Consortium for Educational Communication

Module on

Egg structure, composition and preservation

By

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Text

Introduction

Eggs are external reproductive structures within shells produced by the females of certain animals such as birds. Nature has created eggs for the multiplication of species. But man has exploited it as source of food. The eggs of various birds like hens, duck, geese, turkey etc. are consumed throughout the world. But, the eggs produced by hens are of major economic importance. An average chicken egg weighs about 57 grams. Eggs have been a human food since ancient times. They are one of nature's nearly perfect protein foods and have other high quality nutrients. Eggs are readily digested and can provide a significant portion of the nutrients required daily for growth and maintenance of body tissues. They are utilized in many ways both in the food industry and the home.

Structure of egg:

The avian egg is a complex and highly differentiated reproductive cell. An egg consists of shell, membrane, white or albumen, and yolk, and its structure can be seen with the naked eye or a lens. These are discussed as under for the hen egg:

(i). Shell: The egg is surrounded by a 0.2– 0.4 mm thick calcareous and porous shell. It contributes about 11% weight of the whole egg. It is composed of 94% calcium carbonate, 1% calcium phosphate, 1% magnesium carbonate and 4% organic matrix mainly protein. A transverse section through the shell clearly shows the existence of four layers namely cuticle, spongy layer, mammillary layer and outer shell membrane. Cuticle or bloom is a thin (10 μm) outermost layer consisting mainly of mucilaginous protein layer. The cuticle blocks the pores and protects the egg against outside contamination entering the egg. The spongy layer constitutes greater part of shell. This layer is actually very compact and is traversed by numerous microscopic channels. Mammillary layer is the innermost layer of shell adjusant to outer shell membrane. It is composed of numerous roughly conical knobs or mammille, which are oval to circular in cross section. The mammille are arranged in such a way that it creates spaces/ or pores within the shell.

There are numerous small apertures in the outer surface of the shell, leading to the pore canals, which penetrate to the inner surface. The concentration of pores is usually higher on the broader end where air cell is located than at the pointed end of the shell. The pores allow the oxygen necessary for respiration to diffuse in, and carbon dioxide and other waste gases to diffuse out through the shell during incubation. The colour of the hen egg-shell may vary from white to deep brown. It is due to pigment porphyrin. The depth of the colour is dependent largely on the breed of the hen and is not guide to egg quality.

(ii). Egg membranes: The inside of the shell is lined with two closely adhering membranes (48 and 22 μm, respectively). These are made up of an interwoven network of protein polysaccharide fibers. One of the membranes is attached to the shell while the other is not and moves with the egg contents during separation. The air cell is formed at the broader end of the shell as the egg membranes separate from each other due to shrinking of egg contents.

(iii). Albumen (Egg White): Albumen is a aqueous solution (10%) of different proteins. Besides proteins other components are present in low amounts. Albumen is a pseudoplastic fluid. Its viscosity depends on shearing force. It consists of four concentric layers. The very firm but very thin chalaziferous layer immediately surrounds the yolk and is continuous with the chalazae. It forms 3% of egg white. Chalaze are dense, cordlike strands mostly mucin on each side of the yolk. These strands anchor the yolk near the centre of the egg but allow the yolk to revolve. An inner, thin layer of albumen (17% of white) surrounds the chalaziferous layer followed by a firm or thick layer of albumen (57% of white), which provides an envelope to hold the inner thin white and the yolk in place. An outer thin layer of albumen (23% of white) lies just inside the shell membrane except where the thick white adheres to the shell membrane. The thick, gel-like albumen differs from thin albumen only in its approx. four-fold content of ovomucin.

(iv). Yolk: The yolk consists of alternate layers of dark- and light-coloured material arranged concentrically. The colour of yolk varies depending on the feeding schedule and pigments in the feed of hen. The center of yolk is latebra. Germinal disc or blastoderm is present on the surface of yolk on the lateba neck. The yolk is enclosed by a semipermeable membrane known as vitelline membrane. It is about 0.025 mm thick and is colourless.

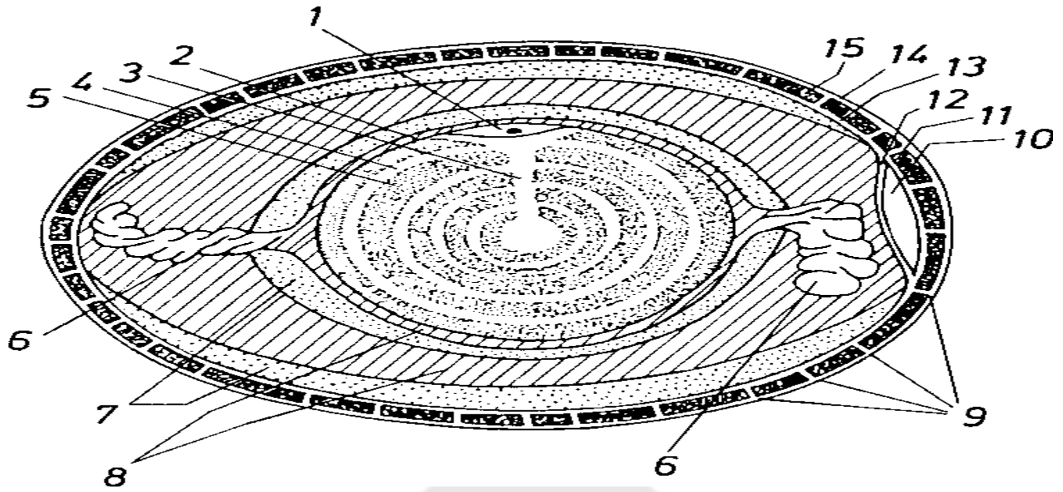

Fig. 1. Cross-section of a chicken egg – a schematic representation. Egg yolk: *1* germinal disc (blastoderm), *2* yolk membrane, *3* latebra, *4* a layer of light colored yolk, *5* a layer of dark colored yolk, *6* chalaza, *7* egg white (albumen) thin gel, *8* albumen thick gel, *9* pores, *10* air cell, *11* shell membrane, *12* inner egg membrane, *13* shell surface cemented to the mammillary layer, *14* cuticle, and *15* the spongy calcareous layer

Composition of egg:

An average hen egg weighs about 57 g, which includes the weight of the white, yolk and shell. Each component differs in composition, as shown in Table 1.

Table 1: Composition of egg and its components

	%	Water	Protein	Fat	Ash
Whole egg	100	65.5	11.8	11.0	11.7
Egg white	58	88.0	11.0	0.2	0.8
Egg yolk	31	48.0	17.5	32.5	2.0
Shell	11	-	3.3	-	95.1

Source: USDA

Egg white (Albumen):

The egg white, also known as the albumen comprises approximately 58% of the weight of an egg. Despite its simple appearance, egg white is a complex mixture of different proteins. Each of these proteins has a different structure and generally they each have specific functions (Table 2). These proteins are briefly discussed as:

Ovalbumin: Ovalbumin is the main albumen protein. It is a glycophospho-protein with 3.2% carbohydrates and 0–2 moles of serine-bound phosphoric acid per mole of protein. Ovalbumin consists of a peptide chain with 385 amino acid residues. It has a molecular weight Mr = 42,699 and contains four thiol and one disulfide group. Ovalbumin is relatively readily denatured, for example, by shaking or whipping its aqueous solution. This is an interphase denaturation which occurs through unfolding and aggregation of protein molecules.

Table 2: Brief description of proteins of egg albumin.

Name of the protein	% of total Protein			Iso-electric point	Properties
Ovalbumin	54	84.5	44.5	4.5	Phosphoglycoprotein
Conalbumin (Ovotransferrin)	12	61.5	76	6.1	Binds metal ions
Ovomucoid	11	70.0	28	4.1	Proteinase inhibitor

Ovomucin	3.5		5.5-8.3×10^6	4.5-5.0	Inhibits viral Hemagglutination
Lysozyme (Ovoglobulin G1)	3.4	75.0	14.3	10.7	Lyses some bacterial cell walls
Ovoglobulin G2	4	92.5	30–45	5.5	Good foam builders
Ovoglobulin G3	4 5			.8	Good foam builders
Flavoprotein	0.8		32	4.0	Binds riboflavin
Ovoglycoprotein	1.0		24	3.9	
Ovomacro-globulin	0.5		760–900	4.5	Inhibits serine and cysteine proteniases
Ovoinhibitor	1.5		49	5.1	Proteinase inhibitor
Avidin	0.05		68.3b	9.5	Binds biotin
Cystatin (ficin inhibitor)	0.05	12.7		5.1	Inhibits cysteine peptidases

Conalbumin (Ovotransferrin): Conalbumin consists of single peptide chain and contains one oligosaccharide unit made of four mannose and eight N-acetylglucosamine residues. It is not denatured at the interphase but coagulates at lower temperatures. It binds about two moles of Mn^{3+}, Fe^{3+}, Cu^{2+} or Zn^{2+} per mole of protein at pH of 6 or above. Sometimes egg products turn red during processing which originates from a conalbumin-iron complex. The complex is fully dissociated at a pH less than 4. Tyrosine and histidine residues are involved in metal binding. Conalbumin has the ability to retard growth of microorganisms.

Ovomucoid: Ovomucoid is a glycoprotein. The carbohydrate moiety consists of three oligosaccharide units bound to protein through asparagine residues. The protein has 9 disulfide bonds and, therefore, stability against heat coagulation. It can be isolated from the supernatants of heat coagulated albumen solutions, and then precipitated by ethanol or acetone. Ovomucoid inhibits bovine but not human trypsin activities.

Lysozyme (Ovoglobulin G_1): Lysozyme consists of a peptide chain with 129 amino acid residues and four disulfide bonds. It is widely distributed and is found not only in egg white but in many animal tissues and secretions. This protein is an N-acetylmuramidase enzyme that hydrolyzes the cell walls (murein) of Gram-positive bacteria.

Ovoglobulins G_2 and G_3: These proteins are good foam builders.

Ovomucin: It is a glycoprotein and has been separated into a low carbohydrate (about 15% carbohydrate) α-fraction and a high-carbohydrate (about 50% carbohydrate) β-fraction. It can apparently form fibrillar structures and thus contribute to a rise in viscosity of albumen, particularly of the thick egg white where it occurs in a four-fold higher concentration than in fractions of thin albumen. It forms a water insoluble complex with lysozyme. The dissociation of the complex is pH dependent. Probably it is of importance in connection with the thinning of egg white during storage of eggs.

Flavoprotein: The flavoprotein is acidic with a molecular weight of 32□36 kDa, and contains a carbohydrate moiety (14%) made up of mannose, galactose and glucosamines, 7□8 phosphate groups and 8 disulfide bonds. All riboflavin in egg albumen is bound in the flavoprotein in a 1:1 ratio. It ensures transfer of the riboflavin from the blood serum to the albumen in the egg white.

Ovoinhibitor: This protein like ovomucoid is a proteinase inhibitor. It inhibits the activities of trypsin, chymotrypsin and some proteinases of microbial origin and acts as a defence against microbial invasion.

Avidin: Avidin is a basic glycoprotein and is a tetramer consisting of four identical subunits, each of which binds one mole of biotin. Avidin is irreversibly denatured at 70 °C, but the avidin□biotin complex is stable to 100 °C.

Other constituents of egg white

Lipids: The lipid content of egg white is negligible and comprises 0.03%.

Carbohydrates: Carbohydrates comprise about 1% of egg white. These are partly bound to protein (approx. 0.5%) and partly free (0.4–0.5%). Free carbohydrates include glucose (98%) and mannose, galactose, arabi-nose, xylose, ribose and deoxyribose, totaling 0.2–2.0mg/100g egg white. There are no free oligosaccharides or polysaccharides.

Minerals: Minerals comprise about 0.6% of egg white. Table 3 lists proportion of different minerals in egg white and egg yolk:

Table 3: Minerals in egg white and egg yolk

Mineral	Egg white (%)	Egg yolk (%)
Sulphur	0.195	0.016
Phosphorus	0.015–0.03	0.543–0.980
Sodium	0.161–0.169	0.026–0.086
Potassium	0.145–0.167	0.112–0.360
Magnesium	0.009	0.016
Calcium	0.008–0.02	0.121–0.262
Iron	0.0001–0.0002	0.0053–0.01

Vitamins: Whole egg contains both fat and water soluble vitamins (Table 4). Fat soluble vitamins like A, D, E and K are found in yolk only while water soluble vitamins like B complex are found in both yolk and white of egg. However, vitamin C is not found in egg.

Table 4: Vitamins of egg.

Vitamin	Whole egg (mg/100g edible portion)	Egg white (mg/100g edible portion)	Egg yolk (mg/100g edible portion)
Retinol (A)	0.22	0	1.12
Thiamine	0.11	0.022	0.29
Riboflavin	0.30	0.27	0.44
Niacin	0.1	0.1	0.065
Pyridoxine (B6)	0.08	0.012	0.3
Pantothenic acid	1.59	0.14	3.72
Biotin	0.025	0.007	0.053
Folic acid	0.05	1 0.009	0.15
Tocopherols	2.3	0	6.5
Vitamin D	0.003		0.0056
Vitamin K	0.009		

Egg yolk:

Egg yolk is fat in water emulsion with about 50% dry matter. The principal constituents of egg yolk solids are 65% lipids, 31% proteins and 4% carbohydrates, vitamins and minerals. Yolk contains particles of varying size that can be divided into two groups viz yolk droplets and granules. Yolk droplets are of variable size. They have diameter in the range of 20-40 μm. They resemble fat droplets, consist mostly of lipids and have protein membranes. They are a mixture of lipoproteins with a low density (LDL). Granules on the other hand are of smaller size with a diameter of 1.0-1.3 μm. They are of more uniform size but less uniform in shape. They consist of proteins, lipids and minerals

Methods of preservation of eggs:

Prior to knowing the ways of preservation, we need first to estimate the different reasons that lead to the deterioration of egg quality. A freshly laid egg is assumed to have maximum quality. As soon as the egg is laid, the deteriorative changes start taking place which pose a danger to the sensory attributes. The quality of egg is the highest at the time of laying. Any subsequent preservative effort is to reduce the deteriorative changes. As soon as the egg is laid, the deteriorative changes start taking place which pose a danger to the quality attributes. The diffusion of CO_2 through the pores of the shell, which starts soon after the egg is laid, causes a sharp rise in pH, especially in egg white from about 7.6- 9.6. The viscosity of the egg white drops dat higher pH. The gradual evaporation of water through the shell causes a decrease in density (initially approx. 1.086 g/cm_3; the daily reduction coefficient is about 0.0017 g/cm_3) and the air cell enlarges. The yolk is compact and upright in a fresh egg, but it flattens during storage. This may be due to migration of moisture from egg white to yolk. In extreme cases the vitteline membrane may tear due to increased pressure of the contents inside. During storage microbial contamination may also occur most commonly by *Salmonella sp*p. That may penetrate through the egg shell and deteriorate its flavor. Changes are increased when the shell has heavy contamination as it overcomes the inbuilt defense mechanism of the egg.

Principles of Preservation of Eggs:

Some principles related to the preservation of eggs are:

- Minimizing loss of carbon dioxide and water by storing at 7-8 ºC and RH of 85%
- Minimizing mis-handling
- Maintaining of shell cleanliness.

Methods of preservation:

The Preservation of Eggs

Eggshells are porous – that's why an incubating chick embryo can breathe. Eggs will spoil and lose freshness due to loss of CO_2 and moisture evaporation leaving through the eggshell. Sometimes bacteria pass through the shell and the membrane which results in its spoilage. Normally the shell has a surface coating of mucilaginous matter, which prevents for a time the entrance of these harmful organisms into the egg. But if this coating is removed or softened by washing or otherwise the keeping quality of the egg is much reduced. These facts explain why many methods of preservation have not been entirely successful, and suggest that the methods employed should be based upon the idea of protecting and rendering more effective the natural coating of the shell.

Methods of preservation

1. **Old Fashioned Methods**

Before the invention of refrigerator/freezers, farmers devised some simple means of preserving their excess eggs. Some farmers relied solely on the use of salt to keep their eggs from rotting. After gathering their eggs, they packed them in a large barrel or crock with plenty of salt and stored them in a cellar or spring house to keep them cool. The majority, however, found some way to clog up the pores of the egg shells so that moisture would not escape and air could not enter. Eggs were rubbed with grease, zinc, or boric ointment, or submerged in a solution of lime, salt, cream of tartar, and water. Probably the most popular way to seal egg shells was to water-glass them. By this method a chemical, sodium silicate, was mixed with water and poured in a crock which was filled with eggs that were about twelve hours old. The sodium silicate would clog the pores in the shells and make them airtight. Some people, even today, use water glassing as a means of preserving eggs, but this storage method has its drawbacks. Eggs preserved this way are not good for boiling because their shells become very soft in the water glass solution. The whites will not become stiff and form peaks, no matter how long they are beaten. There is also a very good possibility that by consuming eggs stored in water glass you would be consuming some of the undesirable chemical, sodium silicate. If you keep roosters with your hens, (which you'll do if you want to maintain a natural, happy environment for your hens and produce wholesome eggs for your family), water glassing may not be a successful means of preservation for you. The life factor in fertilized eggs makes these eggs deteriorate more quickly than sterile, unfertilized eggs, and waterglassing may not be enough of a preventative against spoilage. The way that water glass preservation works is simple and straightforward. The water glass blocks and fills the pores of the eggshell thereby preventing bacteria from entering inside the egg and moisture from leaving the egg.

Eggs that are to be used for water glassing must be completely fresh and clean – they must not ever be washed. By washing a fresh laid egg you will remove the protective coating. It is permissible to lightly wipe an egg with a dry cloth if it is a little soiled. The best eggs are collected from fresh clean nest boxes and will have no cracks or imperfections. One cracked egg will spoil the entire crock of eggs. If has often been said that the best eggs for water glassing are collected during the spring months of March, April and May. The reason for this it that the weather has not turn too hot and the cooler weather keeps an uncollected egg fresher in the nest box.

2. Refrigeration

The best method of preserving whole shell-on eggs is refrigeration (0 ºC to 3 ºC) in a well-sealed container. According to the USDA, shell-on eggs can be stored for up to two months in the refrigerator; however, tests have shown most ultra-fresh home grown eggs carefully refrigerated will last much longer, even up to five months. A temperature of 0 °C and relative humidity of 85-90% is recommended to preserve them for 5-8 months. Store unwashed eggs, towards the bottom of the refrigerator away from the door to avoid the warm air from frequent openings and closings. Storing eggs in a second refrigerator that is less likely to be opened often will prolong their storage life. Once removed from their shells; eggs have a shorter storage life in the refrigerator. Whole eggs without a shell, egg whites and egg yolks can only be refrigerated for up to four days in a sealed container. Cover egg yolks with water before storing to avoid hardening of the yolk. Pour off the water before using the egg yolks. Hard-cooked eggs can be refrigerated up to one week.

3. Dipping eggs in oil

Dipping eggs in oil is very satisfactory method. The oil should be free from odour, but does not need to be colourless. It should be a light grade. Light mineral oil is a very good oil to use. Oil preserved eggs, just like water-glass, have the advantage of allowing the eggs to be kept in cartons or cases. The oil does not need to be heated. The eggs may be dipped by putting the oil in an open container and completely submerging the eggs (eggs should be placed in a small wire basket of some kind for dipping). The tempt of the oil should be in a range of 15-30 ^{o}C for ideal results. They should be allowed to drain for a few minutes on a rack. They are placed in the case with small end down to protect the air cell in the large end.

Oil eggs may be stored at room temperature, although lower temperatures are more desirable. Cool basements are good storage places. Eggs can be stored for least one month, covered in the refrigerator. Freezing is often unnecessary, but it can be done. Oil coating eggs has become popular for short term storage of eggs. Oil coating should be done as early as possible, preferably within first few hours after laying of egg because loss of CO_2 is more during this period and evaporation of moisture is also high during the first few days. Coating should be colourless, odourless, and conform to food grade.

4. Chemical coating

Deterioration of albumen quality and loss of weight of eggs during storage can be retarded by storing at low temperatue under special conditions or by coating the eggs. Polydimethylsiloxane fluids may be used. The results show that a combination of silicon fluids treatment and cool storage conditions can preserve albumen quality (>65 Haugh) for at least two months.

5. **Lime Method:** This method is widely used in Asia, America and Europe. It involves the use of calcium carbonate solution. A litre of boiling water is added to 1kg of quick lime and allowed to cool. Then 5 litres of water are added to it. The solution is then strained through a fine cloth when the mixture settles down. Eggs are then dipped in clear fluid overnight or up to 14-16 hours and then dried at room temperature and stored for 3-4 weeks. The lime being alkaline prevents the growth of microorganisms such eggs have prolonged storage time.

6. **Thermo-stabilisation**

This preservation method involves stabilisation of albumen quality by holding the eggs in an oil bath maintained at 55 ^{o}C for 15 mins or 58 ^{o}C for 10 mins. This process brings about coagulation of thin albumen just below the shell membranes thereby blocking the passage of air and moisture.

7. **MAP/ Gas Method:** Modified atmospheric packaging of eggs in plastic

bags can be done with nitrogen and CO_2 in a ratio of 94:6 in closed boxes. It prevents loss of CO_2.

8. Freezing

Freezing is an efficient method of long term storage of liquid broken eggs. Do not freeze whole eggs in the shell as the shell may burst due to expansion during freezing.To freeze whole eggs, whisk the eggs together until blended. Freeze in airtight containers or, to save space, freeze in small snack-size or quartsize resealable plastic bags and lay flat in the freezer until frozen. The bags can then be stacked until needed. When using frozen thawed eggs, three tablespoons beaten egg equals one whole egg. Egg whites can be stored in the freezer for up to one year. Store in airtight containers, resealable plastic bags or ice cube trays. One egg white equals two tablespoons. Egg yolks become gelatinous during freezing and impossible to use in recipes unless sugar or salt is beaten into them. To freeze, beat four egg yolks with 1/8 teaspoon salt or sugar, depending on the type of recipe you will be using, and freeze in airtight containers or resealable plastic bags. Label with the number of egg yolks and whether they are beaten with salt or sugar. Hard-cooked eggs should not be frozen as they become rubbery.

Eggs should be thawed completely before using. They thaw at refrigerator temperatures in about nine hours and at room temperatures in about four hours. If frozen properly, thawed eggs have the taste, texture and nutritional value of fresh eggs and can be used successfully in all formulations calling for eggs.

9. Dehydrating

Eggs are broken, shell and membranes are separated and liquid eggs are preserved by drying the egg contents i.e., egg white and yolk. This reduces the bulk of eggs and helps in easy transportation and storage. Liquid eggs may become contaminated with pathogenic and spoilage microorganisms that may multiply under improper holding conditions and may survive in uncooked and partially cooked foods. Therefore, egg products are pasteurised under conditions that destroy *Salmonella* besides reducing spoilage microorganisms. Liquid whole eggs have been pasteurized at 60-61 °C for 3.5 min without affecting the functionality of eggs. After pasteurisation de-sugaring is performed to remove traces of glucose (0.5%) to prevent browining due to mallards reaction. Glucose can be removed by three methods, controlled bacterial fermentation using cultures of *Steptococcus*, yeast fermentation using *Saccharomyces*, and enzyme fermentation using glucose oxidase and catalase. Most commercial powders are spray dried, although whites are also dried in trays or as a film on a continuous belt. The core of spray drying technique is spraying a feed material in a liquid state into a hot drying medium (temperature ranging from 100 to 300°C) in which liquid (often water) is evaporated. The final product of a spray drying process is a dried form of powders, granules or agglomerates, depending upon the physical and chemical properties of the feed, the dryer design and operation. Evaporation of water from the droplets is facilitated by heat and vapor transfer through/from the droplets. It is believed that the wet-bulb temperature of the droplets is in the range of 30- 50°C and total duration of drying is only a few seconds.

10. Pickling

Egg pickling is an old-time technique for preserving hard-cooked eggs in a vinegar-brine solution. They are making a comeback due to the increased use of pickled condiments in restaurants and interest in easy home-pickling. Note that pickled eggs should never be stored at room temperature. Botulism has been found in home-canned pickled eggs stored at room temperature. Make sure all of your equipment and hands are thoroughly cleansed and the pickling jars are sterilized. Pickled eggs should be stored in the refrigerator. It is not recommended that pickled eggs be canned. Pickled eggs can be made with a variety of seasonings and vinegars for different flavor profiles. The smaller the egg, the quicker the pickling solution will flavor the egg. The USDA states pickled eggs be kept in the refrigerator a maximum of seven days

11. **Bricks Method (CFTRI Method):** It was practiced by ancient Chinese. Brick powder and salt were mixed in a ratio of 2:1 to which water was added and then it was kneaded. Eggs were kept in pan and covered with brick salt dough. It was kept for 10 days and then washed. This increases the storage quality of eggs.

It is also recommended by CFTRI, Mysore.

12. **Reinhard method:** The Reinhard method is said to cause such a chemical changes in the surface of the egg shell that it is closed up perfectly air tight and an admittance of air is entirely excluded, even in case of long continued storage. The eggs are for a short time exposed to the direct action of sulphuric acid, whereby the surface of the egg shell, which consists chiefly of lime carbonate, is transformed into lime sulphate. The dense texture of the surface thus produced forms a complete protection against the access of the outside air, which admits of storing eggs for a very long time, without the contents of the egg suffering any disadvantageous changes regarding taste and odor. The only disadvantage of this method is that sulphuric acid is a dangerous poison that might, on occasion, penetrate the shell.