars and amino acids. In case of fishes too, presence of sugars and amino acids may be responsible for the Maillard-type reactions during heat processing.

Proline is a prominent amino acid found in fish and may contribute to sweetness. The sugars ribose, glucose and glucose-6-phosphate are flavour contributors, as is 5-inosinic acid, which contributes a meaty flavour note. Volatile sulfur compounds contribute to the flavour of fish; hydrogen sulphide, methylmercaptan and dimethylsulfide may contribute to the aroma of fish.

Browning in canned fish is commonly associated with ribose. Undesirable colour changes in shellfish during canning often involve metal ions, for example, the blue discoloration of crab meat involves iron, whereas a black discoloration in prawns relates to copper content. Eels, abalone and albacore tuna; all undergo discoloration on processing, due to the high iron content of the raw material. Discoloration of this type is increased when the material is held in frozen storage prior to canning, because of the build-up of free sulphur in the tissue. Iron and free sulphur react together during heat processing, precipitating black iron sulphide on the sides of the container, in the fish itself and especially in any free liquid.

Slight losses of B-group vitamins, thiamine, riboflavin, nicotinic acid, folic acid and cyanocobalamine have been revealed in comparisons between fresh and canned fish.

Do you know what factors lead to spoilage of fish flesh? A difference in the composition of tissues among different species, climate, procurement and holding practices are amongst few of the important factors that lead to spoilage of fish.

Spoiling fish flesh, which becomes subject to excessive autolysins, may yield a heat-processed product with a pitted or honeycombed texture, although a restricted degree of proteolysis prior to processing, may result in a desirable softening of the texture of the finished product.

9.7 ALTERATIONS OCCURRING IN EGG

The quality, flavour, composition and functional properties of eggs are adversely affected more rapidly and to a greater extent by the speed and conditions of handling, uncoated shells, storage times and temperatures.

The nutritive value of frozen and dried eggs is essentially the same as that of fresh eggs. The drying or freezing processes do not cause any significant loss of nutrients. Properly stored, dried and frozen eggs show no subsequent nutrient loss. This observation can be substantiated by the following facts.

A comparison of hard-cooked and scrambled eggs showed that none of the methods had an advantage with respect to thiamine content. However, scrambled eggs had about 20% less riboflavin than hard-cooked eggs. The loss of threonine (an amino acid), was the same (0.22%) for both cooking methods.

Drying of eggs under normal conditions causes little loss of the nutritional properties of the eggs. Vitamin A, vitamin B, thiamine, riboflavin, pantothenic acid and nicotinic acid have been determined in dried whole egg and found to be essentially the same as that in fresh egg product. The protein value of dried eggs remains essentially unchanged. Adverse drying conditions or poor storage conditions could damage nutritional properties. However, any egg product without any off-flavour will probably have all its nutritional properties.

Generally speaking, egg products do not lose their heat coagulating properties during drying. If drying conditions are too severe, or if the storage conditions are adverse, whole egg and yolk products can lose solubility and this loss in solubility will coincide with a loss of heat-coagulating properties. One manifestation of excessive heat in drying of plain whole egg and plain yolk is an increase in their viscosity on reconstitution. Change in viscosity of dried plain yolk is much greater than in dried plain whole egg. Viscosity increase in the whole egg and yolk products can also be observed during storage. Reconstituted viscosity increases quite rapidly at the temperatures above 100^{o} F.

The density of egg products is not affected by dehydration. When a dried egg product is reconstituted to its natural solids, it has about the same density as the liquid, from which it was dried. Bulk density of the dried egg product can vary considerably, depending upon the methods and conditions of drying. Pan-dried egg products are much higher in bulk density than their spray-dried counterparts. Freeze-dried egg products are lowest in bulk density.

The changes in functional properties noted above, are undoubtedly caused by the changes that occur in the chemical properties of the various components of the egg. As you are already aware, the major component of egg white is proteins. Thus, any changes that occur in egg white during drying are apparently caused by changes in these proteins. Denaturation and coagulation of the proteins are considered to be the chemical changes, since they involve the unfolding of proteins, which exposes certain chemical groups, such as the sulfhydryl group, thus altering the chemical reactivity of the proteins. Since water is an integral part of the protein molecule, its removal may cause certain changes to occur in the properties of egg white.

The presence of glucose in eggs can cause chemical changes during drying, as well as during storage after drying. In egg white, the reaction involves the reducing or aldehyde groups of glucose and the amino groups of the proteins (Maillard reaction). This reaction results in the development of brown colour and a reduction in solubility. The reaction is minimized by drying to low moisture content and at lower pHs. Because glucose constitutes about 4% of the solids in egg white, almost all egg white that is dried, has had the glucose removed before drying.

The changes that occur in egg-yolk and yolk-containing egg products are apparently even more complex than those in the egg-white. Changes in yolk and whole egg product can also be caused by the reaction with glucose. In this case, glucose can react with the amino groups not only in protein but also in cephalin. The reaction with cephalin causes the development of off-flavours and off-odours during storage. The reaction can be prevented by the removal of glucose and is also inhibited by the addition of carbohydrates like sucrose.

The changes in viscosity of plain egg yolk and whole egg, as indicated previously, are apparently due to the changes in the lipoproteins. The lipids make up approximately 45% of whole egg solids and 60% of yolk solids, and thus play a predominant role in changes during drying. Of the lipids in egg yolk, 62% are glycerides, 33% phospholipids and 5% cholesterol. Of the phospholipids, lecithin is 73% and cephalin is 15%. The oxidation rate of cephalin is extremely rapid, being approximately 100 times that of lecithin. These phospholipids are bound together with protein and water is an essential part of this association. When water is removed, the balance is changed. In general, it is difficult to remove water from lipoproteins without causing changes in their properties.

Gelation, which occurs when yolk is frozen and thawed, is apparently due to the aggregation of yolk lipoproteins because of the imbalance and shift in water. Carbohydrates prevent increase in viscosity of yolk during drying and after drying and storage.

Check Your Progress Exercise 3

1. Fill in the blanks:

a) The myofibrils of fish contains proteins, namely ……………., …………………. , …………………… and ……………………… .

b) On freezing, the fish becomes ……………. , ……………. and …….…….. .

c) Comparison between canned and fresh fish reveal differences in the loss of …………………..

2. State True or False. Also correct false statements.

a) Drying or freezing egg has no effect on the nutritive value of egg.

----

b) Hard cooked eggs were found to have greater thiamine content as compared to scrambled eggs.

----

c) Eggs lose their heat coagulating properties on drying.

----

d) Changes occuring in egg-white is caused due to presence of proteins in it.

----

e) Lipoproteins are responsible for causing changes in the viscosity.

----

3. How is Maillard reaction occuring in egg-white different from that in egg-yolk?

----

4. What do you understand by the term 'Gelation'?

----

5. What is the effect of heat processing on fish?

----

6. Explain the process of browning in canned fish.

9.8 ALTERATIONS OCCURING IN CEREAL & CEREAL PRODUCTS, LEGUMES

You are already aware of the chemical composition of cereals and pulses. We will now look into changes occurring in these food products due to processing and storage.

We all know that cereals can be stored without loss of quality for 2 to 3 years, provided that the kernel moisture content (which is 20-24%) after threshing is reduced to at least 14%. The kernel consists of four parts: the seed coat (pericarp), the fruit coat (aleurone layer), the endosperm and the germ, or embryo. Figure 9.1 depicts these four parts.

Figure 9.1: Cereal grain

The aim of milling (the process including crushing and grinding) is to obtain preferentially a flour, in which the constituents of the endosperm cells predominate. The outer part of the kernel, including the germ and aleurone layer is removed. During milling of the wheat kernel, 5-8% of the starch granules are mechanically damaged. The extent depends both on the type and intensity of milling and on the hardness of the kernel - harder the structure (of the kernel), greater the damage. Since the rate of water absorption during dough making and the enzymatic degradation of starch increases with increasing damage, these are important for the baking process and desirable to a limited extent.

The chemical composition of the flour depends on the milling extraction rate. Increasing the rate of flour extraction decreases the proportion of starch and increases the amount of kernel-coating constituents such as minerals, vitamins and crude fibre. Comparing products of the same extraction rate, rye flour contains higher proportions of both minerals and vitamins than wheat flour. In case of some B-vitamins, such as niacin, this difference is well-balanced by the higher concentrations in wheat in comparison to rye kernels.

The commercial product, semolina, is made from the endosperm cells of hard durum wheat. Semolina keeps its integrity during cooking and is used mostly for pasta production. Since semolina is a milled flour of low extraction rate, it contains few minerals and vitamins.

During baking, the vitamins of the B-group are lost to different extents. In white bread, the losses amount to 20-50% of the thiamine, 6-14% of riboflavin and 0-15% of pyridoxine. The foamy texture of dough is changed into the spongy texture of crumb by baking. Starch degrades to dextrins, mono- and disaccharides at the relatively high temperatures to which the outer part of the dough is exposed. Caramelization and non-enzymatic browning reactions also occur, providing the sweetness and colour of the crust. The thickness of the crust is dependent on the temperature, baking time and type of baked products.

Substances that have high aroma values are of importance in white bread crust and crumb. In the crust, two heterocyclic compounds, furanol as well as 2-and 3-methylbutanol are responsible for the roasty, malty and caramel notes, while the autoxidation products of linoleic acid- methional and diacetyl are involved in the aroma of the crumb. If the dough is fermented for a longer time, 3-methylbutanol and 2-phenylethanol, which are formed by yeast, increase rapidly in the crumb and are responsible for the "yeasty" flavor impression.

Next, let us look at the changes occurring during milling of rice.

Rice milling involves the following processing steps: rough rice (paddy rice) → hull removal → brown rice → polishing to remove the bran coats (fruits and seed coats), the cuticle, the germ and the aleurone layer → rubbing–off or rice polishing to obtain the end product, white rice.

White rice, in comparison to brown rice, is low in vitamin content and in minerals as is evident from Table 9.1.

Table 9.1:Vitamin content of raw, white and parboiled rice

	B-Vitamins (mg/kg)		
	Thiamin	**Riboflavin**	**Niacin**
Raw Rice	3.4	0.55	54.1
White rice	0.5	0.19	16.4
Parboiled rice	2.5	0.38	32.2

A nutritionally improved product may be obtained by a parboiling process, originally developed to facilitate seed coat removal. About 25% of the world's rice harvest is treated by the following process:

Raw rice → steeping in hotwater, steaming in autoclaves, followed by drying and polishing → parboiled rice.

This parboiling treatment causes the following changes: the starch gelatinizes, but partly retrogrades again during drying. Enzymes are inactivated by the heat, causing inhibition of the enzymatic hydrolysis of lipids during storage of rice. The oil droplets are broken and lipids partly migrate from the endosperm to the outer layers of the rice kernels. Since antioxidants are simultaneously destroyed, parboiled rice is more susceptible to lipid peroxidation. In contrast, minerals and vitamins diffuse from the outer layers to the inner endosperm and remain there after the separation of the aleurone layer. Parboiled rice has a better cooking quality and there is a lack of pastiness in the cooked rice.

Now, let us look into certain alterations occurring in legumes due to processing. Toxic substances (e.g., cyanogenic glycosides and anti-nutritive factors, such as proteinase inhibitors, lectins etc.) present in some legumes, can be destroyed by suitable processing procedures, like heating.

The softening of legumes during cooking is due to the disintegration of the cotyledonous tissue in individual cells. This is caused by the conversion of native protopectin to pectin, which quickly depolymerizes on heating. The middle lamella of the cell walls, which consists of pectins and strengthens the tissue, disintegrates in this process.

Conversely, the hardening of legumes during cooking is due to cross linkage of the cell walls. The following reactions which can start even during storage at higher temperatures are under discussion as the cause of cross linkage. Calcium and magnesium phytates included in the middle lamella are hydrolyzedby the phytase present. Apart from meso-inositol and phosphoric acid, Ca2+ and Mg 2+ ions also released, cross link the pectic acids and thus strengthen the middle lamella. Pectin esterases, which demethylate pectin to the acid, promote the hardening of the tissue. In the case of legumes that are relatively rich in phenolic compounds and polyphenol oxidases, the formation of complexes between proteins and polyphenols should contribute to the strengthening of the tissue.

Sprouting of legumes causes partial breakdown of starch and proteins and contributes to better digestibility. The special flavour associated with sprouted legumes is an added advantage. It has been shown that sprouting causes hydrolysis of the oligosaccharides, which are responsible for causing flatulence of legumes.

9.8 ALTERATIONS OCCURRING IN NUTS, OILSEEDS AND SPICES

Some oilseeds have acquired a great significance in the large-scale industrial production of edible oils. You have already studied that most fats and oils consist of triacylglycerols which differ in their fatty acid compositions to a certain extent. Other constituents are the unsaponifiable fraction which make up less than 3% of fats and oils and a number of acyl lipids, e.g., traces of free fatty acids, mono- and di- acylglycerols.

Soybean and peanut (or groundnut) oils are of great economic importance. Refined soybean oil contains branched furan fatty acids in low concentrations which are rapidly oxidized on exposure to light. This can lead to the production of the intensive aroma substance, 3-methyl–2,4-nonandione, which along with diacetyl is involved in the occurrence of "bean-like, buttery, hay-like" aroma defect, called as *reversion flavor*. In the complete absence of light, soybean oil is relatively stable. The shelf life of the oil is also improved significantly by partial hydrogenation to give a melting point in the range of 22-28^{o}C or 36-43^{o}C. Such oils are utilized as raw materials for the manufacture of margarine and shortening.

Processing of fats and oils is significant in the removal of undesirable components present in the raw material. Refining process comprises of lecithin removal, degumming, free fatty acid removal, bleaching and deodorization to remove contaminants.

Now, we move on to the spices. You are aware that some plants in dried or in fresh form, with intensive and distinctive flavours and aromas are used as seasonings or spices. The aroma substances in most spices are present as essential or volatile oils, which are obtainable by steam distillation. The main oil constituents are either mono- and sesquiterpenes or phenols and phenol ethers. Black pepper contains 3-8% of piperine as the most important pungent substance. Pepper is sensitive to light. In the processing and storage of ginger, gingerol gets easily dehydrated to shogaol, increasing the pungency.

Spices are marketed unground or as coarsely or finely ground powders. The flavour is improved when the spices are ground using a cryogenic mill. After grinding, the shelf-life of spices is limited. Crushed spices rapidly lose their aroma and absorb aromas from other sources. Leaf and herb spices are dried before they are actually crushed. The loss of aroma substances depends on the spice and on the drying conditions. With regard to the aroma preservation, the best results are obtained by freeze drying, when the water content is reduced to 16%.

Check Your Progress Exercise 4

1. Fill in the blanks:

a) Cereals can be stored without loss of quality if kernel moisture content is reduced to atleast ------------------- .

b) The extent of milling damage depends on ------------------- and -----------------------

c) Semolina is made from --- .

d) ---------------, ------------- and ----------------- contribute to the roasty, malty and caramel notes of crumb.

e) Fermentation of the dough for a longer time leads to the formation of ----------------------------- and ------------------------- .

2. How does chemical composition of flour varies with the milling extraction rate?

----

3. What are the changes that occur during :

a) baking of cereals

----

b) storage of bread

----

c) sprouting of legumes

----

4. What are the factors leading to softening and hardening of legumes during cooking?

----

5. Explain 'reversion flavor' in oils.

9.9 LET US SUM UP

In this unit, we studied about chemical, physical and nutritional changes that occur in foods during processing and storage. These alterations were discussed among a variety of food groups such as fruits and vegetables, milk and milk products, meat and poultry, fish, egg, cereal, cereal products and legumes, and nuts and oilseeds. A number of processes that occur as a result of such alterations were also dealt with, such as browning, caramelization, gelation etc.

You have also learnt about the perspective of food processing in the current scenario, that is, you came to know of the various desirable and undesirable changes that occur during processing of foods.

9.10 GLOSSARY

Autolysins : A substance, such as an enzyme, that is capable of destroying the cells or tissues of an organism within which it is produced.

Blanching : The process of exposing a food product to either steam or hot water for a short time, before being placed in packages and frozen or dried.

Browning : A chemical reaction that takes place between amino group and the sugar.

Canning : A process of preserving foods by sealing them in an air-tight vacuum containers for future use.

Cold Shortening : a phenomena in which there is a tendency for shortening of meat muscles and thereby toughness on subsequent cooking.

Cold shortening : A phenomenon, whereby, there is a tendency for shortening and toughness of meat muscles, when stored at a temperature of -10 to -15^{o}C.

Convenience foods : Any packaged dish or food that can be prepared quickly and easily as by thawing or heating.

Cryogenic Freezing : The freezing at very low temperatures, in which the products are exposed to sprays of liquid nitrogen or carbon dioxide at temperatures of minus 150 degrees F or below.

Dehydration : Complete removal of water under controlled conditions, in such a way that minimal changes occur in the food item.

Food processing : The process in which the perishable food materials are given a suitable physical or chemical treatment.

Freezing : Foods maintained in a frozen condition at a temperature of about -18 degrees C or below.

Gelation : Process of formation of a gel from a solution; solidification; solidifying of a liquid matrix due to internal bonding.

Homogenization : The action of making something uniform in composition.

Irradiation : The physical process of exposing an object, system, or a material to a high radiant energy for the sterilization or preservation.

Pasteurization : The act or process of heating a beverage or other food, to a specific temperature for a specific period of time in order to kill microorganisms that could cause disease, spoilage, or undesired fermentation.

Radiation Sterilization : The process of sterilizing carried out by means of radiation.

Reversion flavor : The rapid oxidation of branched furan fatty acids on exposure to light, leads to the production of an intensive aromatic substance, which along with diacetyl contributes to the bean-like, buttery, hay-like aroma defect.

Sterilization : The physical process of killing microorganisms, including pathogenic and the bacteria, vegetative forms and other spores on or in an inanimate object or material.

Sulfhydryl compounds : Compounds with a-SH group, found in many plant and animal enzymes.

Surface Tension : A state of stress at the surface of a liquid due to the attraction of the molecules for each other.

Syneresis : The separation of liquid from a gel that is caused by contraction or spontaneous shrinking.

Thawing : A process whereby heat changes something from a solid to a liquid.

Viscosity : It is the resistance to flow.

9.11 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1.

a) Cellulose; pectic substances

b) Starch

c) Anthoxanthins and anthocyanins

d) Pectic substances, starch, intercellular air

e) Pectinesterase

2.

a) Dehydration: Reduces the natural water content below the level critical for the microbial growth, concentrates major ingredients such as proteins carbohydrates and minerals. It leads to degradation of fats, maillard reaction and drop in vitamin levels. Original volatile aroma and flavour compounds are lost.

b) Freezing: Preservation/ moderate loss of vitamin A and carotenes. No effect on B-Vitamins, Vitamin C leaching by water or steam is detrimental. Irreversible textural changes occur in deep frozen vegetables.

3.

$$C_{32}H_{30}ON_4Mg\left\langle\begin{matrix}COOCH_3\\COOC_{20}H_{37}\end{matrix}\right. + 2H^+ \longrightarrow C_{32}H_{30}ON_4H_2\left\langle\begin{matrix}COOCH_3\\COOC_{20}H_{31}\end{matrix}\right. + Mg^{++}$$

(Chlorophyll) (Pheophytin)

Check Your Progress Exercise 2

1.

a) False; Low temperature and aging are the factors that increase the viscosity of milk.

b) False; Autoclaving milk causes browning in milk

c) True

d) True

e) False; Surface tension of milk lowers with an increase in fat and protein

f) True

g) False; Radiation sterilization leads to decreased thiamine losses in pork than conventional thermal processing
h) True

2.

a) calcium caseinate
b) Sulfhydryl compounds
c) decreases
d) Pasteurization; Homogenization
e) Whole; skim

3.

a) Browning in heated milk: Heating milk to a higher temperature, such as 119^{0}C or higher leads to browning in milk. The brown colour is caused due to the heat effecting a change between the casein or amino acids and the sugar.
b) Cooked flavour in milk: Production of sulfhydrul compounds in milk at high temperatures leads to the formation of cooked flavour in milk.
c) Freezing alters the properties of milk: Freezing causes fat globules to lose their complete emulsion structure, to clump and become distorted and attain irregularity in shape and size. Casein, the milk protein gets precipitated as flakes.

4. Over-effective chilling of hot carcasses can lead to toughness. If the relationship between the refrigeration system and the bulk of meat exposed are such that temperature of muscles can be reduced below -10 to -15^{o}C, there is a tendency for shortening and thereby, toughness on subsequent cooking. This is referred to as cold shortening.

Check Your Progress Exercise 3

1.

a) Myosin, actin, actomyosin, tropomyosin
b) Tough, rubbery, lose moisture

c) B-group vitamins

2.

a) True

b) False; Hard cooked eggs had an equal Thiamine content as of scrambled eggs.

c) False; Eggs do not lose their heat coagulating properties on drying.

d) True

e) True

3. In egg white, the Maillard reaction involves the reducing or aldehyde groups of glucose and the amino groups of protein. While in yolk, the glucose reacts with the amino groups of not only protein but also in cephalin. This leads to development of off-flavours and off-odours during storage.

4. Gelation is a process which occurs when yolk is frozen and thawed. It is due to the aggregation of yolk lipoproteins because of the imbalance and shift in water.

5. No significant effect on the dietary values of protein, softening of certain proteinaceous component was observed as a consequence of heat processing. Water loss between 9 to 28%. Textural changes, excessive protein denaturation and decrease in the water-holding capacity.

6. Browning reactions occur in fish during heat processing. Sugars (ribose) along with amino acids are involved in browning reactions.

Check Your Progress Exercise 4

1.

a) 14%

b) Type and intensity of milling; hardness of the kernel

c) Endosperm cells of hard durum wheat

d) Heterocyclic compounds, furanol, 2- and 3- methylbutanol

e) 3- methylbutanol and 2- phenylethanol.

2. Increasing the rate of flour extraction decreases the proportion of starch and increases the amount of kernel coating constituents. Hence, varying the chemical composition of the flour.

3.

a) During the baking of cereals, there are losses of B-Group vitamins to different extent, B_1- 20 to 50%, B_2- 6 to 14% and B_6- 0 to 15%. The foamy texture of dough is changed into spongy texture of crumb. Degradation of starch to dextrins, mono- and disaccharides. Caramelization and non-enzymatic browning occur.

b) Storage of bread results in the moisture absorption which leads to loss in crispiness and glossyness of crust. Aromatic compounds of freshly baked bread evaporate. Changes in crumb structure are observed it becomes firm, loses its elasticity and juiciness.

c) Sprouting of legumes causes partial breakdown of starch and proteins and contributes to better digestibility. The special flavour associated with sprouted legumes is an added advantage. It causes hydrolysis of the oligosaccharides, which are responsible for causing flatulence of legumes.

4. The softening of legumes during cooking is due to the disintegration of the cotyledenous tissue in the individual cells. This is caused by the conversion of native protopectin to pectin, which quickly depolymerizes on heating. Hardening of legumes is due to crosslinkage of the cell calcium and magnesium phytates in the middle lamellae. Release of Ca^{++} and Mg^{++} with meso-inositol and phosphoric and cross links pectic acids and strengthen middle lamellae.

5. The rapid oxidation of branched furan fatty acids on exposure to light lead to production of the intensive aromatic substance, 3-methyl-2, 4-nonandione. This

alongwith diacetyl, contribute to the bean-like, buttery, hay-like aroma defect, which is called as reversion flavour.