Avian Digestive Anatomy and Physiology

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- An understanding of the avian digestive system is essential to developing an effective and economical feeding program for your poultry flock.
- Knowledge of avian anatomy and what the parts normally look like, will help you to recognize when something is wrong and take the necessary action to correct the problem.

Introduction
- High metabolic rates require large amounts of fuel.
- Digestive system needs to be as light as possible and effective.
- Problem for birds – need to keep low body weight.
- Thus, little fat storage need to locate.
- They need to ingest and digest food as quickly and efficiently as possible.
Birds can be carnivores, herbivores, omnivores. Meat (grubs, worms, the occasional mouse) Vegetation (grass, weeds and other plants).

Digestion is completed by the action of various enzymes secreted by different organs and accessory gland of the digestive system.

**The Digestive System**

The digestive system is responsible for the break down of complex non absorbable components like:
1. Carbohydrate
2. Protein
3. Fats
into relatively simplest and absorbable units like:
1. Glucose
2. Amino acid
3. Fatty acids

**Digestion**

An animal's body breaks down food through both mechanical and chemical means. In many animals, mechanical action involves chewing; however, because birds do not have teeth, their bodies use other mechanical action.

Chemical action includes the release of digestive enzymes and fluids from various parts of the digestive system.
Digestive System

**Organs**

1. Mouth
2. Pharynx
3. Esophagus/gullet
4. Crop
5. Proventriculus
6. Gizzard
7. Small intestine
8. Caeca
9. Large intestine
10. Cloaca
11. Vent

**Accessory Glands**

1. Salivary glands
2. Liver
3. Pancreas

**Organs and Functions**

**The Mouth**

- Mouth is made up of upper mandible and lower mandible collectively known as beak.
- It is used for eating and preening, manipulating objects, killing prey, fighting, probing for food, courtship and feeding young.
- The base of the mouth is made up of tongue and it has rough surface to force food into esophagus or pharynx.
- The base of the tongue has papilla, which contains very few numbers of taste buds. The taste buds help to taste the feed.
The salivary glands secrete mucous, and depending on the species, amylase.

Although amylase is not present in the saliva of Gallus and Meleagris, it is found in the saliva of the house sparrow and other species.

The volume of daily salivary secretion in Gallus ranges from 7 to 25 ml.

Mucous functions to lubricate food and allow it to move down the esophagus.

In some species, mucous also functions as an adhesive coating on the tongue to aid in capturing insects or as a material that cements components during the construction of nests.

Cont. …

The roof of mouth is made up of hard palate that is divided by a long narrow slit in the center that is opened to the nasal passage.

The soft palate is absent in chicken.

Cont. …

The slit in the hard palate and the absence of soft palate make it impossible for the birds to create a vacuum to draw the water or feed into the mouth.

Thus birds have to scoop up the water when drinking, elevates its head, and then let the water run down the gullet by the action of gravity.
Cont. …

- The base of mouth is made up of tongue and it has rough surface at the beak to help force the feed into esophagus or gullet.
- The mouth is also very sensitive to temperature differences.
- The base of the tongue has papilla, which contains very few numbers of taste buds.
- The taste buds help to taste the feed

<table>
<thead>
<tr>
<th>Organs and Functions</th>
<th>The Pharynx</th>
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<tbody>
<tr>
<td>Pharynx is a common passageway for feed and air, it is divided into two parts:</td>
<td></td>
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<tr>
<td>1. Esophagus</td>
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<td>2. Larynx</td>
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<tr>
<th>Organs and Functions</th>
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<td>Esophagus: Transports food from the mouth to the stomach.</td>
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Organs and Functions

The Esophagus

Description
Esophagus is a tube-like structure that extends from mouth to Proventriculus.

Functions
1. Helps carry feed from mouth towards Proventriculus.
2. Secrets mucous for lubrication.

The Crop

Description
- Crop is the extension of esophagus located in the neck region.
- The capacity of normal crop is 45 cc, so chicks eat in small increments all day long.
- Cropectomy has no effect on growth rate of ad-libitum fed chickens.

Cont. …

Feed can remain for up to 12 hours.
**Functions:**

1. Storage of feed, so when the proventriculus or gizzard is empty the feed is bypassed by the crop.
2. Little digestion takes place with the action of salivary amylase.
   1) Amylase activity at this site comes from either salivary secretions, intestinal reflux, or plant and/or bacterial sources.
   2) Starch is hydrolyzed within the crop where it can either be absorbed, converted to alcohol, lactic or other acids.

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**Chickens sleep with nice full, firm crops and by the morning, they should be empty.**

- A full crop on the morning indicates a problem.
- Empty crop stimulates a chicken’s appetite.
- Full crop is the signal to the bird to stop eating.
- An impacted crop will stay firm and can get as large as a tennis ball and a little tender.

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**Tips To Keep a Healthy Crop**

1. Avoid feeding chicken large hard to digest food.
2. Avoid using metal water containers that may rust.
3. Feed your flock plain yogurt with live and active cultures to help promote the good gut bacteria.
4. Add probiotics to feed.
5. Avoid feeding chickens sugary human food.
6. Inspect chickens crops regularly.
CROP MILK

- In pigeons and doves, "crop-milk" is produced during the breeding season under the influence of prolactin.
- Crop milk contains 12.4% protein, 8.6% lipids, 1.37% ash, and 74% water.
- Rich in protein and essential fatty acids and is devoid of carbohydrates and calcium.

Organs and Functions

Proventriculus

- Stomach: Principally the organ where food is broken into smaller units. It has two parts:
  1. Proventriculus
  2. Gizzard

- The proventriculus is a muscular part of the stomach that uses grit to grind grains and fiber into smaller particles.
- Digestive enzymes are added to the mix and physical grinding of the food occurs.
### Description
- Also called glandular stomach or true stomach.
- It is a specialized enlargement of the gullet just before entry into the gizzard.

### Description
- Also called muscular stomach or ventriculus.
- It is made up of two pairs of powerful muscles capable of crushing and grinding the feed particle, which act as the bird’s teeth.
- (The tunica muscularis of gizzard is made up of two layers of smooth muscles, inner circular & outer longitudinal)

### Functions: Gastric juice
- Gastric juice is made up of the proenzyme known as pepsinogen and hydrochloric acid, both are produced by oxyntico-peptic cells.
- Gastric juice produced in response to protein content in diet.
- Acid secretion of chickens is high relative to mammals.
- Amylolysis occurs in the crop, it is not evident in the ventriculus.

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Cont. …

Functions
1. It performs powerful muscular contraction, which ultimately leads to crushing and grinding of feed particles.
2. This process is aided by the presence of grit or rocks present in the gizzard.
3. The gizzard performs 2-5 contractions per minute according to the consistency of the feed particle!!!!!!!

Organs and Functions

Small Intestine
- Aids in digestion and nutrient absorption.
- Composed of the duodenum, jejunum and ileum.

- The small intestine begins at the exit from the gizzard and ends at the junction of the small intestine, caeca and colon.
- It is relatively long and has a constant diameter.
- Of the three parts of the mammalian small intestine, the duodenum, jejunum and ileum, only the duodenum can be easily distinguished in the fowl.
- There is no clear demarcation between the jejunum and ileum and the small intestine appears as one long tube.
- Much of the digestion of the food and all of the absorption of the nutrients takes place in the small intestine and hence its structure is quite important.
The structure is as follows:

1. Serosa – a serous membrane on the outside of the intestine.
2. A layer of longitudinal muscle – fibres run along the length of the intestine.
3. A layer of circular muscle – three times as thick as the longitudinal muscle. Located between the two muscle layers are:
   - Blood vessels
   - Lymph vessels
   - A network of nerve fibres
4. An ill-defined sub-mucosa – the areolar of the oesophagus.
5. Mucous membrane consisting of:
   - A thick muscular mucosa of longitudinal and circular muscle
   - Corium – many glands, lymphoid tissue, muscle fibres and a variety of free cells
   - Epithelium or surface

The small intestine has a number of very important functions:

- Produces a number of enzymes involved in the digestion process
- Site of much of the digestion of the food
- Site of much of the absorption of food

Villi

- When a piece of the small intestine is immersed in water it takes on a very velvety appearance because of the presence of villi – long flattened, fingerlike projections that extend into the lumen (inside) of the intestine like flexible fingers.
- The villi are very actively involved in the absorption process.
- A single layer of columnar epithelium together with goblet cells covers the lining.
- The goblet cells secrete mucus. Permanent folds in the mucous membrane called the “valves of kerkring” are located at the proximal end (closest to the front) of the duodenum.
- A lacteal (lymph vessels), capillaries, bundles of plain muscle fibres, nerves and other tissues and cells occupy the core of the villus.
- The villi have the function of providing a vastly increased surface area for the more efficient absorption of the nutrients.
- The efficiency of the absorption is influenced by the surface area available for the nutrients to move through i.e. the more villi the better the absorption.
- They also provide a means of concentrating the nutrients collection ability once they have moved through the intestine wall.

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**Cont.**

- Small intestine is 1.5 meters long in the adult bird.
- It has three parts;
  1. Duodenum
  2. Jejunum
  3. Ileum
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<thead>
<tr>
<th>Organs and Functions</th>
<th>Small Intestine - Duodenum</th>
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<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Duodenum makes the loop known as duodenal loop which contain the pancreas.</td>
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<tr>
<th>Cont. …</th>
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<tbody>
<tr>
<td><strong>Function</strong></td>
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<tr>
<td>➢ Digestion of carbohydrates, protein, and fat take place in the small intestine with the help of intestinal juice, pancreatic juice, and secretion of liver known as bile.</td>
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<th>Organs and Functions</th>
<th>Small Intestine – Jejunum &amp; Ileum</th>
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<tbody>
<tr>
<td>➢ The jejunum and the ileum, together about 120 cm long.</td>
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<tr>
<td>➢ Starts at the caudal end of the duodenum where the bile and the pancreatic duct papilla are located.</td>
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<tr>
<td>➢ Ends at the ileo-caecal-colic junction (This junction is where the small intestine, the two caeca and the colon all meet)</td>
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</table>
This portion of the small intestine is similar in structure to the duodenum except that:
1. It is suspended in the mesentery
2. Villi are shorter
3. There is less lymphoid tissue

Meckel's Diverticulum is a constant feature about half way along the small intestine and appears as a small projection on the outer surface of the small intestine.
This projection is where the yolk sac was attached during the development of the embryo.

Intestinal juice contains variety of enzymes such as:
1. Amylase, carbohydrates digestion.
2. Invertase, carbohydrates digestion.
3. Trypsin, proteins digestion.
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<td>Similarly, pancreatic juice contain variety of enzymes that do take part in digestion of carbohydrates, protein and fat.</td>
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<tr>
<td>➢ The bile produced from the liver is responsible for emulsification of fat which is then digested by variety enzymes.</td>
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<th>Small Intestine - Absorption</th>
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<tr>
<td>➢ After completion of digestion, the end product of carbohydrate (glucose), protein (amino acid), fats (fatty acid) are absorbed by the finger like projections of small intestine known as villi.</td>
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</tr>
<tr>
<td>➢ The amino acid, fatty acids and glycerol are absorbed into the lymphatic vessels</td>
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<tr>
<td>➢ These end products are ultimately reach the liver via portal vein.</td>
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### Organs and Functions

**Ceca**

Bacterial action in the ceca helps break down undigested food passing through the intestine.

- **Description**
  - These are two blind pouches located between the small intestine and large intestine having a length of 16 - 18cm.
  - The ceca empty their contents two or three times a day.
  - They produce pasty droppings that often smell worse than regular droppings and often mustard to dark brown in color.
  - The frequency of cecal droppings, as well as their appearance among regular droppings, tells you the chicken’s digestive tract is functionally normally.

### Description

**Function**

The function of Ceca is not clear.

1. It is thought that it takes part in digestion of carbohydrate, proteins, and crude fiber with the help of bacterial action.
2. Re-absorption of water takes place in the ceca.
3. Fermentation of coarse materials and production of the eight B vitamins (Thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folic acid and vitamin B12) also occur in the ceca.
   - Because the ceca are located near the end of the digestive tract there is minimal absorption of any nutrients released.
Organs and Functions

Large Intestine

Description
- Large intestine is much shorter when compared to small intestine and caecum.
- The length of large intestine is 10 cm.
- The diameter is twice the diameter of small intestine.
- It extends from small intestine to cloaca.

Function
- It helps to maintain water balance by water absorption.

Cloaca and Vent

Cloaca:
Where the digestive, urinary and reproductive systems meet.

Vent:
The external opening of the cloaca that passes waste to the outside.
### Description
- It is the bulbous/enlarged area located at the end of large intestine.
- It is also known as common sewer because it receives the openings from digestive system, reproductive system and urinary system.
- External opening of the cloaca is known as vent and its size is variable depending upon the productivity of the birds.

- Chickens usually void fecal material as digestive waste with uric acid crystals on the outer surface—that is, chickens do not urinate.
- The color and texture of chicken fecal material can indicate the health status of the chicken's digestive tract: the white, pasty material coating chicken fecal material is uric acid, the avian form of urine, and is normal.

The reproductive tract also exits through this area. When a hen lays an egg, the vagina folds over to allow the egg to leave through the cloaca opening without coming into contact with feces or urine.

The average daily production of faeces from laying hens is between 100 and 150 grams. These fresh droppings are approximately 75% water and will air dry under favourable conditions to approximately 30% water.
With few exceptions (presence of crop, gizzard, proventriculus, a short colon, the cloaca), the GIT anatomy and physiology of the birds is similar to mammals. Because of adaptation for flight, the GIT size, relative to body weight is small in birds. However, this is compensated by the higher vascularity, higher gastric secretion rate, increased transit time, and acidity of the GIT compared to mammals.

Birds also have high numbers of intestinal villi and high epithelial turnover rate (48 to 96 h), and rapid inflammatory response (less than 12 hours, as compared to 3-4 days in mammals), which makes them more susceptible to disturbances in absorptive capacity than mammals.
The rate of movement of the food through the digestive system with a meal of normal food taking approximately 4 hours to pass through in the case of young stock, 8 hours in the case of laying hens and 12 hours for broody hens.

Intact, hard grains take longer to digest than the cracked grain and, quite often some whole grain will pass through unchanged.

**Intestinal Microflora**

Both the small and large intestines normally are populated with beneficial organisms (bacteria, yeast, etc.), referred to as microflora (micro meaning "small" and flora meaning "plants").

These microflora aid in digestion.

When chicks hatch, their digestive tracts are virtually sterile.

If raised by a mother hen, a chick obtains the beneficial microflora by consuming some of its mother's fecal material.

In artificial incubation and brooding, chicks do not have this option.

In such situations, producers can provide the chicks with probiotics, which are preparations containing the beneficial microflora that normally inhabit a chicken’s digestive tract.
Through the probiotics, the chicks receive the beneficial bacteria they need to fight off infection by pathogenic bacteria, such as salmonella.

Intestinal disease in chickens normally occurs when the balance of normal microflora is upset—that is, the normal microflora are overrun by too many foreign organisms.

The result is enteritis, or inflammation of the intestines.

Enteritis produces symptoms that include diarrhea, increased thirst, dehydration, loss of appetite, weakness, and weight loss or slow growth.

Severe damage to the intestinal tract typically is called necrotic enteritis (necrotic meaning "dead tissue"), which is a problem in many types of production systems.

**Accessory Digestive Glands**

There are three accessory digestive glands which play a vital role in the process of digestion:

1. **Salivary Glands**
2. **Pancreas**
3. **Liver**
Accessory Digestive Glands
Salivary Glands

- It is responsible for production of saliva.
- Its secretion ranges from 7 to 30 ml per day.

Cont …

The salivary glands are:
1. Maxillary – in the roof of the mouth.
2. Palatine – on either side of the nasal opening in the roof of the mouth.
3. Apreno-pteroid glands – in the roof of the pharynx on each side of the common opening for the eustachian tubes.
4. Anterior sub-mandible glands – in the angle formed by the union of the upper and lower beaks or mandibles.
5. Posterior sub-mandibular glands.
7. Crico-arytenoid glands – around the glottis.
8. A small gland in the angle of the mouth.

Cont …

The saliva has following functions:
1. Lubrication of the feed.
2. Digestion, it contains salivary amylase which is responsible for carbohydrates digestion.
3. Acts as a buffer, it contains bicarbonate and other salts.
4. Helps tasting the feed.
5. Protects the mucus membrane and keeps it moist.
6. Helps regulate the body temperature.
7. Contains enzyme known as muramidase which is bacteriocidal in nature and thus it produces the local immunity.
Accessory Digestive Glands
Pancreas

- Pancreas produces a pancreatic juice.
- Its pH is 6.9
- It is released in the distal end of the loop of duodenum.
- Pancreatic juice contains four kinds of enzymes:
  1. Proteolytic Enzymes
  2. Lipolytic Enzymes
  3. Carbohydrate splitting Enzymes
  4. Nucleolytic Enzymes

Cont…

A- Proteolytic Enzymes
There are five different kinds of proteolytic enzymes
1. Trypsinogen
2. Chymotrypsinogen A
3. Chymotrypsinogen B
4. Procarboxy peptidase A
5. Procarboxy peptidase B
These enzymes are responsible for the break down of protein molecules into simpler units.

B- Lipolytic Enzyme
There are three types of lipolytic enzymes which are produced by the pancreas;
1. Phospholipase, lipid breakdown.
2. Pancreatic lipase, lipid breakdown.
3. Cholesterol esterase, esterification of cholesterol.

Cont…
C- Carbohydrate splitting Enzymes

- These consist of:
  1. Pancreatic amylase, acts on the starch and converts it into simpler units.
  2. Invertase, acts on the sucrose and converts it into simpler sugar.

D- Nucleolytic Enzymes

- There are two kinds of nucleolytic enzymes:
  1. Ribonuclease
  2. Deoxyribonuclease

Besides enzymes, pancreatic juice also contains cations and anions.

Cations:
- Na+, K+, Mg++, etc.
- These act as buffer, cofactors, and osmotic regulators.

Anions:
- HCO3-
- These mainly act as buffer and osmotic regulators.
Liver

The largest glandular organ in the body. Aids in the metabolism of carbohydrates, fats, and proteins.

Liver is a bilobed structure and it performs the following functions:

1. Detoxification.
2. Store of vitamins and carbohydrates, carbohydrates are stored in the form of glycogen.
3. Formation plasma protein like albumin and globulin.
4. It activates and inactivates the protein and peptide hormones.
5. Liver is a site for the destruction of old RBCs.
6. Formation of bile, which is responsible for the emulsification of the fat.

Mechanism Of Enzyme Production and Activation

The activities of gastrointestinal tract are controlled by:

1. Nervous system
2. Endocrine system
The nervous system
In particular, the autonomic nervous is responsible for controlling the activity of gastrointestinal tract.

The nervous system has two parts:
1. Parasympathetic nervous system
2. Sympathetic nervous system

- The parasympathetic nervous system activates the gastrointestinal tract while sympathetic nervous system activates as well as deactivates the gastrointestinal tract.

Stimulation of the parasympathetic to produce saliva is occurred by:
1. Food entering the oral cavity
2. Visual stimuli
3. Smell
4. Taste
Cont …

- Feed enters the Proventriculus and the walls are stretched
  This stimulate the release of **Gastrin** hormone which stimulates secretion of gastric juice.

- Feed enters small intestine
  Duodenum produces **secretin** hormone which stimulate the pancreas to produce pancreatic juice.

Cont …

- Fats in the duodenum
  Duodenum produces **cholecystokinin** hormone which stimulates gall bladder to release bile.

Cont …

- In the gastric juice
  - Pepsinogen is activated into pepsin by HCl.

- In the pancreatic juice
  - Trypsinogen is activated by another enzyme known as enterokinase, which is released from duodenum.

- Carboxy peptidase ← Procarboxy Peptide
- Chymotrypsin← Chymotrypsinogen
Mechanism of Hunger

There are two systems or centers located in the brain or liver which controls the feeding behavior of animals

1. Satiety center
2. Appetite center

Cont …

Satiety Center

- It is located in the liver of the chicken, while in other animals it is located in the brain.
- This center is also known as glucostatery Centre.
- Level of glucose in the blood activates and stimulates the satiety center leading to cessation of feed intake.

Cont …

Appetite Center

- The stimulation of this Centre results in feed intake or hunger.
- This centre is stimulated by low concentration of glucose in the blood. This is located in the brain.
Fertile (hatching eggs) and infertile eggs have many of the same structures. These structures can be classified:

- Nutritional
- Protective (biological and physical)
- Facilitative
Many physiological changes occur in the hen approaching sexual maturity.

- At 12-14 weeks of age (broiler breeder hen) the developing ovary begins to release estrogen.
- Estrogen's main role is in preparing the hen's body for reproduction.

**Egg Production**

**Estrogen's role in sexual maturity:**
- Enlargement and growth of the reproductive tract (oviduct)
- Increased calcium flux into the medullary bones
- Enlargement of the vent area
- Spreading of the pubic bones (between which the eggs pass)
- Formation of lipids in the liver

**Other factors for initiating egg production:**
- Adequate body size must be obtained
- Photosimulation

**Photostimulation:**
- Over 14 hrs of light
- Initiates cascade of hormones resulting in ovulation

**AGE + BODY SIZE/CONFORMATION + INCREASED PHOTOPERIOD = INITIATION OF EGG PRODUCTION**
### Egg Production

Events that occur with increasing photoperiod:

- Hypothalamus responds to increasing photoperiod
- Hypothalamus signals anterior pituitary to produce FSH
- FSH = follicle stimulating hormone
- FSH travels to ovary in blood
- Stimulates development of follicles

**Diagram:**
- Hypothalamus
- Anterior pituitary
- FSH
- Ovary
- Follicle maturation

### Follicle Maturation

Follicles will be in various stages of development:

- More mature follicles appear yellow because of accumulated pigment

Follicles are categorized as follows:

- Small white follicles
- Large white follicles
- Small yellow follicles
- Large yellow follicles

**Diagram:**
- FSH
- Follicle maturation
- Ovary

### Egg Production

At any given time a normal ovary will contain several mature (large yellow) follicles:

- Largest follicle is the next to be released and is called F1
- Next largest follicle is the F2, etc.
When a follicle is fully mature, it releases progesterone. Progesterone travels to the anterior pituitary, which responds by producing LH. LH travels back to the mature follicle, causing it to rupture.

Egg production continues with the follicle ruptures and the yolk is released, referred to as ovulation. Empty follicle after ovulation is referred to as the post-ovulatory follicle (POF). Follicles rupture at the stigma.

- Stigma - area on the follicle where there are no blood vessels.
- If does not rupture at the stigma, a blood spot will occur on the yolk.

The reproductive tract of a hen is a very specialized organ capable of producing different parts of the egg:
- Estrogen released from the developing ovary initiates oviduct growth and maturation
- The oviduct contains the following structures:
  - Infundibulum
  - Magnum
  - Isthmus
  - Uterus
Egg Production

It takes approximately 24 hours for an egg to form.

The time spent in each segment of the oviduct is proportionate to the function of the segment:

- Infundibulum – 15-30 min
- Magnus – 3 hrs
- Isthmus – 1.25 hrs
- Uterus – 20-21 hrs

Egg Production

Egg shell is approximately 40% calcium carbonate crystals (CaCO₃)

High levels of dietary calcium are required for hens during egg production:

- Dietary calcium is not directly used in egg shell formation
- Replaces used calcium from bones
- Most of the calcium used for shell formation is released by the medullary bones

- Ribs
- Femur
- Tibia
Hens usually lay eggs on several consecutive days • Number of eggs in a row is called the clutch length
  - Leghorn hens which have been bred for egg production have very long clutches
  - Broiler breeder and turkey hens have shorter clutch lengths

Hens must have dark hours to initiate egg production
  - LH is released 1 hr after dark
  - Too little dark will reduce clutch length

Learning evaluation

Why is it important to expose a hen to dark hours?

LH release only occurs during dark periods, therefore darkness is required for egg production. Too few dark hours will result in the number of consecutive LH releases to be reduced, resulting in short clutch lengths.
Learning evaluation

Critical thinking:
How is the process of shell formation affected by heat stress?

Heat stress leads to panting, causing a drop in carbon dioxide levels. To balance pH in blood HCO₃⁻ is excreted resulting in a decrease in raw materials for eggshell formation. Decreases feed intake also therefore decrease in calcium consumption. Potential for formation of thin shelled eggs.