

# EGGS

Although eggs of all birds may be eaten, the egg of chicken is used more often than any other. The natural function of an egg is to provide for the development of the chick. Its whole structure and composition are designed to fulfill this natural purpose.

## STRUCTURE

The different parts of an egg are shown in figure 6-a:

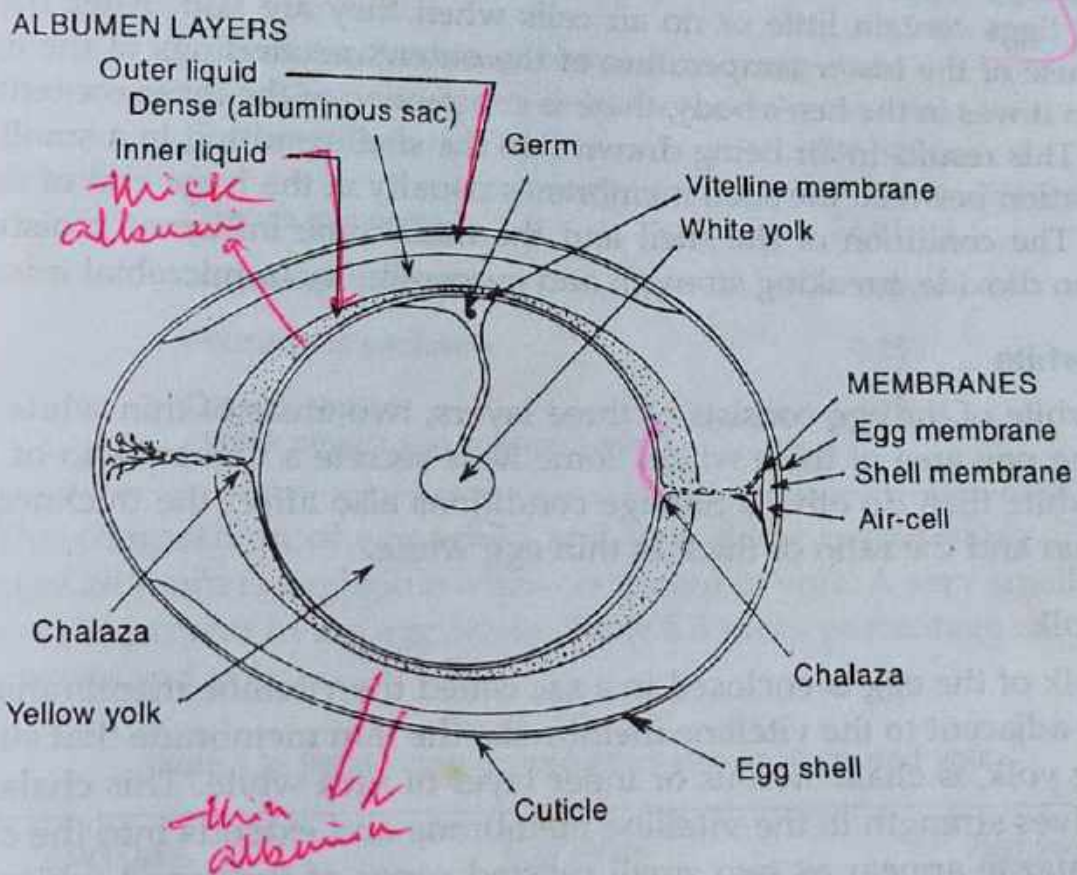


Figure 6-a: Different parts of an egg.

Source: Shakuntala Manay N. and M. Shadakshara Swamy, 2001, Foods, facts and principles, New Age International Publishers, New Delhi.

## Shell

It forms the protective covering of the inner contents of the egg along with the two membranes. Shell is made up of protein polysaccharide complex and calcium carbonate. An egg shell is brittle and easily breaks. Some shells are glossy others dull. Some may be smooth and others may be rough.

It is porous and contains thousands of small holes which allow gases to pass in and out of the egg for the developing embryo. The small holes are

covered with a thin layer of gelatinous material mucoprotein called cuticle or bloom. The cuticle seals off the pores of the shell to some extent and helps avoid an excessive evaporation from the inner contents of the egg. It also restricts the entry of microorganisms into the egg and thus protects the inner contents from various infections. The cuticle is soluble in water and easily removed by washing which results in hastening the deterioration of egg quality.

### Shell membranes

Within the shell are an inner and outer membrane that also protect the quality of the egg. Both the membranes are porous and composed of fibres. The outer membrane which is thicker (48  $\mu\text{m}$ ) than the inner one (22  $\mu\text{m}$ ) is firmly attached to the shell. The outer membrane has six layers of fibres, whereas, the inner one has three layers. The inner membrane is attached to the outer and the two membranes are loosely attached to one place usually at the broad end of the egg. The membranes are composed of protein and polysaccharide.

Eggs contain little or no air cells when they are laid. After being laid because of the lower temperature of the outer surroundings of the egg than when it was in the hen's body, there is contraction of the inner contents of the egg. This results in air being drawn into the shell resulting in a small air cell formation between the shell membranes usually at the large end of the egg.

The condition of the shell and the membrane influence moisture and carbon dioxide, breaking strength and susceptibility to microbial invasion.

### Egg white

The white of the egg consists of three layers, two areas of thin white encompassing one area of thick white. Some hens secrete a higher ratio of thick to thin white than do others. Storage conditions also affect the thickness of the albumin and the ratio of thick to thin egg white.

### Egg yolk

The yolk of the egg is enclosed in a sac called the vitelline membrane. Immediately adjacent to the vitelline membrane, the thin membrane that surrounds the egg yolk, is chalaziferous or inner layer of firm white. This chalaziferous layer gives strength to the vitelline membrane and extends into the chalazae. The chalazae appear as two small twisted ropes of thickened white, one on each end of the yolk and anchor the yolks in the centre of the egg. Chalazae appear to have almost the same molecular structure as ovomucin.

The yolk carries the indistinct germinal disc or germ spot which under suitable conditions develops into a chick. Beneath the germ spot extends a white part called latebra. The yolk itself is layered into sections of white and yellow yolk but they are not readily distinguishable.

In infertile eggs the female reproduction nucleus is not fertilised by union with the sperm of the cock. These are incapable of producing chicks and therefore called lifeless or vegetarian eggs. Infertile eggs are produced when a male bird is not kept with the laying hens.

## COMPOSITION

The distribution of weight of egg is given in Table 6.1:

Table 6.1: Percentage distribution of components of egg

Part	Weight
Shell	8-11
White	56-61
Yolk	27-32

## Egg shell

It is primarily calcium carbonate deposited in an organic matrix. The composition of egg shell is given in Table 6.2. This portion of the egg is inedible. *Protein & polysaccharide*

Table 6.2: Percentage composition of egg shell

Component	Per cent
Calcium carbonate	93.07
Magnesium carbonate	1.39
Phosphorus pentoxide	0.76
Organic matter (matrix protein and polysaccharide)	4.15

The composition of egg white and yolk differ considerably. The lipid content of albumin is negligible when compared to yolk. A very small amount of glucose is present in the egg white. Table 6.3 gives percentage composition of egg white and yolk.

Table 6.3: Percentage composition of egg white and yolk

Nutrients	Egg White	Egg yolk
Water	88.0	48.0
Protein	11.0	17.5
Fat	0.2	32.5
Minerals	0.8	2.0

## Egg white

Egg white is composed of thin and thick portions. 20-25% of the total white of

fresh eggs (1-5 days old) is thin white. The chief constituents of egg white besides water are proteins. Different types of proteins are present in egg white.

**Ovalbumin:** This constitutes 55% of the proteins of egg white. This is a phosphoglycoprotein and is composed of three components  $A_1$ ,  $A_2$  and  $A_3$  which differ only in phosphorus content. The relative proportion of  $A_1$ ,  $A_2$ ,  $A_3$  component is about 35:12:3. The carbohydrate component of ovalbumin are mannose and glucosamine in the ratio of 5:3. Ovalbumin in solution is readily denatured simply by mechanical agitation (whipping) but is resistant to thermal denaturation. At pH 9 and at 62°C only 3-5% of ovalbumin is denatured.

**Conalbumin:** This constitutes 13% protein of the egg albumin. It consists of two forms neither of which contains phosphorus nor sulphur. Conalbumin is more easily heat coagulated and less susceptible to surface denaturation than ovalbumin. The protein easily binds metallic ions such as iron, copper, aluminium, zinc forming heat stable complexes.

**Ovomuroid:** It is a glycoprotein. This constitutes about 10% of the egg white proteins. It exists in three forms and all of which are trypsin inhibitors. It is resistant to heat denaturation in acid media but is rapidly denatured in alkali solution.

**Ovomucin:** This protein is responsible for the jelly-like character of egg white and the thickness of the albumin. It contains 2% of the egg white. Its content in the thick layers of albumin is about 4 times more than in thin layers. It is insoluble in water but soluble in dilute salt solution. Purified ovomucin in solution is resistant to heat denaturation. It is a very large molecule with a filamentous or fibre-like nature.

**Lysozyme:** 3.5% of the egg white protein is lysozyme. This is an enzyme capable of lysing or dissolving the cell wall of bacteria. It is heat sensitive. Hen's egg white has three to four times more lysozyme than does duck egg white.

**Avidin:** This protein is 0.05% of the egg white protein. It is composed of 3 components A, B and C. It binds biotin and makes the vitamin unavailable. Avidin is denatured by heat and cooked eggs do not affect the availability of biotin.

**Ovoglobulin:** It is a protein consisting of two components  $G_1$  and  $G_2$  and both are excellent foaming agents.

**Ovoinhibitor:** 0.1% of egg protein is made up of ovoinhibitor. It is another protein capable of inhibiting trypsin and chymotrypsin. Summary of egg white proteins is given in Table 6.4.

## Egg yolk

Solid content of yolk is about 50%. Yolk is a dispersion containing a variety of particles distributed uniformly in a protein solution. On high speed centrifugation yolk separates itself into granules and a clear supernatant called plasma. Granules are composed of 70%  $\alpha$  and  $\beta$  lipovitellins, 16% phosvitin and 12% low density lipoprotein. Phosvitin, lipovitellin complex is a basic unit of granules. Plasma is composed of the globular protein livetin and a low density lipoprotein fraction.

The major proteins in egg yolk are lipoproteins which include lipovitellins and lipovitellin. The lipoproteins are responsible for the excellent emulsifying properties of egg yolk, when it is used in such products as mayonnaise.

Table 6.4: Proteins in egg white

Protein Isoelectric point	Type	Comment	Cooking properties
Ovalbumin pH 4.6-4.8	Fibrous	70% of white protein.	Readily denatures
Conalbumin	Globular	Interferes with absorption of iron.	Coagulated by heat
Ovomucoid pH 3.8-4.5	Glycoprotein	Trypsin inhibitor	Resistant to heat, denaturation in acid.
Ovomucin	Conjugated fibrous forms	Conjugated with carbohydrate structural basis of thick white	Resistant to heat denaturation, stabilises egg white foams.
Lysozyme pH 10.5-11	Globular	Natural bactericide protecting the egg from bacterial invasion.	It is heat sensitive, has foam forming property.
Avidin pH 10.0	Basic protein	Combines with biotin, render it unavailable.	Becomes inactive by cooking.

**Lipovitellins:** These are high density lipoproteins comprising 16 to 18% of egg yolk solids. They can be separated into two fractions  $\alpha$  and  $\beta$  lipovitellins. Each fraction contains 40% neutral lipids and 60% phospholipids.

**Phosvitin:** This comprises 5-6% of yolk solids. This is rich in phosphorus and accounts for 80% of the protein phosphorus of yolk. It is rich in serine and phosphate is esterified to this amino acid. Phosvitin binds tightly ferric ions and forms a soluble complex and is thus the iron carrier of the yolk.

**Livetin:** This comprises 4-10% of yolk solids. This consists of three components  $\alpha$ ,  $\beta$  and  $\gamma$  livetins. This is a water soluble protein and is rich in sulphur. Components of this protein differ in their molecular weight.

**Low-density lipoprotein:** Low-density lipoprotein of egg yolk has a density of 0.98. It consists of 74% neutral lipids and 26% phospholipids. It can be separated into components  $LDL_1$  and  $LDL_2$ .

A number of enzymes are also present in the protein fraction.

### Fat in the egg yolk

It contains triglycerides, phospholipids and lipoproteins. Lipoproteins are

complexed with phospholipids and cholesterol. The main phospholipids is lecithin. The main fatty acids in the triglycerides of the egg yolk are oleic, palmitic and linoleic and stearic in order. Table 6.5 shows fatty acid composition of egg yolk.

Table 6.5: Fatty acid composition of egg yolk

Fatty Acid	% of total fatty acids
C <sub>16</sub> : 0 Palmitic acid	23.5
C <sub>18</sub> : 0 Stearic acid	14.0
C <sub>18</sub> : 1 Oleic acid	38.4
C <sub>18</sub> : 2 Linoleic acid	16.4
C <sub>18</sub> : 3 Linolenic acid	1.4
C <sub>20</sub> : 4 Arachidonic acid	1.3

In view of the presence of highly unsaturated fatty acid in egg yolk fat, it is prone to undergo oxidation easily and develop off flavour.

Egg yolk viewed under the microscope is seen to consist of a relatively a small number of larger spherical bodies called granules and numerous smaller less regular shaped bodies called mycelles. Both granules and mycelles are suspended in the liquid or plasma portion of the yolk. Egg yolk does not contain free fat as such in spite of its high content of triglycerides. Instead most of the triglycerides and a high proportion of the phospholipids are found in the mycelles. Mycelles contain an encased layer of phospholipid surrounding a layer of protein. Thus these mycelles are in the nature of micro emulsion. Almost 90% of the fat of the egg is found in these mycelles.

## PIGMENTS

**Shell:** The colour of the shell is white in majority of the breeds. Sometimes it is in shades of brown, depending upon the breed. Colour does not indicate quality or the nutritive value.

**Egg white:** Egg white contains small amounts of ovoflavin due to which a greenish tinge can be seen. The more the riboflavin in the egg white, the greener is the colour.

**Egg yolk:** The colour of the egg yolk varies from a pale yellow to brilliant orange depending upon the amount and type of the pigment present in the diet of the hen. The colour is due to the presence of carotenoids and xanthophylls. The carotenoids can be converted into vitamin A in the body. Mostly deep coloured yolks are rich in vitamin A content. Xanthophylls are responsible for the yellow colour and are not converted to vitamin A. If the hen is fed with pure vitamin A, the yolk may be rich in vitamin A but there may not be any colour.

## NUTRITIVE VALUE

Eggs are rich source of all nutrients except ascorbic acid. Nutritive value of egg is given in Table 6.6.

Table 6.6: Nutritive value of egg/100 g

Nutrient	Amount	Nutrient	Amount
Energy kcal.	173.0	Carotene $\mu\text{g}$	600*
Protein g.	13.3	Thiamine mg.	0.1
Fat g.	13.3	Riboflavin mg.	0.4
Calcium mg.	60.0	Niacin mg.	0.1
Phosphorus mg.	220.0	Folic acid $\mu\text{g}$	78.3
Iron mg.	2.1	Vitamin B <sub>12</sub> $\mu\text{g}$	0.2

\* + 360  $\mu\text{g}$  of vitamin A. (0.6  $\mu\text{g}$  of carotene = 0.3  $\mu\text{g}$  of vitamin A)

### Proteins

Egg contains 12-14% proteins which are well balanced with respect to all the essential amino acids. Hence it is used as standard against which the chemical score of other proteins is compared.

The contents of two eggs provide nearly 25% of daily protein requirements of an adult man. Besides egg proteins have an excellent supplementary value to all other plant protein foods. For example, cereal proteins are poor in amino acid, lysine. Pulses and oilseed proteins are poor in sulphur containing amino acid cysteine. Hence a combination of egg with any of the cereal or cereal pulse mixture will enhance the protein quality of food.

Table 6.7: Nutritive value of proteins from different foods

Foodstuff	Biological Value
Egg	96
Milk	90
Fish	80
Rice	80
Meat	74
Bengal gram	74
Red gram	72
Wheat	66
Gingelly seeds	62
Ground nut	55
Maize	50

Source: Gopalan, C., B.V. Rama Sastri and S.C. Balasubramanian, 1999, Nutritive value of Indian foods, National Institute of Nutrition, Indian Council of Medical Research, Hyderabad-500 007.

The biological value of egg protein is the highest among the proteins from various foods.

### Fat

Egg is one of the richest sources of lecithin—a phospholipid which forms a part of the structure of every cell wall in the body. Besides contributing to energy it is the source of essential fatty acids, linoleic acid and arachidonic fatty acids. Vitamins A, D, and E are present in the yolk and egg fat also acts as the vehicle for these fat soluble vitamins. Egg fat is in highly emulsified form hence it is readily digested and absorbed.

On an average each egg contains 250 mg of cholesterol and the permitted intake is 300 mg of cholesterol per day. Three to four eggs per week can be consumed by normal persons without any adverse effect.

### Minerals and vitamins

There is a strong relationship between the mineral content of the hen's diet and the concentration of minerals in the egg. Calcium is the most abundant mineral in the whole egg but it is concentrated in the shell. Important minerals such as phosphorus, iron, zinc and other trace elements are present in the egg. Egg is a rich source of biologically available zinc. Egg iron is bound to conalbumin and poorly absorbed in man.

Except for vitamin C which is totally absent in the egg, other water soluble as well as fat soluble vitamins are present in the egg in appreciable amounts. Egg is particularly rich in vitamin A, riboflavin, folic acid and B<sub>12</sub>. The amount of these vitamins in the egg depends upon these nutrients present in the feed of the bird.

### Modifying nutrient composition

The nutritive value of the egg can be changed by manipulating the diet of the hen. Protein content cannot be changed much but addition of liquid oils to the hens diet, can increase the fat content of the egg. Exposure of the birds to sunshine or addition of vitamin D to the feed improves the vitamin D content of the egg. Vitamin D deficiency in the hen reduces egg output. Even cholesterol content of egg yolk can be reduced by feeding fish oil to the hen's diet.

No difference in nutritive value is noted between infertile and fertilised eggs.

### Effect of cooking on nutritive value of egg

By cooking egg there is little or no change in the nutritive value of protein, minerals or the fat soluble vitamins except there is some loss of thiamine and riboflavin. In hard cooked eggs, fried, poached and scrambled eggs the retention of riboflavin and thiamine is more than 85%. Heating egg white improves the availability of biotin as avidin gets denatured.

### QUALITY OF EGG

Egg is an excellent food 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 part 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 microorganisms. (Weak shells, rough handling results in damage to the shell. Good 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  $3/8$ 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 the 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.

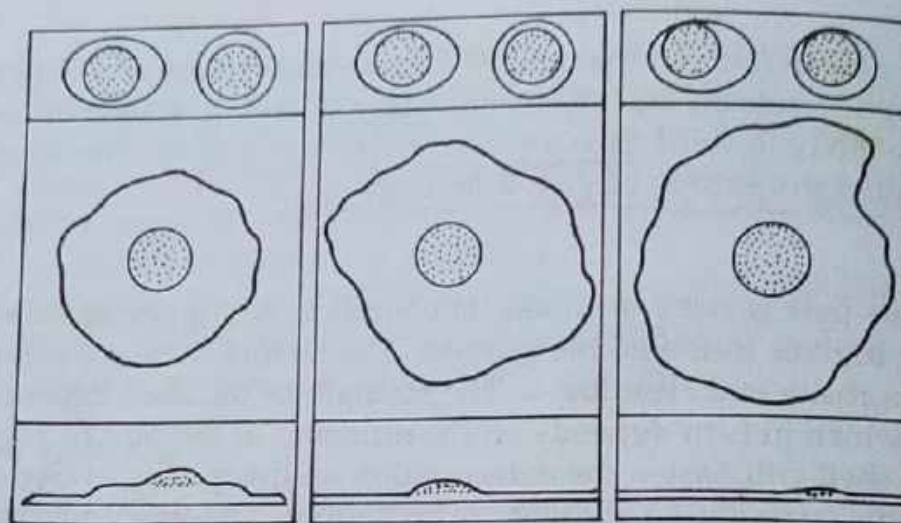


Figure 6-b: Quality of egg.

Source: Kinton Ronald and Victor Ceseram, 1989, The theory of catering, ELBS, Churchill Livingstone

### Chalazae

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

## EVALUATION OF EGG QUALITY

### Candling

The quality of the egg in the shell is evaluated by candling. The egg is held against a source of strong light. Candling will reveal:

- (a) a crack in the shell.
- (b) the size of the air cell.
- (c) the firmness of albumin.
- (d) the position and mobility of yolk and
- (e) the possible presence of foreign substances like blood spots, moulds and developing embryo.

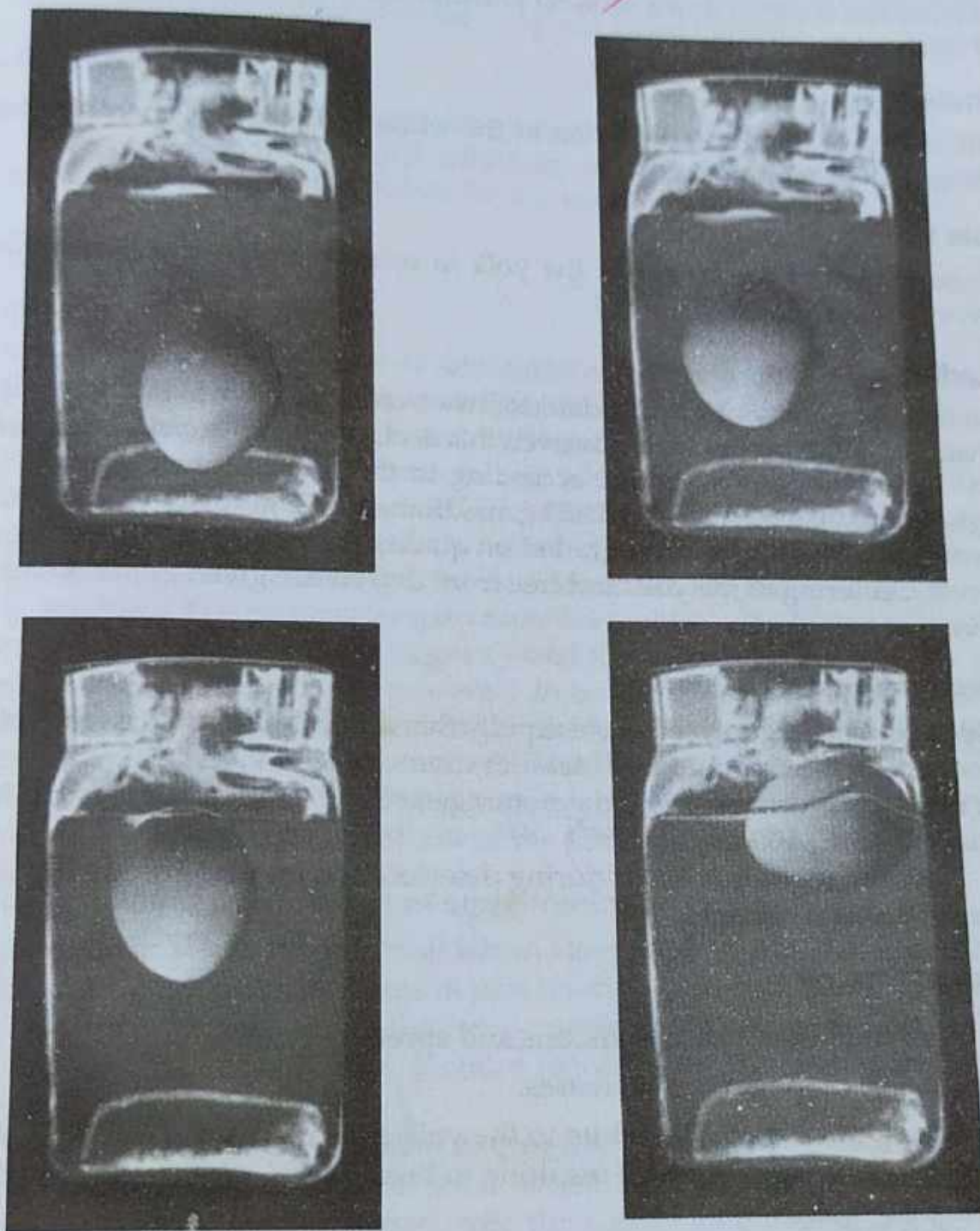
As the eggs deteriorate, the chalaza weakens and the yolk tends to settle toward the shell rather than remain suspended in the firm white. Under such circumstances the yolk is more fully visible when the egg is candled. Dark yolks cast a more distinct shadow than light coloured yolks.

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 eggs float due to increase

in size of the air cell and due to loss of moisture.)



**Figure 6-c: Floating test to evaluate the quality of egg.**

To test the freshness of an egg, plunge it into a 12 per cent solution of salted water: A fresh egg falls at once to the bottom; An egg 2 days old floats midway; An egg 4 days old rises to the surface; A 2-week old egg floats on top.

*Source:* New Larousse, 1983, *Gastronomie—The world's greatest cookery reference book*, Prosper Montague publishing group Ltd. Hamlyn, London.

### Haugh's Unit

Measurement of the height of the thick white in relation to the weight of the

egg gives haugh unit. Good quality egg has 72 haugh units and as the quality deteriorates it comes down to 36-60. Micrometer 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 minimised.

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 grade A and B in India.

### Deterioration 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 16°C, 100 days at 2°C.

These changes that occur during deterioration may be grouped as physical and chemical changes.

### Physical Changes

- Egg white becomes less viscous and spreads rapidly.
- The size of the air cell increases.
- 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

- Loss of water.
- Loss of carbon dioxide.
- Change in pH 7.6 to 9.7 in egg white.
- The breakdown of proteins.
- Increase in the amount of free ammonia.
- Increase in water soluble inorganic phosphorus.
- Increase in free fatty acid in yolk fat.

- Deterioration in the flavour of eggs occurs by the invasion of microorganisms and by the changes that take place in fat and protein.

### **Bacterial Decomposition**

As 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 microorganisms.

## **EGG COOKERY**

### **Effects of Heat**

Upon heating the egg proteins are denatured and then gradually aggregate to form a three dimensional gel network. The network is stabilised 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  $60^{\circ}\text{C}$  or  $140^{\circ}\text{F}$  with the white no longer able to flow near  $65^{\circ}\text{C}$ . Coagulation of the yolk begins near  $65^{\circ}\text{C}$  and the yolk no longer flows when the temperature nears  $70^{\circ}\text{C}$ . Heating on egg much beyond this temperature shrinks and toughens the coagulum of the white.

### **Factors affecting coagulation of egg proteins**

**Concentration:** The temperature at which egg proteins coagulate and the time required for coagulation depends 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 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 microstructure of egg yolk with stirring. The tiny discrete granules of the intact yolk may form a highly cross linked protein network 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  $85^{\circ}\text{C}$  that will produce a texture that is tender yet firm)

Oven temperatures from  $148.8-176.6^{\circ}\text{C}$  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 overcooked.

### Microorganisms

*Salmonella enteritidis* may infect the reproductive system of some laying hens, which may lay eggs contaminated with the organism. A possible danger might arise, therefore, from eating raw or lightly cooked eggs. Hence such egg preparation should not be served for infants and pregnant mother. At warm temperatures, microorganisms can increase rapidly which is why eggs should always be properly refrigerated.

### Effect of other ingredients on egg protein

**Sugar:** Addition of sugar to an egg mixture elevates the temperature at which coagulation takes place, the more sugar the greater the heat required to bring about the coagulation. The addition of sugar also increases the heat stability of the proteins.

**Salt:** The addition of salt to an egg mixture lowers the temperature at which coagulation takes place. Certain salts such as chlorides, phosphates, sulphate and lactates aid in gel formation in cooked egg mixtures. They may be added before or after heating. If they are added after heating, curdling may occur during the addition.

**Acids:** Any acid material added to an egg mixture coagulates more rapidly and produces a firmer gel and lower the coagulation temperature of the mixture. Prolonged heating of an acid egg mixture, however, will bring about peptidisation—breaking up of large aggregate of molecules into smaller ones resulting in thinning out of the mass and curdling. The hardness and cohesiveness of egg white gels have been reported to a minimum at pH 6 and increases as the pH is either decreased to 5 or increased to 9.

**Starch:** It is better to bring the starch mixture to its maximum thickness before adding the uncooked egg, because coagulation and gelatinization temperatures of egg and starch differ.

### BUYING AND HANDLING

The following points one need to remember while buying and handling eggs.

- Discard any broken ones.
- Refrigerate eggs immediately at  $4-7^{\circ}\text{C}$ .
- Purchase only the amount of eggs needed for 1-2 weeks.

- Cook eggs atleast until the whites are completely coagulated and the yolks begin to thicken and are no longer liquidy. Cook slowly over moderate heat.
- It is best to cook and serve immediately.
- Do not leave egg dishes at room temperature for more than one hour.

## 4. PRESERVATION / Processing

### Freezing

Egg breaking, separation and pasteurisation and freezing are the steps involved. Eggs are pasteurised to kill all *Salmonella* organisms. The usual pasteurisation practice for liquid whole egg involves heat treatment at 60°C and 62°C for not less than 3½ minutes. Increasing the acidity of the egg whites before pasteurisation seems to protect the proteins from damage to heat.

The functional properties of raw egg whites are not altered by freezing and thawing. Frozen egg yolks become viscous and gummy on thawing unless they are mixed with sugar, salt or syrup before freezing. Freezing process destabilises the surface of the tiny lipid protein particles (lipoprotein) in egg yolk. The fragments that are liberated then aggregate together on thawing to form a meshy type structure or gel. Cooked egg white is not stable to freezing and thawing. The gel structure of the coagulated protein is damaged by ice crystal formation. Syneresis occurs on thawing.

### Cold storage

Eggs are usually stored at -1.5°C to 0°C which is just above their freezing point. Only eggs of high quality should be stored. They remain in desirable condition only if the storage room is well controlled as to humidity, 85-90% circulation of air and free from objectionable odours. A controlled atmosphere of carbon dioxide or ozone is advantageous in maintaining quality.

Before being placed in cold storage, eggs may be dipped in light mineral oil. The thin film of oil left on the eggs partially closes the pores in the shell, reducing the loss of moisture and carbon dioxide. If the oiling process is done, usually upto twelve hours the pH of the egg will not rise appreciably on storage. This in turn minimises changes in egg white proteins particularly ovomucin and ovalbumin. It also retards the development of increased permeability in the vitelline membrane that surrounds the yolk.

Eggs can be stored satisfactorily in the home refrigerator for a few weeks. To retard moisture loss, the eggs should be stored in closed containers. Eggs broken out of the shell can be frozen for longer storage.

Eggs may retain quality as long as 6 months in cold storage.

### Drying

It is a satisfactory method for preserving eggs, either whole or as separated yolks or whites. Spray dried egg white and egg yolk have long shelf lives. To retain their functional properties, as well as good colour and flavour, dried

whites require treatment to remove the last traces of glucose. This helps to control the Maillard reaction during storage. Dried eggs keep best if the initial moisture content is low and if they are kept in a tightly sealed container. Low storage temperatures are also important in maintaining the quality of the dried products. For reconstitution dried egg should be sprinkled over the surface of luke-warm water, stirred to moisten and then beaten until smooth.

## RECIPES

### Soft and Hard Cooked Eggs

For a soft cooked egg, the white should be in the consistency of a soft quivery jelly and the yolk a thick liquid. This requires 3-5 minutes of cooking in boiling water. An addition of 2 minutes should be allowed if eggs are at refrigerator temperature. Or should be cooked at  $85^{\circ}\text{C}$  for 4-6 minutes.

Eggs hard cooked in a shell need to be cooked until the white changes to an opaque tender gel and the yolk becomes pale yellow and has a mealy rather than a pasty consistency. Eggs should be cooked at  $85^{\circ}\text{C}$  for 18 minutes or at  $100^{\circ}\text{C}$  for 8-10 minutes. Heat is transmitted from hot-water around the egg to the yolk through the coagulating white by conduction. To get the yolk hot enough to coagulate the surrounding white must be heated somewhat over cooked by the time yolk is fully cooked. The yolk can be hard cooked with minimum damage to the white if the water in which the egg is cooked is not above  $85^{\circ}\text{C}$ . If the temperature of the water is too low, cooking time is excessively long, the white is so tender that it is difficult to remove the shell without tearing the white and the yolk is waxy and has the colour of an uncooked egg.

In both the methods, eggs should be submerged in cold water for 5 minutes. Boiling for 20 minutes produces hard cooked eggs that are firm and exhibit strong egg odour and more off flavours.

**Ferrous sulphide formation:** The formation of dark greenish discoloration in hard eggs is due to iron and sulphur present in white and yolk. The percentage concentrations of yolk are 11 mg of iron and 0.016 mg sulphur and of white are 0.9 mg iron 0.195 mg of sulphur.

On heating hydrogen sulphide is liberated from sulphur containing proteins, which combines with the iron of the yolk and ferrous sulphide is formed. The amount of hydrogen sulphide evolved depends on time and temperature of heating and pH of the eggs.

The effect of temperature and period of cooking on the development of green colour on the surface of the yolk is given in Table 6.8.

From the Table it can be concluded that

- Even if the eggs are cooked for a long time there is no green colour if cooked at low temperature.
- When it is put in cold water, after cooking there is no green colour due to the diffusion of hydrogen sulphide gas at the surface of the cooling.
- If eggs are cooked for a long time and at a higher temperature ferrous sulphide ring formation occurs, even if cooled in cold water immediately.

Table 6.8: Temperature and period of cooking on ferrous sulphide formation

Temperature °C	Period of Cooking min	Colour of the surface of the yolk
70	60	No green colour
85	30	No green colour
100	15	Green discolouration
100	15 (cooled in cold water)	No green colour
100	30	Dark green colour
100	30 (cooled in cold water)	Dark green colour

Source: Swaminathan, M., 1992, Food science and experimental foods. The Bangalore Printing and Publishing Co. Ltd., Bangalore.

Eggs which have undergone deterioration during storage lose carbon dioxide, with the result there is increase in the alkalinity. High pH favours the production of hydrogen sulphide. In stale eggs there is more chance for ferrous sulphide ring formation.) *pH ↑ favours H<sub>2</sub>S formation*

To hard cook an egg with the minimum discolouration of the yolk a fresh egg should be cooked in water at simmering temperature followed by prompt cooling.

### Poached Eggs

Poached egg is made by breaking and directly putting the egg in boiling water. The egg is left in the hot water until the white is jelly like and uniformly coagulated and the yolk is semi liquid and covered by a thick coating of white. Ideally, a poached egg should be compact with no ragged edges. This needs an egg of top quality. The technique used to put the egg in water also influences the end product.

The addition of vinegar or salt to the cooking water hastens coagulation and hence may improve the shape of poached eggs, particularly having thin whites.)

### Scrambled Eggs

The yolk and white are blended with or without the addition of milk. The mixture is then heated to effect coagulation of proteins. The secret of making scrambled eggs which is moist but not watery, tender and fluffy, is to heat the mix slowly at the bottom of the pan as it coagulates. This prevents the cooked part being over coagulated and allows the uncoagulated part to contact the hot pan. Once the coagulum forms, further heating causes it to shrink and squeeze out more and more liquid and the product becomes dry. Cooking scrambled egg in a double boiler gives better control over the intensity of heat applied to the egg.

## Fried Eggs

The shape of a fried egg depends on the thickness of its white and on the temperature at which it is cooked. If cooked at too lower temperature i.e., 115°C it will spread excessively and if the temperature is too high 140°C it will be overdone. The ideal temperature to prepare fried egg is around 126-137°C.

## Custards

In custard, egg acts as thickening agent. A true custard consists only of eggs, milk, sugar and flavouring compounds. Custards are of two types, the stirred or soft custard which is given a creamy consistency by being stirred while it is cooking and the baked custard which is allowed to coagulate without stirring, thereby producing a gel. Recipe for custard is as follows.

Milk	1 cup
Eggs	1 - 1½
Sugar	25 g.
Vanilla essence	¼ tsp.

**Baked custard:** This is made at 350°F. It is done when the tip of a knife inserted halfway between the centre and outside, comes out clean. When a custard is over cooked, some clear liquid separates from the gel structure, that is syneresis occur. In an over cooked custard, the egg proteins that form the mesh like gel structure apparently shrink and squeeze out some of the liquid that was held in the mesh. Fruits, dry fruits and caramelised sugar can be added to give variety.

**Soft Custard:** Same ingredients are used as in baked custard. The vanilla, because of its volatility is added after the other ingredients are cooked. Custards that are cooked more slowly coagulate more completely at a lower temperature than custards that are cooked rapidly. There is less danger of curdling and both consistency and flavour are better in stirred custards cooked relatively slowly. The total cooking time, in a double boiler should be 12 to 15 minutes, heating more rapidly at first and then more slowly (70°C-75°C water temperature) while stirring thoroughly and rapidly should be done during the entire process. Stirring separates the coagulated particles, resulting in a creamy consistency. The custard will be thicker when it is cold. When the knife comes out coated, the end point has come.

Success in making stirred and baked custards depends on cooking just enough to coagulate the protein of egg. Excessive heat results in over coagulation and syneresis of protein characterised by curdling in stirred custards and in baked custards. Scalding (heating) the milk, used in custards shortens the cooking time and may also improve the product. Baked custards are better when made from milk pre-heated to 90°C than to 50°C. Custards cooked over rapidly boiling water thicken at 87°C and curdle at 90°C thus leaving a narrow margin of safety. However if the water in the bottom of the double boiler was cold when cooking started and was brought to boil slowly the custard

thickens at 52°C and curdles at 87°C. The consistency of a curdled custard can be improved greatly by pouring it into a cool dish and immediately beating with a rotatory beater.

The temperature at which gelation occurs depends on many factors.

**Proportion of ingredients:** The temperature required is higher than that required to coagulate the egg because the protein of egg is diluted with milk. The higher the proportion of egg to milk the lower the temperature at which the custard sets. But two egg yolks in the place of one egg raises the coagulation temperature. The protein of the egg is not readily denatured by heat when sugar is present. The sweeter the custard the weaker is the gelation at the given temperature.

**Rate of cooking:** When the cooking is rapid the margin of safety is reduced and curdling can occur easily.

**Acid:** Acid lowers the setting temperature. The acid supplied by the fruit in custards lowers the gelation temperature and it gets done sooner than one without fruit.

### Egg White Foams

The foaming of egg white plays an important role in many foods because it makes the products light in texture and contribute to leavening. Egg white foam is a colloid consisting of bubbles of air surrounded by albumin that has undergone some denaturation on the liquid air surfaces. This denaturation which is due to the drying and stretching of the albumin during beating makes some of the albumin insoluble thus stiffening and stabilising the foam. During denaturation the protein molecules unfold and their polypeptide chains lie with their long axis parallel to the surface. Over beating incorporates too much air, stretching the albumin so that it becomes thin and less elastic. Elasticity is needed especially in foams that have to be baked so that before the albumin is coagulated by the heat of the oven, the incorporated air can expand without breaking the cell wall.

The ease with which the egg white can be whipped to a fine foam with small air cells is attributed to the presence of ovomucin, ovoglobulin and conalbumin. Duck eggs which are deficient in globulin do not foam.

Table 6.9 shows the description and uses of egg white foams.

### Stability of the foam

Stability is measured by finding how much liquid drains from it on standing. This is usually done by transferring the foam to a funnel and measuring or weighing the liquid that drains from it. More the water drains means the foam is less stable.

### Factors affecting egg white foams

**Effect of beating time:** As the time of beating egg white is increased their volume and stability increase at first and then decrease. The actual time required depends on the type and speed of the beater. Higher the speed, shorter

the period of beating required. Maximum stability is reached before maximum volume.

Table 6.9: Characteristics and uses of egg white foams.

Stage	Description	Uses
Slightly beaten	frothy, slightly foamy, large air bubbles, transparent, flows easily	clarifying, coating, emulsifying and thickening.
Stiff foam	Frothy quality disappearing, air cells smaller, whiter, flows, very shiny, glossy and moist in appearance, if left to stand liquid separates out readily, when beater is withdrawn white follows forming rounded peaks.	meringues.
Stiff	Air cells small and white, glossy, smooth and white in appearance.	cakes, omelettes, ice-creams, souffles.
Dry	Very white but dull. Small flakes or curds beginning to show. Rigid and almost brittle. If left to stand liquid separates at the bottom slowly.	shirred egg.

**Type of beater used:** If the beater has thick blades or wires, they do not divide egg whites as easily as fine wires and the resulting air cells are therefore larger. Egg whisks sometimes give a larger volume of beaten egg mass than do rotatory types of beaters but the cells are larger.

**Type of container in which eggs are beaten:** Bowls with small rounded bottoms and sloping sides are preferable to bowls with large flat bottoms because, in the former, the beater can pick up the egg mass more easily. The size of the bowl must obviously be adapted to the amount of egg to be beaten. If whisks are used for beating egg whites, a large plate is preferable to a bowl for holding the whites because of the over-and-over strokes that are used.

**Temperature:** Egg white can be beaten more readily at room temperature than at refrigerated temperature possibly because of lowered surface tension at higher temperature.

**Thick and thin whites:** Thin whites can be beaten more readily and produce greater volume than thick white. Stored eggs may beat more quickly than those fresh eggs as in stored eggs the white is thin. Thick whites seem to produce a more stable foam even though thin whites may initially beat to a larger volume.

The volume of cooked products such as cakes and meringues is greater when thick whites are used rather than thin whites.

**Addition of acid:** Addition of acid to egg white makes the foam more stable but increases the time necessary for beating. Cream of tartar is more

effective in increasing the stability than acetic or citric acid) Acid is best added during the first portion of beating period. The addition of acid to egg white also makes the foam more stable to heat. e.g., meringue.

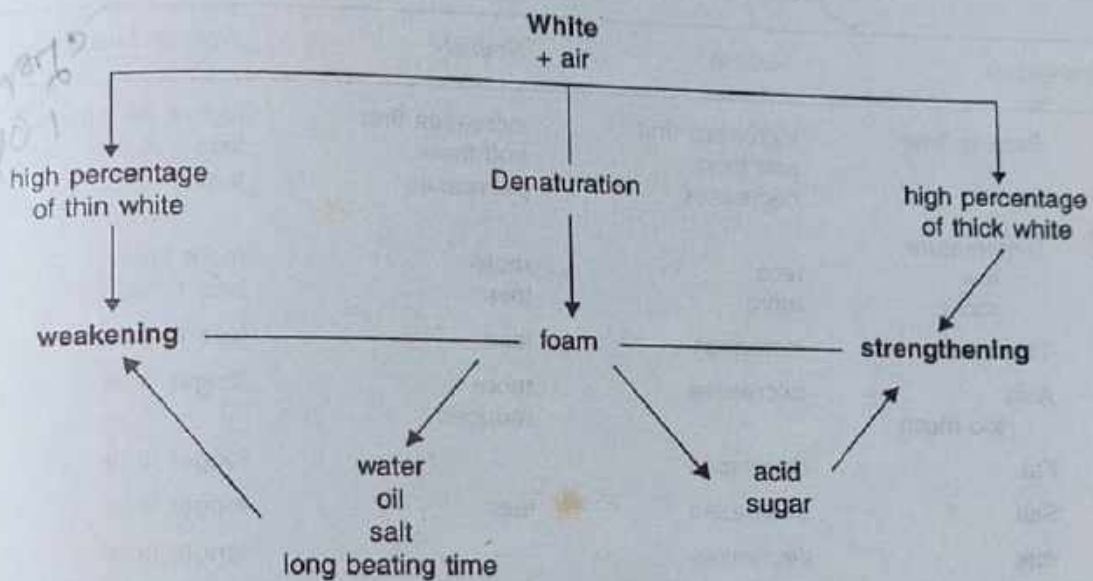


Figure 6-d: Factors affecting egg white foam.

Source: Robins G.V., 1982, Food Science in Catering, Heinemann, London.

**Addition of fat:** The presence of fat interferes with foam formation and decreases the foam. Similar effect is observed when yolk is added to white. This effect is the result of the fat probably the lipoproteins, in the egg yolk which may form a complex with proteins in the white.

**Addition of salt:** Addition of salt to egg white (1g to 40g egg white) or whole egg lowers the quality (volume and stability) of the foam as it becomes less elastic. The addition of salt to fresh egg white decreases the stability of foam unless the beating time is increased from 6-9 minutes. The addition of salt to whole eggs before beating results in a foam of small volume that would not form peaks. Sponge cakes made from such a foam has smaller volume and less tender when salt is added to the egg rather than adding salt to the flour.

**Addition of water:** Dilution of egg white with water upto 40 per cent of the volume of egg increases the volume of foam but decreases the stability.

**Addition of sugar:** If sugar is added before beating is started, extensive beating is needed to produce a foam. Once formed the foam is stable and very fine although the volume may be less. The shine of egg white foam with added sugar is in part to the prevention of coagulation of proteins with accompanying opaqueness. Once sugar is added to egg white beaten to a foamy stage to the soft peak or to the stiff peak stage beating can continue longer without the foam being over beaten. After sugar has been beaten into a foam it can stand for sometime without becoming coagulated and losing its elasticity. The foam can be manipulated and spread without rupturing the cells perhaps because sugar retards the denaturation of egg white.

Table 6.10 summarises the factors affecting volume, stability and time of beating of foams.

Table 6.10: Factors affecting foam formation.

Variations	Volume	Stability	Time of beating
Beating time	increases first and then decreases	increases first and then decreases	higher the speed lesser is the time.
Temperature			
low	less	more	more time.
room	more	less	less time.
Thin White	increases	less	less time.
Acid	decreases	more	longer time.
too much	—	reduces	—
Fat	decreases	—	longer time.
Salt	decreases	less	longer time
Yolk	decreases	—	longer time.
Water	increases	less	lesser time.
Sugar	—	less	longer time.

### Omelettes and Souffles

Omelettes and souffles are similar in that the main ingredients in both products is egg. Omelettes may be plain or foamy. The plain omelette is made without separating the yolk from white. The whole egg is beaten together with flavouring materials. The foamy omelette is prepared by beating the whites and yolks separately. The whites are beaten until stiff and then folded into the yolk mixture. For preparing foamy omelette the omelette should not be turned on the tawa but should be folded to preserve the air cells that are formed. Foamy omelettes puff up on cooking and they are light and have a better texture due to the incorporation of air. The centre of foamy omelettes would be soft and creamy with small bubbles of air.

For making an omelette, the heat should be kept low so that the mass cooks slowly and can be heated uniformly throughout without toughening the bottom layers. The coagulation of a puffy omelette may be finished in a moderate oven.

### Factors affecting omelette quality

- Sometimes green colour develops in the omelette. This is due to the formation of iron sulphide and when a part of the white separates and drains to the pan underneath the omelette. This can be prevented by beating the yolk with white thoroughly.
- Addition of liquid to egg dilutes the protein and increases the tenderness of omelette. Omelettes made with tomato or orange juice appear to co-

agulate more rapidly at a somewhat lower temperature. Acidic products like vinegar with water or tomato juice give more tender omelette than water. Addition of acid products increases the beating time. When milk is added to the egg the foam formation is not obtained properly hence the addition of milk affects the quality of omelette.

- Overbeating of egg results in loss of air from the foam and reduces the volume of omelette. The omelette becomes hard and leathery.

Variety in omelette can be made by using the following:

- Addition of onions, tomatoes, pepper, greens.
- Stuffed omelette —with vegetables.
- Cheese omelette.
- Addition of mutton and chicken gravy.
- Bread omelette.
- Egg dosa.
- Chapati omelette.

### Souffles

They are similar to foamy omelettes, except that they have a thick white-sauce base and contain additional ingredients such as grated cheese, vegetable pulp or ground meats. Dessert souffles are sweet and may contain lemon, strawberry and chocolate. Souffles are usually baked though they can be steamed. Crepes are thin, tender pan cakes containing a relatively high proportion of egg. They can be filled with a variety of items, including fish, meat, poultry, cheese, vegetables or fruits. Crepes can also be served with sweet, dessert type fillings.

### ROLE OF EGG IN COOKERY

There are few ingredients in food preparation that are useful in so many different ways as are eggs. Used alone or in combination with other foods, they may become the major protein dish for a meal.

- Eggs are used as boiled, scrambled or poached for table use.
- Used as a thickening agent —stirred custards and baked custards, soups, puddings. Help in gel formation.
- Emulsifying agent—mayonnaise, ice-cream.
- Leavening agent—cakes, foamy omelette, souffles, meringue. Egg white foam used in certain candies also improves the texture by controlling crystallisation of sugar.
- Binding and coating agent—cutlet, french toast or Bombay toast, banana fritters.
- Interfering substances—ice-creams.

Beaten egg white act as interfering substance in frozen desserts. Tiny bubbles of air trapped in egg prevent ice crystals from coming together and creating large masses of icy material.

- Clarifying agent—raw eggs can be added to hot broths and coffee. When protein in egg coagulates they trap the loose particles in liquid and clarify it.
- Garnishing agent—hard boiled eggs are often diced and used to garnish dishes.
- Flavouring agent—custards
- Enriching agent—to enrich the nutritive value e.g., Bombay toast.
- Glazing agent—for pastries to give the surface a golden brown colour when cooked.
- Improve colour—custards.

The changes in pH in the egg-white and yolk also result in the rupture of the vitelline membrane. The mixing of the yolk and albumen results in chemical disintegration and decomposition, producing an odour inside the egg. Unpleasant odours are also absorbed by eggs if care is not taken to prevent odours in storage areas.

The contents of newly-laid clean egg are usually free from contaminating organisms. During storage, microbial spoilage sometimes takes place. Micro-organisms may be drawn in through the porous shell, the most likely contaminants being the *Salmonella* species. The chances of microbial invasion are increased if the shell is dirty. Even if the micro-organisms penetrate the shell, the shell membranes, the alkaline pH of the egg, the bacteria lysing enzyme (lysozyme), the iron containing conalbumin, and the biotin binding avidin-resist their growth. However, heavy contamination overcomes the defence mechanisms and causes spoilage during storage.

In a fertile egg, the development of the germinal disc is arrested when the egg is laid. However, as soon as the egg is exposed to a temperature of 20°C or above, the embryo starts growing. The development of the embryo deteriorates the quality of the egg contents. At a temperature below 38°C, the growth of embryo is defective and it usually dies after some time. If the death of the embryo takes place before blood has been formed, a red spot appears at the place of the germinal disc (heat spot). This lowers the edible quality of the egg. If the death of the embryo occurs shortly after blood has been formed, a small red ring is produced at the surface of the yolk (blood ring). Eggs having blood rings or dead embryos are inedible.

#### 22.4.4 Egg Storage

i) Eggs subjected to varying temperatures deteriorate more quickly than eggs held at a constant temperature. Therefore, for household purposes eggs must be kept under refrigeration where they will keep well for 1–2 weeks. Storage of eggs at room temperature may cause a reduction in quality within one week.

ii) Egg production is not uniform throughout the year; there is more production during spring. The preservation of surplus eggs produced during the peak season for use during the lean season becomes necessary. For the preservation of eggs, control of temperature, humidity and sanitary conditions are necessary. Clean eggs maintained at a temperature of -1°C and a relative humidity of 80 per cent can be stored for as long as six months without any deterioration.

iii) Some lengthening of egg storage stability can be achieved by storing eggs under carbon dioxide to minimize carbon dioxide loss. A more common method of slowing deteriorative changes in eggs during storage is to spray them with some mineral oil, preferably containing some fungicides, before storage. The mineral oil should be very clean, colourless, odourless and tasteless to prevent flavour impairment or spoilage. The deposited oil film partially closes the pores of the shell, retarding the loss of moisture, and the rise in pH resulting from loss of carbon dioxide. Oils of vegetable or animal origin should not be used for spraying as they undergo oxidative rancidity during storage.

iv) Another method of prolonging storage life is by a process known as thermostabilization. This consists of heating the egg in water at a temperature of 54°C for about 15 min. or in boiling water for 5 secs. before storage. This treatment coagulates a thin layer of albumen around the inside of the shell and thus seals the pores from inside. The heat also kills some of the surface bacteria.

## 22.5 Egg Processing

### 22.5.1 Egg Freezing

Eggs, in addition to storage in the shell, may be preserved by freezing or by the drying of their contents. An egg cannot be frozen in the shell since the egg shell would crack with the expansion of liquids when frozen. Therefore, the whole of the liquid contents of the egg is frozen or it is separated into yolk and white, and frozen.

One of the important problems in freezing is the control of micro-organisms. To reduce contamination, the shells are usually washed just before the eggs are broken from the shell, and then freezing is done as quickly as possible. Because of the prevalence of *Salmonella*, which are pathogenic, it is better to pasteurize the white, yolk, or whole egg. Egg-white is very sensitive to heat, being easily coagulated very near the pasteurization temperature. By heating for 2 min. at 58°C, albumen becomes turbid and viscous and loses its foaming properties. Whole egg or yolk, in contrast, can be pasteurized at 60°–61.5°C for 3.5 to 4.0 min., without significant changes in physical and functional properties. The pasteurized whole or separated eggs are placed in cans or suitable containers and frozen in a sharp freezer room with circulating air at -29°C. Freezing may take from about 48 to 72 hours.

While frozen egg-white retains its qualities fairly well, yolk and whole egg cannot be frozen satisfactorily. On freezing, the yolk or whole egg becomes viscous and gummy, a condition known as "gelation" resulting in altered functional properties. Yolk gelation is due to the formation of ice crystals on the lowering of storage temperature to below -6°C (the freezing point of yolk is about 0.58°C). Freezing also reduces the distance between reactants, such as lipoproteins, which enhances their aggregation. This is prevented by the addition of sugar, salt, or corn syrup to the egg-yolk and whole egg before freezing. Sugared yolk is used satisfactorily in dessert products, confectionery and other products that tolerate sugar, while salted yolk is used in the manufacture of mayonnaise. By enzyme treatment with pepsin it is claimed that egg-yolk maintains functional properties during frozen storage.

### 22.5.2 Dried Eggs

Drying is another method of egg preservation and there is a demand for egg powder for the preparation of commercial egg products. The white, yolk or whole egg, after pasteurization, may be dried by any of the several methods of drying. The most common method employed for drying eggs is spray drying. The liquid egg is forced through an atomizer as a fine spray into a drying chamber through which hot air is blown. The powdered egg is cooled, collected and packaged.

Egg-white contains traces of glucose. When the dehydrated white or whole egg is stored at temperatures much above freezing, the glucose combines with egg proteins resulting in browning. To prevent this, glucose is to be removed with glucose oxidase or by fermentation with yeast prior to drying.

The functional properties of an egg are not adversely affected by drying. The heat coagulation properties remain practically the same. Dried eggs keep best when the moisture content is low and if they are kept in tightly sealed containers. Dried egg-white is quite stable during storage. However, objectionable changes in colour, flavour, odour and solubility occur when either dried yolks or whole eggs are held at temperatures higher than 5°C. A lower temperature retards the undesirable changes, until at -18°C when very little change occurs. Dried eggs may be reconstituted before use by mixing

with an appropriate quantity of water. The nutritive value of frozen eggs and dried eggs will practically be the same as shell eggs, if properly stored.

*Egg substitutes:* Because of the high cholesterol content of egg-yolk, several commercial egg substitutes have been introduced for a cholesterol-free diet. The basic principle of these substitutes is to eliminate the egg-yolk and to retain the natural egg-white. Various ingredients are added to egg-white to simulate whole fresh egg. Egg substitutes are available in fresh, refrigerated or frozen forms. The nutritional and caloric value of the substitute depend upon the ingredients. Though they are used in various products where the whole fresh egg is an ingredient, the result is not frequently identical to the product made using fresh egg. However, for some preparations like scrambled egg and French omelette they are found quite satisfactory.

*except egg yolk.*