UNIT 2 NUTRITIVE VALUE AND PHYSICO-CHEMICAL PROPERTIES OF EGG

Structure

2.0 OBJECTIVES

After reading this unit, you will be able to :

- describe the process of formation of hen's egg;
- describe the structure of egg;
- state the nutritive value of the egg;
- explain the role of egg constituents like egg white, egg yolk proteins; and
- narrate the physico-chemical properties of egg.

2.1 INTRODUCTION

Eggs are very important for human nutrition. Eggs are an important source of protein, essential vitamins and minerals and can make a significant contribution to a healthy diet. The structure and composition of eggs has been described in this unit. It is very important to know about the egg formation in the ovary and oviduct so as to have clear understanding of egg quality, nutritional value and deterioration after the egg is laid. Here you will also learn about the physico-chemical properties of egg which will help you to select proper processing and preservation techniques for the egg.

2.2 FORMATION OF THE EGG

The yolk is formed in the ovary of hen and rest of the component is formed in the oviduct – the egg factory. The ovary is a cluster of many follicles, each of which is independently attached by a slender stalk. Each sphere is a more or less developed ovum or yolk, enclosed in a thin membrane of follicle. The mature yolk is about 40 mm in diameter.

In a laying hen the oviduct appears as a large, much coiled tube occupying a large part of the left side of the abdominal cavity. The oviduct is in continuous movement during the time when an egg is formed.

An oviduct is a tube like organ around 60 to 86 cm in length divided into five areas, which perform the function of formation of different parts of egg.

The oviduct is divided in five clearly defined regions as shown in Fig. 2.1.

1) The funnel or infundibulum nearest to ovary.
2) The magnum, where egg white is secreted.
3) The isthmus, which secretes shell membranes.
4) The uterus or shell gland.
5) The vagina, which leads to cloaca.

The yolk is formed in the ovary and rest of the process occurs in the oviduct. The ovum or the yolk when reaches full diameter of 40 mm is shed from the ovary and is picked up by infundibulum. The albumen secreted from the magnum is homogenous and gel like in structure due to its mucin content. The chalaziferous layers thin white, middle thick white and the outer thin white layers emerge out of this homogenous gel of albumen. Fertilization takes place immediately after ovulation. The spermatozoa make their way through the entire length of oviduct after mating has occurred by a cock. When the egg is laid, the small end of egg comes first as it moves down the oviduct. The time between laying and next ovulation ranges from fourteen to seventy five minutes.

2.3 STRUCTURE OF THE EGG

The structure of hen's egg is shown in Fig 2.2. It consist of following parts:

1) **Egg shell:** It is the outer covering of an egg (constitutes 9 to 11 % of egg wt.) which consists of pores. The air gets in through the pores for the embryo to breath. There are approximately 7,500 pores per egg. Size of pores is big at broader end of egg. The outer surface of the shell is covered with cuticle which seals the pores and checks outer temperature and prevents carbon-dioxide to escape from the egg. The shell also consists of inner and outer shell membrane. The air cell is formed between the shell membranes usually at the broader end of the egg. The outer shell membrane is the air cell membrane.
2) **Albumen:** The white portion or albumen of an egg (constitutes about 58 to 60 % of egg wt.) has three distinct layers of outer thin, middle dense and inner thin liquid. It is also consist of chalazae which is attached to chalaziferous layer. The chalaziferous layer is around the yolk.
3) **Yolk:** The yellow portion or yolk of an egg (constitutes around 31 % of egg wt.) has following layers:

   Yolk consists of germinal disc, latebra, concentric rings of yolk material and vitelline membrane.

   i) **Latebra**: The white yolk which connects the germinal disc with the centre of the yolk.
   ii) **Light yolk layer**: Where no dietary pigment is available.
   iii) **Dark yolk layer**: The colour is dark yellow due to periodic deposition of carotenoid pigment.
   iv) **Yolk membrane**: It is also called as vitelline which surrounds the yolk.
   v) **Blastodisc/Germinal disc**: The germinal disc is known as blastoderm in fertile eggs and blastodisc in infertile eggs. It is located in the cone like portion of latebra, known as *"Nucleus of Pander"* which is connected with its neck to the centre of the yolk.

4) **Air cell :** There is no air cell in a fresh egg at the moment it is laid. The moment the contents contract following cooling, a slight vacuum is created drawing air through its pores and gives rise to an air cell between the two shell membranes. The size varies with duration of holding egg and the species of the bird.

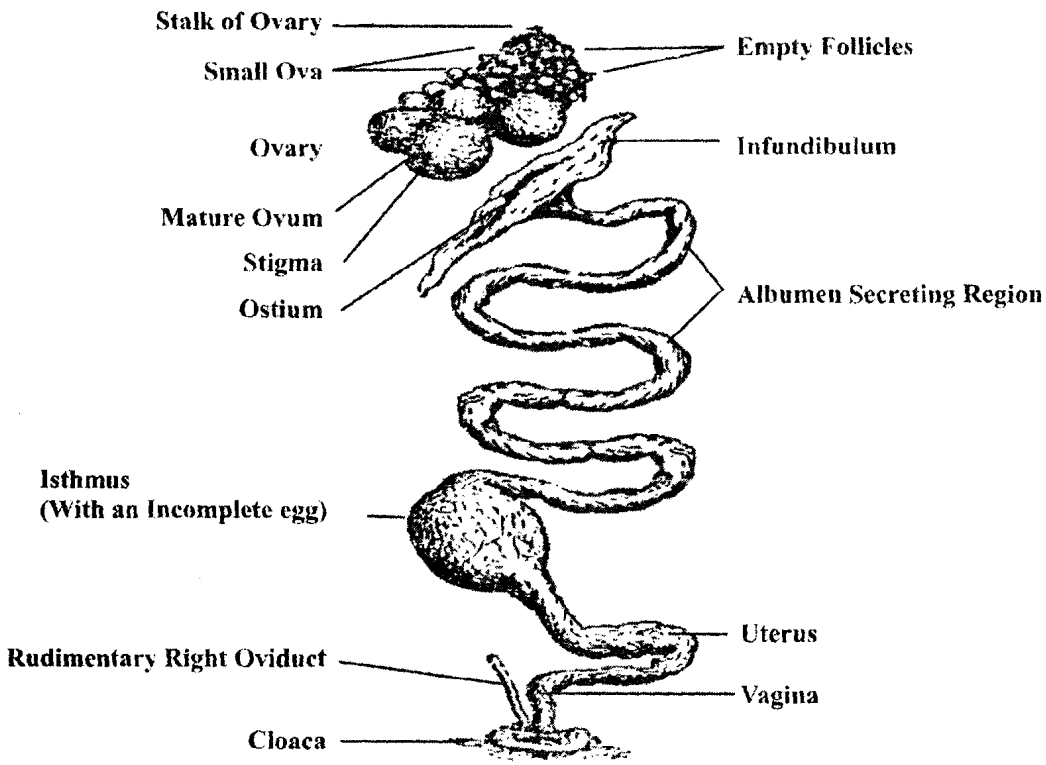

Fig. 2.1: Reproductive organs of the hen

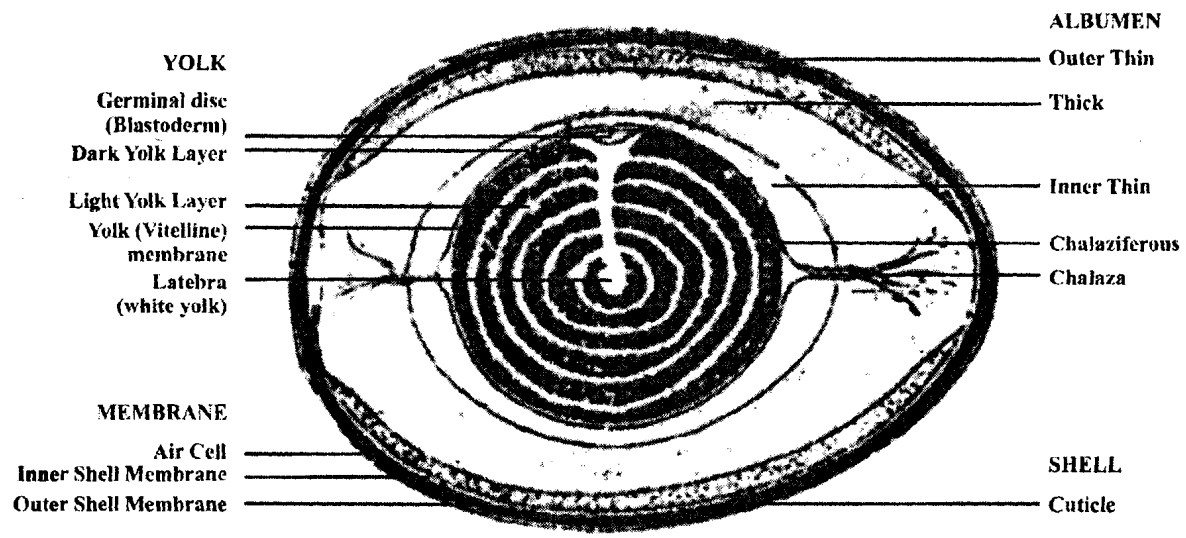

Fig. 2.2: Structure of the hen's egg (From AMS, 1983)

2.4 COMPOSITION OF THE EGG

The three main components of the egg are:

i) Shell 10%

ii) Yolk 28%

iii) Albumen 62%

The albumen consists of different layers:

Chalaziferous layer - 2.7%

Inner thin layer - 16.8%

Middle dense or thick layer - 57.3%

Outer thin layer - 23.2%

As usual egg is also composed of water and solids. There are two types of solid materials viz., organic and inorganic. Proteins, lipids and carbohydrates compose the organic part. All these are presented in the following table.

Table 2.1: Composition of Hen's egg

Constituents	Entire egg (%)	Egg Content (%)	Yolk (%)	Albumin (%)	Shell (%)	Shell Membrane (%)
Water	65.6	73.6	48.7	87.9	1.6	20.0
Solids	34.4	26.4	51.3	12.1	98.4	80.0
Organic matter	23.5	25.6	50.2	11.3	3.3	70.00
Proteins	12.1	12.8	16.4	10.6	3.3	70.00
Lipids	10.5	11.87	32.8	Trace	Trace	Trace
Carbohydrates	0.9	1.0	1.0	0.9	-	-
Inorganic	10.9	0.8	1.1	0.6	95.1	10.00

Inorganic matter (i.e. in shell):

Calcium Carbonate 98.43%

Magnesium Carbonate 0.84%

Tri calcium Phosphate 0.73%

The values given in the table show that eggs can act as an important source of protein, fat and minerals by providing a well balanced source of nutrients for persons of all ages. Its rich protein content and low caloric value are mostly sought for in this modern days to curb obesity and other health problems. Species of bird, diet, age of bird, season of laying, storage and processing influence the composition of egg.

2.5 NUTRITIVE VALUE

Eggs are considered as a delicacy and recognized as an important protective food from ancient times. Eggs are rich in easily digestible fat, high quality protein, good source of vitamins and valuable source of minerals. Eggs are palatable and useful in special diets and indispensable in cookery practices.

Traces of carbohydrates (1.0 per cent) is present in egg content which reacts with egg protein during cooking causing maillard reaction (browning) specifically in egg powder manufacture. The lipid content in egg is 11.87 per cent of egg content, 32.8 per cent of yolk. Types of lipids are phospholipids (32.8 per cent), sterols (4.9 per cent) and neutral fats (62.3 per cent). Fatty acids are palmitic, stearic, linolenic, linoleic and arachidonic acids.

Egg is a rich source of quality protein, important source of unsaturated fatty acids (oleic), iron, phosphorus, trace minerals, vitamin A, E, K and B complex vitamins, especially vitamin B_{12}. As a source of vitamin D, egg ranks second to fish liver oils. Eggs are low in calcium (present in shell) and have no vitamin C. Due to low caloric value and easy digestibility, egg is included in the diet of older people. Egg protein and emulsified egg fat – (egg yolk) are most suitable for babies and growing children. Eggs find place in all diets including infertile eggs for vegetarian people.

In the egg, all the essential amino acids are present. As you know that essential amino acids are required for the body and have to be provided in the diet, it can not be synthesized in the human body. The amino acids which are essential to human being are given below:

1. Tryptophan
2. Threonine
3. Histidine
4. Arginine
5. Lysine
6. Leucine
7. Isoleucine
8. Methionine
9. Valine
10. Phenylalanine

The nutritional value of protein depends upon its amino acid composition and proportion. Table 2.2 gives daily requirement of amino acids in human diet which can be met by including 2 eggs in the diet.

Table 2.2: Amino acid requirements for man

Amino Acids	Daily Minimum Requirement for an Average Man (in mg.)	Quantity in Two Eggs (in mg.)
Arginine	6	756
Histidine	-	260
Threonine	500	605
Valine	800	853
Leucine	1100	1096
Isoleucine	700	756
Lysine	800	745
Methionine	1100	390
Phenylalanine	1100	690
Tryptophane	250	140

Table 2.3: Role of Egg as a Good Nutrient

	Recommended daily allowance for a moderately active man	Quantity in two eggs	% of daily requirement supplied by two eggs
Energy , Calories	3000	180	6
Proteins, gm	70.0	13.2– 14.0	20
Fat, gm	50.0	11.0	22
Carbohydrate, gm	570.0	-	-
Calcium, gm	0.8	0.06	8
Phosphorus, gm	0.9	0.24	30
Iron, mg	12.0	3.20	26
Iodine, mg	0.1	0.01	10
Vitamin A, I.U.	5000	1000 – 1500	20 – 30
Vitamin D, I.U	400	100	25
Vitamin C, mg.	75.0	-	-
Vitamin B_1, mg.	1.5	0.12	8
Vitamin B_2, mg.	2.0	0.32	16
Niacin, mg	20.0	1.20	6

The egg proteins are easily digested and its biological value is high as compared to other food as shown in Table 2.4

Table 2.4: Biological Value and Protein Efficiency Ratio

	Digestibility	Biological Value	Protein Efficiency Ratio
Egg	98	92	4.0
Milk	95.6	93.4	2.0
Beef	98	84	3.8
Mutton	98	78	3.2
Pork	98	76	3.2
Chicken	98	80	3.3
Fresh water fish	97	88.5	2.0
Rice	96.5	85.1	2.0
Wheat	93	68.0	1.8

Thus, findings in different tables reveal that egg can act as a good source of protein, vitamin A, vitamin D, riboflavin, folic acid, vitamin B_{12} and various essential amino acids (threonine, valine, leucine, isoleucine, lysine, methionine, phenylalanine and tryptophan). Two medium sized eggs can meet upto 50 % to 100% dietary requirement of these amino acids. Minerals obtained from two medium sized eggs also fulfill around 10% of our daily requirement of calcium and iron. So, at the existing situation, egg can be considered as the cheapest source of pure quality protein available in the market.

Egg white proteins (Albumen proteins):

All egg white proteins are globular. Globular proteins are important for foaming properties of egg white. Different egg white proteins are as follows:

1) **Ovalbumin**: It is the main protein constituent. It is 55 per cent of the protein of egg white and is a phosphoglycoprotein.

   The carbohydrate components of albumen are mannose and glucosamine. Ovalbumin in solution denatures by mechanical agitation but is resistant to thermal denaturation.

2) **Conalbumin**: It constitutes 13 per cent protein of egg albumen. Conalbumin complexes with iron making iron unavailable to the system. Conalbumin is easily heat coagulated.

3) **Ovomucoid**: It constitutes 10 per cent of the egg white protein. Ovomucoid is a trypsin inhibitor.

4) **Ovomucin**: It is responsible for thickness of albumen and largely present in thick albumen and is insoluble in water but soluble in dilute salt solution.

5) **Lysozym**: It acts as antibacterial by dissolving the cells of bacteria (lysis). Lysozyme is heat resistant.

6) **Avidin**: It binds biotin and makes the vitamin (biotin) unavailable to the system.

Egg Yolk proteins

Phosvitin: It is rich in phosphorus. This accounts for 80 per cent of the protein of yolk. It binds tightly ferric iron and forms a soluble complex and thus is the iron carrier of yolk.

Lipovitellins: These are high density proteins separated into two fractions. The α and β lipovitellins, contain 40 per cent neutral lipid and 60 per cent phospholipids.

Livetin: It has three components - α, β and γ – livetin. These differ in their molecular weight.

Low density lipoprotein (LDL): Egg yolk consists of 74 per cent neutral lipids and 25 per cent phospholipids. It can be separated to tow components LDL and LD_2.

Pigments

Yolk pigments are yellow or dark depending upon amount and type of pigment present in the feed. Colour of yolk is due to carotoenoid and xanthophyll pigments. Carotenoids are converted to vitamin A in the body.

Minerals

Egg shell is the major source of calcium present in the egg. Calcium is present significantly in egg yolk but less in albumen. Other minerals present in yolk and albumen are sodium, potassium, magnesium, sulphur and chlorine. The mineral content of eggs depends on mineral content of the feed of chicken.

The distribution of minerals in different portion of egg is shown in table 2.5.

Table 2.5: Minerals in Hen's Egg

Minerals	Quantity in Yolk (in mg)	Quantity in Albumen (in mg)	Quantity in Shell (in mg)
Phosphorus	110	6	20
Calcium	27	4	2210
Magnesium	24	3	20
Chlorine	23	51	-
Potassium	21	55	-
Sodium	13	53	-
Sulfur	3	64	Trace
Iron	2	0.3	Trace
Copper	0.05 – 0.13	0.02	Present
Iodine	0.003 – 0.008	0.008 – 0.002	0.001 – 0.003
Manganese	0.004 – 0.018	0.0014	0.000012
Zinc	0.70 – 1.00	0.007	Occasionally Present

Vitamins

The yolk is a good source of Vitamin A and Vitamin D. Egg is also a good source of Vitamin B complex. The distribution of vitamins in egg is shown below (Table 2.6)

Table 2.6: Distribution of Vitamins in the Egg Content

Vitamins	Quantity in Yolk	Quantity in Albumen
Vitamin A, (I.U.)	600.27	--
Vitamin D, (I.U.)	25.70	--
Thiamine, (mg)	0.05	...
Riboflavin, (mg)	0.066	...
Niacin, (mg)	Traces	0.033
Pantothenic acid, (mg)	0.875 – 1.220	0.025 – 0.890
Choline chloride (mg)	320	--

2.6 PHYSICO-CHEMICAL PROPERTIES OF THE EGG

You are now aware of the chemical composition of the egg. The knowledge of the chemical composition and physico-chemical properties of albumen and yolk should be useful for interpreting the changes that occur during shell egg storage and during pasteurization, drying and freezing.

The alteration in the egg components may lead to loss of functionality of albumen (foaming power) and yolk (emulsifying ability). Both of these functional properties are significant in the quality of food products such as egg noodles, mayonnaise, cakes where egg is a useful ingredient.

Diverse biological properties, including antimicrobial activity, protease inhibitory action, vitamin–binding properties, and antigenic or immunogenic characteristics have also been attributed to specific egg components.

The physico-chemical properties of albumen and yolk vary due to their inherent chemical composition. These properties can be studied under the following categories:

(1) Viscosity of albumen and yolk

The viscosity of egg albumen is dependent on the age of the bird, mixing treatment of the albumen, temperature and rate of shear. It has been reported that unmixed albumen is pseudo plastic at 32°C. With a constant shear rate, the albumen viscosity decreased with time and approached equilibrium in a few minutes. It also has been found that mixed albumen also displayed pseudo-plastic behavior at 10°, 20° and 30°C.

Egg yolk is a pseudo plastic Non-Newtonian fluid. The particulate matter (granules) in the yolk must be responsible for Non- Newtonian characteristic since plasma (yolk without the granules) is essentially a Newtonian fluid. A marked reduction in apparent viscosity is noted when albumen is added to yolk.

(2) Surface activity of albumen and yolk

Since proteins and phospholipids are capable of lowering the surface and interfacial tensions, albumen and yolk have low surface tensions. The surface tension of a 12.5% solution of albumen at pH 7.8 has been reported to be 49.9 dynes/cm at 24°C. It has also been reported that the low-density lipoprotein fraction of yolk lowered the surface tension to about 42 dynes/cm even at a concentration as low as 0.25%.

Egg yolk is, itself, an emulsion, a dispersion of oil droplets in a continuous phase of aqueous components. In addition, the yolk is an efficient emulsifying agent. The emulsifying substances, also known as surface–active agents, are mixtures or complexes of egg yolk protein fraction such as livetin and lipovitellins. Lecithin present in egg is a natural emulsifying agent.

(3) pH of albumen and yolk

The pH of albumen from a newly laid egg is between 7.6 and 8.5. During the storage of shell eggs, the pH of albumen increases at a temperature dependent rate to a maximum value of about 9.7. The rise in the albumen pH is caused by a loss of carbon dioxide from the egg through the pores in the shell. The pH of albumen is dependent on the equilibrium between dissolved carbon dioxide, bicarbonate ions, carbonate ions and protein. The pH of yolk in freshly laid eggs is generally about 6.0, but during storage of eggs, the pH gradually increases to 6.4-6.9.

The pH of egg is largely influenced by storage temperature, carbon dioxide present inside the egg and in the external environment. With an increase in the concentration of carbon dioxide in the environment, the concentration of bicarbonate ions of albumen increases as the carbonate concentration decreases.

(4) Colour of yolk and albumen

The albumen of a fresh egg is a clear mass with a yellowish tint. But for the presence of two chalazae, which have a cloudy appearance, the rest of the albumen should be free from any muddy appearance. On coagulation the albumen assumes a milky white colour and therefore it is also called as egg white.

The yellow-orange colour of yolk has been attributed to the presence of fat-soluble carotenoids in the lipid portion of lipoproteins. The majority of carotenoids in yolk are hydroxy compounds called xanthophylls with minor amounts of carotenes. The factors that influence the degree of yolk pigmentation include the chemical structure of the xanthophylls, the presence of antioxidants in feed, and the fat content of feed. In addition, it has been shown that the genetic capability to absorb and deposit

xanthophylls in yolk varies among individual hen within a single strain. Highly pigmented yolks are required for the manufacture of bakery products, pasta and mayonnaise.

(5) Freezing point

The freezing point of egg yolk is about -1°C (30.2°F), yet, gelation does not occur until a temperature of –6°C (21.2°F) is attained. Freezing causes only minor changes in raw egg white. Depending on the moisture or solids content of egg products, the thermal properties like specific heats, latent heats and freezing point may vary.

(6) Flavour

One of the most important factors influencing acceptability of eggs is flavour. It is generally acknowledged that a fresh egg has a mild flavour and odour. The development of characteristic egg flavour takes place for the most part during cooking. Loss of flavour or development of off-flavours may be due to feed ingredients, storage and handling of eggs both before and after cooking. Egg researchers have reported the presence of carbonyls (Acetone, acetaldehyde, formaldehyde, z – pentanone, z – butanone and diacetyl) in fresh egg white. Basic compounds recovered were ammonia, methylamine, dimethylamine and putrescine. The dominant odour of cooked egg white is sulfur, mostly due to the release of H_2S gas. In low concentration, H_2S has a positive effect on flavour, while high concentrations make eggs unpalatable.

Check Your Progress 1

1) List the different regions of the oviduct along with the parts of egg formed there.

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2) Write the parts of an egg.

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3) Eggs are a rich source of quality protein. Justify.

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4) pH of albumen, yolk and size of air cell are important indicators of egg quality. Explain.

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5) Comment on the emulsifying nature of egg yolk.

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6) Why the colour of yolk is yellowish orange?

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7) Fill in the blanks:

(a) ..... present in egg white causes lysis of bacterial cells.

(b) The pH of yolk in freshly laid eggs is generally about .....

(c) ..... present in egg binds biotin and makes it unavailable.

(d) ..... is the main protein constituent of the egg white.

2.7 LET US SUM UP

The formation of the egg is integral part of the reproductive cycle of a bird. The different layers of egg are arranged in a unique way as explained using the structure of hen's egg. Main components of an egg are – shell, membrane, albumin, egg yolk and air cell. Eggs have an excellent nutritive value. They are rich source of good quality protein. Egg contains all the essential amino acids and 2 eggs in diet can meet the daily requirement of amino acid human diet. They also contain unsaturated fatty acids, minerals, Vit A, Vit D, and Vit B. Digestibility, biological value and protein efficiency ratio of egg are very high as compared to other foods. You have learnt, the chemical composition of the egg in this unit. The physico-chemical properties and chemical composition are useful in understanding the changes which occurs in egg during storage. Egg albumen is alkaline and yolk is acidic in nature. Yolk is yellowish-orange in colour due to the presence of carotenoides. Surface tension of the egg is not high because of its protein content.

2.8 KEY WORDS

Albumen : White component of an egg.

Biological Value : It is a measure of the proportion of absorbed protein from a food which becomes incorporated into the proteins of the organism's body.

Newtonian Fluid : It is a fluid that flows like water.

Non-Newtonian Fluid : It is a fluid in which the viscosity changes with the applied shear stress.

Ovary	:	Here the egg yolk is formed in hen.
Oviduct	:	In oviparous animals (those that lay eggs), the passage from the ovaries to the outside of the body is known as the oviduct.
Ovulation	:	Release of ovum or yolk.
Pasteurization	:	Heat treatment of contents to kill salmonella and other pathogenic bacteria.
Pigment	:	Colouring matter of yolk obtained mainly from feed.
Protein Efficiency Ratio	:	It is based on the weight gain of a test subject divided by its intake of a particular food protein during the test period.
Spermatozoa	:	Sperm which fertilize eggs.
Stigma	:	Called suture line from when yolk is shed or released from ovary to oviduct.
Viscosity	:	Resistance to flow.
Yolk	:	Yellow component of an egg.
Pseudo Plastic Liquid	:	Also called as shear thinning liquids because with increase in shear rate, the apparent viscosity decreases.

2.9 SOME USEFUL BOOKS/REFERENCES

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Panda, P.C. (1995) *Text book on Egg and Poultry Technology* – Vikas Publishing House Pvt. Ltd.

Sharma, B.D. (1999). *Meat and Meat Products Technology*. 1st edition, JAYPEE Brothers, New Delhi.

2.10 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1)

Region of the oviduct	**Parts of the egg formed**
Infundibulum	-
Magnum	Albumen
Isthmus	Shell membranes
Uterus	Shell glands
Vagina	-

2) Parts of the egg are as follows:

1. Shell
2. Shell membrane
3. Air cell
4. Albumen (Thick white and thin white)
5. Yolk (Vitelline membrane, latebra, germinal disc, dark yolk layer, light yolk layer).

3) Eggs are a rich source of quality protein because of following reasons-

- The eggs contain all the essential amino acids.
- The protein efficiency ratio (PER) is 4.0 and very high compared to other food.
- The protein of egg is of a high biological value.
- The protein quality of the egg is often the standard for measuring the quality of all other food protein.

4) pH of albumen and that of yolk and size of air cell are important indicators of egg quality because of following reasons:

- The pH of albumen of fresh egg is around 7.6 and of a stale egg is to a maximum value of about 9.7.
- The pH of yolk in fresh egg is about 6.0 but on storage increases to between 6.4 to 6.9 in a stale egg.
- The size of air cell in fresh egg is very small and increases due to the loss of moisture and carbon dioxide from the internal contents of the egg if stored under improper conditions.

5) Yolk is an efficient emulsifying agent. Lecithin present in egg is a natural emulsifying agent. The emulsifying substances are mixtures or complexes of egg yolk protein fraction such as livetin and lipovitellins.

6) The yellow-orange colour of yolk is due to the presence of fat-soluble carotenoids in the lipid portion of lipoproteins. The majority of carotenoids in yolk are hydroxy compounds called xanthophylls with minor amounts of carotenes.

7) (a) Lysozyme

(b) 6.0

(c) Avidin

(d) Ovalubumin