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External description and morphometrical comparison of midgut development in domestic chicken (*Gallus gallus domesticus*) and duck (*Anas platyrhynchos domesticus*) embryos

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Abstract

Domestic bird embryos are considered one of the main models for studying prenatal development. This work presents the general macroscopic development and compares midgut growth in local chickens and ducks. One hundred and four fertilized chicken eggs and one hundred and forty fertilized duck eggs were obtained from Mosul city and placed in an automatic incubator with ventilation, sixty percent humidity, and a temperature of 37.7ºC for chickens and 37.5ºC for ducks. The morphometrical study measured the length of the embryos after separation from the fetal membranes and the length of the small intestine parts using an electronic vernier. The results showed identical macroscopic development between the two species during the early stages. In the first trimester of incubation, the small intestine formed like a small tube, where the three parts of the intestine cannot be distinguished. During the second trimester of incubation, the intestine continued to protrude, rotate, and extend out of the abdominal cavity from the yolk stalk. In the third trimester of incubation, the intestines begin to retract into the abdominal cavity. During the incubation period, significant variances appeared among the lengths of the embryos and between the lengths of the small intestine parts, except for the last two days of the incubation period, where no significant differences were found. In conclusion, the birds' most significant differences and rapid physical and embryonic development and midgut occurred in both birds' second and third trimesters of the incubation period.

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Introduction

Poultry farming is important and impacts the global economy. It plays a key role in securing animal protein, such as meat and eggs, with high nutritional value and at reasonable prices compared to the prices of meat and other animal derivatives (1). Raising chicks and ducks, especially, set up one of the greatest progressive protein manufacturing systems in the world. The digestive system of any animal is a typical system that is vital in altering the spent food into nutrients that the body requires for growing and manufacturing (for example, eggs) (2). In chicks and ducks, the digestive system begins with the mouth and ends with the anus (3). The small intestine is characterized by its simplicity and relatively short length, but it is highly efficient. It extends from the pyloric end of the stomach to the area connecting to the colon and the cecum. It turns around and forms a series of intestinal loops inside the abdominal cavity. The small intestine divides into three parts: the duodenum, the proximal jejunum, and the distal ileum (4). The study of embryonic development in fowls is vital because it clearly outlines the stages of embryonic growth (5). Embryonic development includes several important stages, the result of which are three germ layers: the ectoderm, the mesoderm, and the endoderm (6-7). The stage of organogenesis is the most important stage of

development in which the embryo can live, and the cells differentiate from less specialized to more specialized. The gastrointestinal channel develops from the endo-derm enclosed by the visceral mesoderm, it begins to differentiate on the third day of incubation into a primary, middle, and posterior intestine (8-11). The primitive mid-gut is linked to the yolk sac through the vitelline duct, so the walls of the intestine and the yolk sac are continuous (12). The length of the small intestine in chicks is about 1.5 meters on average. However, it must be packed to fit the narrow space of the body cavity. This problem is eliminated by forming loops identified early in embryonic development. At the same time, any elongation in the midgut that exceeds the elongation of the embryonic axis is forced into the loop that wraps ventrally in a place outside the abdominal wall (inside the yolk stalk in fowls) on about the fifth day in chick embryos. On the sixth day, the loop of the duodenum and caecum is developed (13-14). It is possible to obtain 90 degrees of rotation in the subsequent days. The gut undergoes a further 180° counterclockwise rotation before being pulled into the body region late in development (just before hatching) (14-15). A few scientific papers have documented the developmental morphology of the digestive system in certain fowl species (16-19).

However, limited data is available on developing the small intestines of chicks and ducks. Accordingly, the current study aims to expand the existing knowledge regarding the developmental morphology of the midgut in domestic chicks and duck embryos to provide a database for academic lecturers, students, and researchers.

Materials and methods

Ethical improvement

College of Veterinary Medicine, University of Mosul, has permitted the current work through ethical approval document No.: UM.VET.2022.061.

Embryo preparations

One hundred four fertilized eggs from domestic chicks and 140 fertilized eggs from domestic ducks were collected from the city of Mosul from September 2022 to the beginning of January 2023 and placed in an automatic incubator with ventilation, humidity of sixty percent, and temperature of thirty-seven and seven out of ten degrees Celsius for chickens and thirty-seven and five out of ten degrees Celsius for ducks.

Separation, macroscopic examination, and fixation of embryos

Embryos were separated according to (20). The morphological description and morphometrical parameters of the embryos and small intestine parts were studied using a dissecting microscope (Huma scope stereo 14900/5, Germany), a naked eye by using the numerical Vernier (LOUISWARE, China), and a measuring tape (21). The embryos from 2-6 days of incubation were fixed in Bowen's solution, and the embryos of 7-21 days of age for domestic chicks and 7-28 for domestic ducks were fixed in the neutral buffer formalin. The embryos of 14-21 days of incubation for chicks and 14-28 days of incubation for duck were dissected, and the intestine was separated and placed in neutral buffer formalin (22).

Gross measurements of embryos

The length of the embryos was measured using the numerical Vernier (LOUISWARE, China) and a measuring tape before fixing them in the buffer formalin. Then, the fixed embryos were dissected after 14-21 days of incubation in chicks and 14-28 days in ducks. The intestine was separated, and the length of the duodenum, jejunum, and ileum was measured using the digital Vernier.

Statistical analysis

Means and standard errors were calculated for the standard variables (macroscopic measurements) using the Statically Package for Social Sciences (IBM SPSS, v25 UK). After ensuring the normality of the data distribution, the independent samples t-test was used to find significant differences between the two types of birds. All tests were conducted at a significant value of $P \leq 0.05$ (23).

Results

The current work included studying the embryos' external appearance and the midgut's embryonic development in domestic chicks and ducks by taking anatomical measurements of the intestine during the incubation stages until the day of hatching.

Description of the external appearance and embryonic formation of domestic chicks and duck embryos

The external appearance of 48 hours incubated chicks and duck embryos looked like a P-shape letter; the head was large and curved towards the abdomen, and the heart looked like an S-shape letter, with a network of blood vessels that represented the right and left Omphalomesenteric arteries that connect the embryo to the external embryonic blood vessels (Figure 1). At 72 hours, the incubated chick embryo looked like a C-shaped letter because the forebrain had become almost at the level of the posterior brain, with an increase in the curvature of the head and tail towards the abdominal region. The brain consisted of three parts: the forebrain (Prosencephalon), the middle brain (Metencephalon), and the hindbrain (Rhombencephalon), and the optic vesicles were distinguished. In the duck embryo, the head size increased in volume and curved towards the abdomen, so the embryo looked like a P-shape letter (Figure 2).

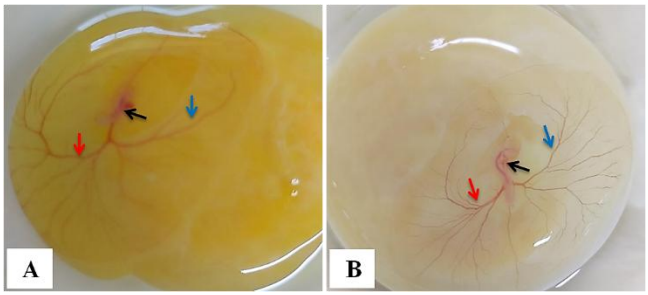

Figure 1: A: a chick embryo and B: a duck embryo, incubated for 48 hours. The blue arrow indicates the right mesenteric artery, the red arrow shows the left mesenteric artery and the black arrow shows the heart.

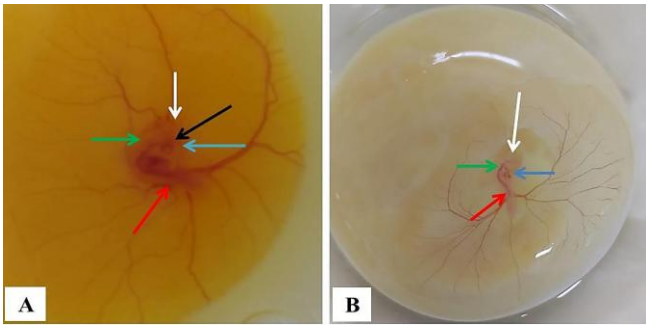

Figure 2: A: a chick embryo and B: a duck embryo, incubated for 72 hours. The blue arrow shows the forebrain, the green arrow shows the hindbrain, the white arrow shows the midbrain, the red arrow shows the tail, and the black arrow in the chick embryo shows the optic vesicle.

Also, 4 days incubated chick embryo still looked like a C-shape letter; the curvature of the head and tail increased towards the abdominal region more than the previous incubated age, and the head approached the tail. The parts of the brain increased in size; the optic vesicles were more distinguished than before, and the beginning of the appearance of terminal buds. The duck embryo was still in the form of a P-shape letter (Figure 3). In a five-day incubated chick and duck embryo, the head approached the tail, the appearance of the eye's lens increased in the length of the peripheral buds, and the differentiation of the beak region (Figure 4).

At six days of incubation, the chick's embryo showed an increase in the length of the wing and thigh buds, and the borders of the fingers were distinguished. In duck embryos, the beak region is notable. At seven days of incubation, the knee joint is prominent, and feather papillae begin to form on the back chick embryos only.

After eight days of incubation, chicks and duck embryos showed the appearance of eyelids, increased growth of the limbs, as more twisting appeared in the elbow joint, and more bending in the knee joint, clarity of the wing and thigh toes, the appearance of feather on the tail in chicks only, and the beginning of differentiation of the beak region in duck embryo. At nine days of incubated chicks and duck embryos, the eyelids surrounding both eyes and the circumference of the eye turned from circular to almost oval, the appearance of the beak prominent, with the differentiation of the wing limbs and the appearance of the web, the differentiation of the second and third toes, and the appearance of feather papillae on the head and tail with few papillae appeared on wing and leg area in chick's embryo only. At ten days of incubated chicks and duck embryos, the eyes took an oval shape, the clarity of the beak (upper and lower jaws), the appearance of feather papillae on the entire body of the chick embryo, and the beginning of the appearance of feather papillae on the back of duck embryo.

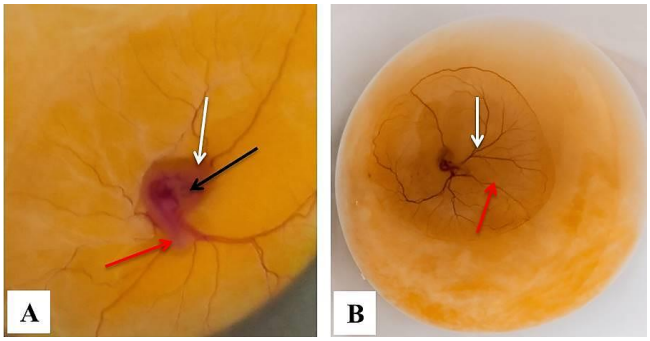

Figure 3: A: a chick embryo and B: a duck embryo 4 days old. The white arrow shows the head, the red arrow shows the tail, and the black arrow in the chick embryo shows the eye.

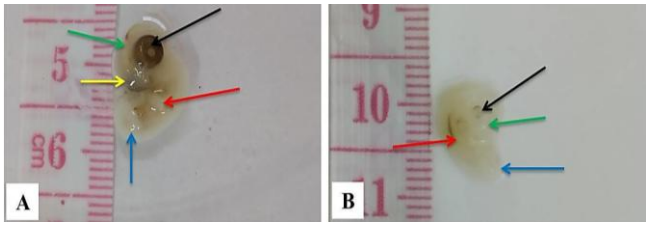

Figure 4: A: a chick embryo and B: a duck embryo 5 days old. The black arrow shows the eye, the green arrow shows the head, the blue arrow shows the tail, the red arrow shows the terminal buds and the yellow arrow in the chick embryo shows the beak.

At eleven days of incubation of chicks and duck embryos, the beak was more pointed, the wings and leg were fully formed with clarity of the web between the toes, the appearance of feathers on the back and wing in chicks with the beginning of the appearance of feather papillae on the back and feet of the duck embryo. After twelve days of incubation, the chick embryo noted an increase in the clarity of feather papillae on the head and eyelids. Feathers

cover the entire wing, while the neck and abdomen area are covered with a few feathers, with the beginning of the appearance of scales on the upper surface of the leg and the beginning of the exit of the intestine to circulate outside the abdominal cavity. Duck embryos noted the rise of feathers on the back, abdomen, tail, and head.

At thirteen days of incubation, the intestine of the chick embryo continues to rotate outside the abdominal cavity. In duck embryos, the eyes are oval and surrounded by eyelids, the feathers cover the back area, the feather papillae cover the entire body, and the beginning of the intestine rotates outside the abdominal cavity. After fourteen days of incubation, chick embryos showed that the feathers covered the embryos completely, the scales covered the upper and lower part of the leg, and the continuation of the intestine rotated outside the abdominal cavity. As for the duck embryo, the feathers covered the back and tail area with the beginning of the formation of the toenails.

During fifteen days of incubation, the intestine of the chick's embryo continues to rotate outside the abdominal cavity to take the desired shape. The duck embryo showed an increase in the length of the beak, and it appeared more rounded, and the feathers covered the back, feet, and neck. Sixteen days of incubation, the chick embryo showed an increase in the length of the feathers covering the embryo's body, and the intestine continued to rotate outside the abdominal cavity. As the duck embryo, the beak increased in width and was round, and the nails were prominent on the feet.

Seventeen days of incubation, the chick embryo showed the appearance of keratinization in the scales and toenails, and the intestine continued to circulate outside the abdominal cavity. The duck embryos noticed an increase in the length of the feathers that cover the entire body. At eighteen days of incubation, the chick embryo noticed the scales and toenails were keratinized, and the beginning of the withdrawal of the intestine into the abdominal cavity. The duck embryo was similar to the previous age.

Nineteen days of incubation, it was noticed that the chick embryo beak was more pointed and shinier than previous ages, the withdrawal of the yolk sac into the abdominal cavity, and the entry of the intestine into the abdomen. In duck embryos, the beginning of the formation of scales on the feet and the increase in the width of the beak are noticed. After twenty days of incubation, the chick embryo showed an increase in keratinization of nails and foot scales, the beak had a pointed frontal edge, the yolk sac completely entered the abdominal cavity with the entire intestine entering inside the abdominal cavity with the obstruction of the umbilicus, where the beak of the embryo towards the air hole to start clicking the shell to hatch. In duck embryos, the eyes were completely covered with eyelids, and the intestine continued to circulate outside the body, increasing the length of the toes.

Finally, after twenty-one days of incubation, the chick embryo was fully formed with the umbilicus obstructed. The embryo was wet during hatching (Figure 5). The duck embryo showed a noticeable increase in the toenails on the same day of incubation. The feet with the peritoneum and scales that cover them were fully formed, and the intestine continued to circulate outside the body. At 22-24 days of incubation, the duck embryo's beak was wider than the previous ages. 25-day incubation, the duck embryos showed a noticeable increase in body mass macroscopically, with an increase in the width of the beak. In 26-day incubation, the intestine and yolk sac began to enter the abdominal cavity. In 27-day incubation, the intestine and yolk sac entered the abdominal cavity completely, and the umbilicus was obstructed. The embryo's beak was towards the air hole to prepare for hatching. Finally, during 28-day incubation, the duck embryo appeared fully formed, the umbilicus obstructed, as the embryo at hatching was wet (Figure 6).

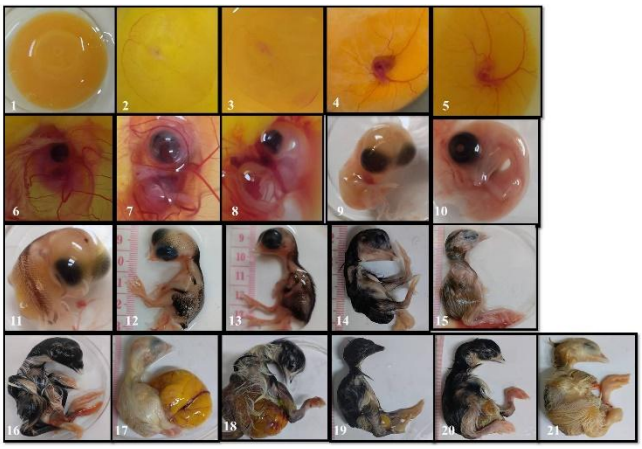

Figure 5: A macroscopic image of the chick's incubation stages from the first day until the hatching. The numbers show the incubation days in sequence.

Measuring the lengths of domestic chicks and duck embryos

The present work presented that the length of the embryos began to increase gradually from 3 days of incubation in domestic chicks and ducks till the hatching, where significant variances appeared among the lengths of the chicks' embryos during incubation days, except for days 6 and 7, days 17 and 18, and days 20 and 21 where no significant differences appeared between them (Figure 7). As for the lengths of the duck embryos, there were significant differences during the incubation days, except for days 24 to 27, where no significant differences appeared between them (Figure 8).

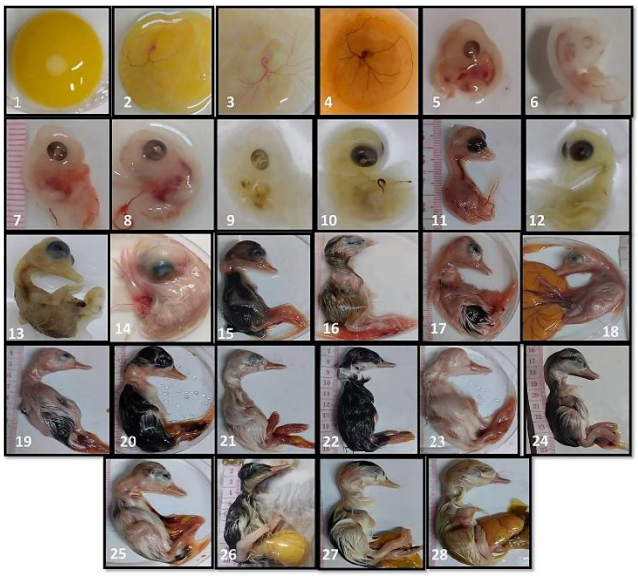

Figure 6: A macroscopic image of the duck incubation stages from the first day until the hatching. The numbers show the incubation days in sequence.

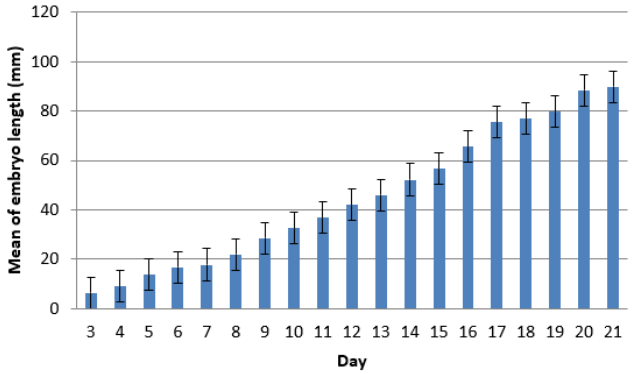

Figure 7: The mean of total length and standard error of the mean of the chicks' embryos during the incubation period.

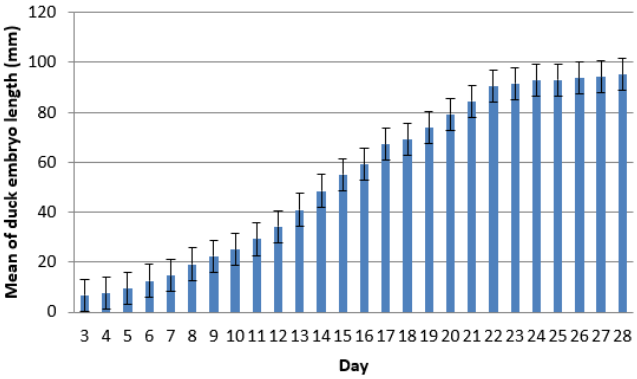

Figure 8: The mean of total length and standard error of the mean of the duck embryos during the incubation period.

Macroscopic anatomical examination of the midgut in domestic chicks and duck embryos

The anatomical study of the small intestine showed that it occupied a large part of the abdominal cavity, extended from the pyloric end of the stomach to the area where the jejunum connected with the two caeca. The intestine increased in length from the age of 14 days till the hatching for both kinds of fowls.

The first trimester is from 1st-7th days of incubation in chicks and 1st-9th days of incubation in ducks

The small intestine was at the beginning of formation as a small tube, where the three parts of the intestine could not be distinguished.

The second trimester is from 8th-14th days of incubation in chicks, 10th-18th days of incubation in duck

The small intestine was still a small tube, and it was impossible to distinguish between the three parts on days 8, 9, 10, and 11 in the chick's embryo and 10, 11, and 12 in the duck embryo. But at 12 days of incubation in chicks and 13 days in ducks, the intestine came out of the abdominal cavity to turn, elongate, and take the correct shape of loops (Figure 9). The anatomical study of the chick embryo incubating for 14 days and the duck embryo incubating for 18 days using a stereo-microscope showed that the small intestine was located in the right part of the abdominal cavity and began to elongate. The U-shape consisted of the ascending and descending duodenum, and the pancreas was positioned between the two arms of the duodenum. As for the jejunum and the ileum, they formed a group of loops outside the abdominal cavity (Figures 10 and 11).

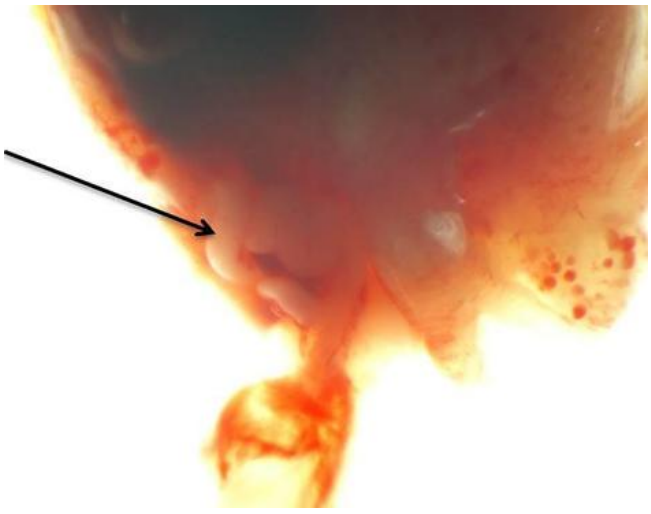

Figure 9: A stereo-microscopic image of a chick embryo incubated for 12 days. The black arrow shows the exit of the intestine outside the abdominal cavity for rotation (7X).

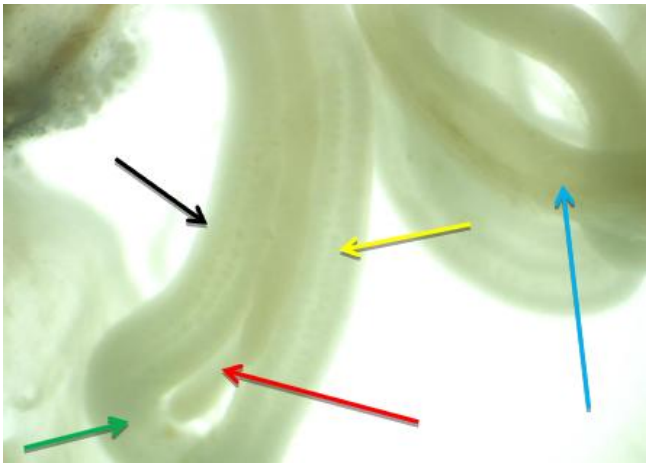

Figure 10: A stereo-microscopic image of the intestine of a chick embryo incubated for 14 days. The red arrow shows the pancreas, the black arrow is the ascending duodenum, the yellow arrow is the descending duodenum, the green arrow is the cranial flexure of the duodenum, and the blue arrow is the jejunum (10X).

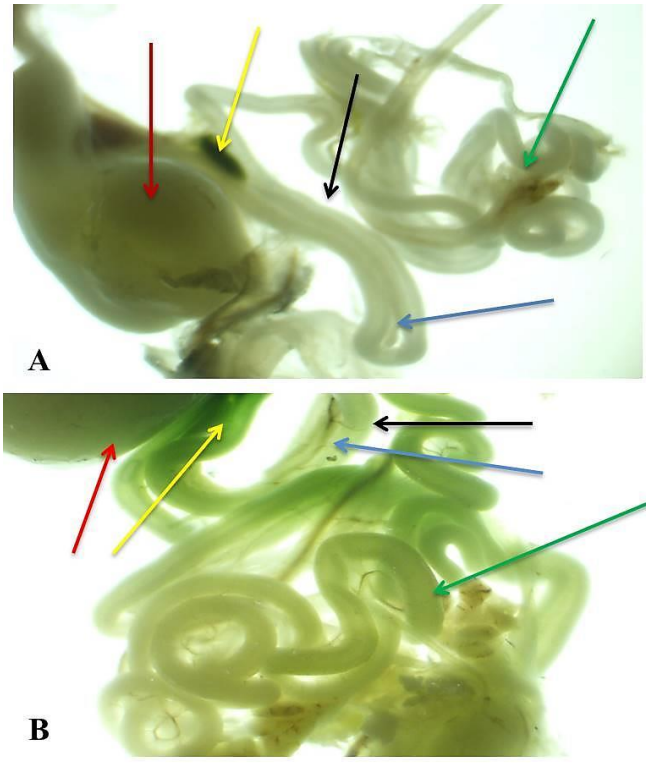

Figure 11: A stereo-microscopic image, A: a chick embryo incubated 14 days and B: a duck embryo incubated 18 days. The red arrow is the gizzard, the black arrow is the duodenum, the blue arrow is the pancreas, the yellow arrow is the gall bladder, and the green arrow is the jejunal and ileal loops (7X).

The third trimester is from 15-21 days of incubation in chicks, 19-28 days of incubation in duck

The intestine was fully formed and present inside the abdominal cavity with the entry of the yolk sac into the abdomen, in addition to the clarity of the Meckel diverticulum separating the jejunum and the ileum (Figures 12 and13).

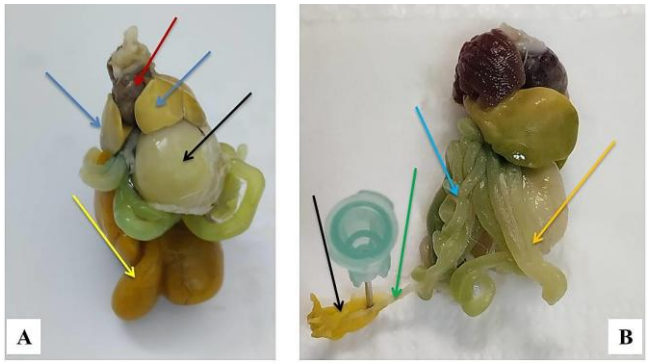

Figure 12: A macroscopic anatomical image of a chick embryo incubated for 21 days, A: (dorsal view) showing the parts of the digestive system and its adjacent organs. The red arrow is the heart, the blue arrow is the liver, the black arrow is the glandular stomach, the yellow arrow is the yolk sac, B: (lateral view) showing the duodenum, the blue arrow is the ileum, the green arrow is Meckel's diverticulum and the black arrow is the yolk sac.

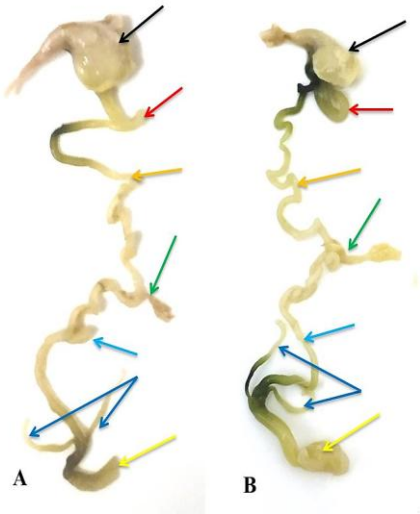

Figure 13: Macroscopic anatomical image showing gastrointestinal tract, (A) 28-day-old duck embryo, (B) 21-day-old chick embryo. The black arrow shows the gizzard, the red arrow the duodenum, the orange arrow the jejunum, the green arrow the Meckel diverticulum, the light blue arrow the ileum, the dark blue arrow the cecum, and the yellow arrow is the rectum.

Measurement of small intestine length in domestic chicks and duck embryos

The present work presented that the small intestine began to increase in length significantly and gradually from day 14-21 in chicks and day 14-28 in ducks. For the duodenum, jejunum, and ileum in chick embryos, significant differences appeared in their lengths during incubation days, except for days 20 and 21, where no significant differences appeared between their lengths (Figure 14). As for the lengths of the parts of the small intestine in duck embryos, significant differences also appeared during incubation days, except days 26 and 27 for the duodenum, days 17 and 18, and the last three days before hatching for the jejunum, and days 22, 23, 26 and 27 for the ileum where no significant differences appeared between their lengths (Figure 15).

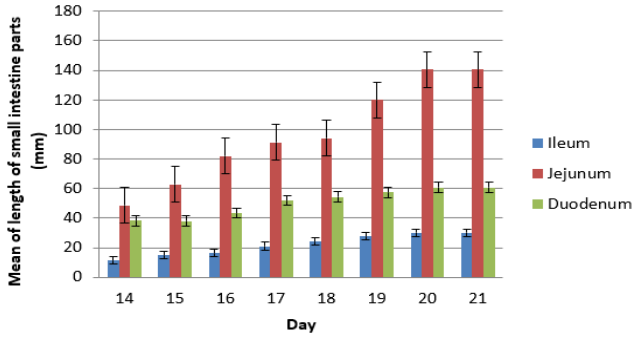

Figure 14: The mean of total length and standard error of the mean of the parts of the small intestine of the chick embryo during the incubation period.

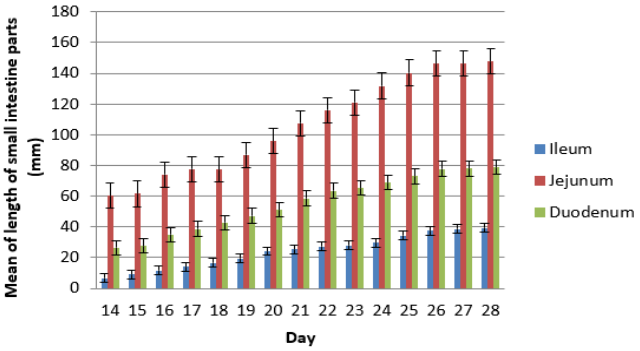

Figure 15: The mean of total length and standard error of the mean of the 3 parts of the small intestine of the duck embryo during the incubation period.

Discussion

This is the first comparison study of the midgut development between domestic chicks and duck embryos. The domestic chick, *Gallus gallus domesticus*, is one of the most preferred animals for embryonic study (24-25). The current embryological study of a 48-hour-old domestic chicks and duck embryo showed that the embryo looked like a P-shape letter with the formation of the right and left mesenteric arteries. This outcome is consistent with Hamilton (26) in his reading of embryonic formation in chicks and agrees with Ainsworth *et al.* (20) in their revision of the stages of embryonic development of the Japanese quail Coturnix because of the similarity in the development of the first five days of incubation in chicks, duck and Japanese quail embryos.

As a 72-hour-old appeared to look like a C-shape letter, where the forebrain was parallel to the hindbrain, and the optic vesicle was observed for the first time, this result is consistent with Ainsworth *et al.* (20) in their reading of the fetal development of Japanese quail, and with Toledo Fonseca *et al.* (27) on the fetal development of the chicks fowl from the first day to 19 days of incubation, as they mentioned that the brain vesicles were evident in the third day of incubation.

At 4 days of incubation, an increase in the curvature of the head and tail towards the abdominal side was observed, and the optic vesicles were more distinguished than ever. This outcome is consistent with Hamilton (26) in his study of the chick's fowl embryo and with Hamburger and Hamilton (28) in their reading of stages embryonic formation in the chick's fowl, where they confirmed that the embryo at this age has C-shape letter with the appearance of the optic vesicles, and with Toledo Fonseca *et al.* (27) during their study of the fetal development of chicks, where they noticed the optic vesicles for the first time in the fourth day of development.

At 5 and 6 days of incubation, the chick's embryo was distinguished by the appearance of the beak region and the eyes' lens, and this is consistent with Hamilton (26) in his study of the chick embryo and with Ainsworth *et al.* (20) in their reading of the Japanese quail embryo due to the similarity of the embryonic development of fowls in the first 5 days of incubation, and with Toledo Fonseca *et al.* (27) in their reading the fetal development of chicks, they noticed in the fifth day of incubation the beginning of eyes' lens formation. As for the duck embryo at the same age of incubation, the beak region did not differentiate yet, and this is steady with what was stated by Lumsangkul *et al.* (29) in their reading of the stages of fetal development of duck and geese, and with what was mentioned by Schneider and Helms (30) and Schneider *et al.* (31) for the development of the beak in duck embryos, this is due to the similar developmental characteristics between chicks, duck and geese embryos, except for the variance in growth and the length of the incubation period.

In a 7-day-old, an increase in the growth of wings and legs, the differentiation of the knee joint with the beginning of the formation of feather papillae on chick embryos, and this is consistent with what was mentioned by Hamilton

(26) on the chick's embryo, and with Hamburger and Hamilton (28) in their reading of the stages of embryonic formation of the chick's fowl. As for duck embryos, feather papillae did not appear on this day of incubation, and this is consistent with what was mentioned by Schneider and Helms (30), Schneider *et al.* (31), and Wu *et al.* (32) in their reading of the embryonic development, as they mentioned that the feather follicles in geese appeared in 8 days of incubation. While Lumsangkul *et al.* (29) mentioned in their reading of the phases of embryonic growth in ducks and geese, an 8-day-old embryo presented the start of the differentiation of the beak area and feather follicles and an increase in the elbow joint curvature. This result is consistent with this study's results about the appearance of feathers and the beginning of beak region differentiation in 8-day-old duck embryos.

A 9-day-old embryo showed a clear protrusion of the beak. A 10-day-old embryo showed oval eyes with eyelids surrounding them, clearing the upper and lower part of the beak, and the appearance of feather papillae on the entire body of the chick embryo. While an 11-day-old showed an increase in body mass and embryo length, with the appearance of the peritoneum between the toes and feathers on the back of the chick embryo, while the 12-day-old-chicks-embryo and the 13-day-duck embryo, the intestine exited to rotate outside the abdominal cavity, this outcome is consistent with what was stated by Davis *et al.* (13) and Soffers *et al.* (14) who mentioned that the length of the small intestine exceeds the length axis of the embryo, and this is why the intestines exit for rotation and elongation inside the yolk sac in fowls.

As for days 14 to 19 days in chicks and from day 14 to day 26 in ducks, the intestine began to withdraw into the abdominal cavity, especially at the end of the incubation period; scales appeared on the upper surface of the leg in chicks and duck, with the continuation of keratinization of the beak and scales, the completion of the growth of the toenails which hooked to inside with the continuation of their length. At 21 days of incubation in chicks and 28 days in ducks, representing the hatching day, the embryos were completely shaped, and the belly button was locked. These morphological characteristics of the current study agree with what was mentioned by Hamilton (26), Toledo Fonseca *et al.* (27), and Hamburger and Hamilton (28) in their reading of embryonic development in chicks, as well as with what was stated by Ainsworth *et al.* (20) in their reading of the stages of fetal development of the Japanese quail. Perhaps this similarity in the morphological characteristics is due to the use of the same genera in the studies and the fact that the domestic chick fowl and the Japanese quail belong to the same family, Phaslanidae.

This work also presented that the small intestine appeared in chick embryos on the third day of incubation and on the fourth day in duck embryos (33). In the first trimester of incubation, the researchers Savin *et al.* (34) mentioned that the small intestine began on the sixth day of incubation to form the duodenum loop, the small intestine, and the cecum, and this is consistent with this study about the time of the appearance of the small intestine in the form of a small tube in 7 days of incubation in chicks and 9 days of incubation in duck.

In the second trimester of incubation, a chick embryo of 12 days of age and a duck embryo of 13 days of age showed that the small intestine began to exit, switch, and extend outer the abdominal cavity in the yolk stalk, this outcome is consistent with what was stated by Davis *et al.* (13) and Soffers *et al.* (14) who mentioned that any elongation in the intestine that exceeds the elongation of the embryo axis lead to force the intestine to enter into rings that wrap ventrally inside the yolk stalk in fowls.

In the last trimester of the incubation, the embryo showed that the small intestine started from the end of the pyloric stomach and ended at the junction of the ileum with the two caeca. The jejunum started from the end of the duodenum, where the bile duct was located with the pancreas, and the ileum began from the end of the jejunum to meet the two caeca. The jejunum and the ileum were a group of loops, this outcome is steady with what was stated by Zaher *et al.* (4) in their anatomical and histological study of the digestive system of fowls and with what was stated by Calhoun (35) in his study of the anatomy of the digestive system in chicks, who mentioned that the small intestine extends from the pyloric end of the stomach to the area where the small intestine connects to the colon and the cecum.

The current study showed that the jejunum and the ileum were almost similar in diameter and length macroscopically, and it was impossible to distinguish between them except by the Meckel diverticulum, a protrusion on the surface that separates them. This outcome is consistent with Gofur (36) 's review of Meckel's diverticulum in animals and fowls. The present work also presented that the small intestine began to withdraw and entered the abdominal cavity in 19 days of incubation in chicks and in 26 days of incubation in ducks to be in the day of hatching inside the abdominal cavity with the umbilicus completely blocked, this outcome is consistent with what stated by Davis *et al.* (13); Soffers *et al.* (14) and Southwell (37), who said that the small intestine begins to withdraw in the last days of incubation and just before hatching.

The present work also showed that the small intestine began to form loops and elongated to its appropriate length. This outcome is consistent with what was stated by Nerurkar *et al.* (15) and Savin *et al.* (34) in their reading of the growth and development of the intestine, who said that the process of torsion and formation of intestinal loops are molecular signals that determine the rate of development in chick embryos. The current anatomical and morphometrical study presented the length of the bird and the length of the

duodenum, jejunum, and ileum. During the incubation period, significant variances appeared among the lengths of the embryos and between the lengths of the small intestine parts, except for the last two days of the incubation period, where no significant differences were found. Increasing the length of the bird and its intestine parts with the progress of the incubation days in each of the domestic chicks and duck embryos which was directly proportional to the body size, and this outcome is consistent with what was stated by Wang and Peng (18); Iji *et al.* (38); Applegate *et al.* (39) and Wang *et al.* (40), where their results showed that the body size increases and is directly proportional to the length of the small intestine (in broiler embryos, ostrich embryos, turkey embryos and duck embryos) with the progress of incubation days, and the development of the small intestine varies with the diversity of animals, and with what mentioned by Hassouna (41) in his anatomical and morphometrical study of the intestine in chicks, duck, goose, turkey, pigeon, dove, quail, sparrow, heron, jackdaw, hoopoe, kestrel and owl, who said that the length of the intestine increase with age; and by Ibrahim *et al.* (42); Mustafa (43), Al-Hamdany and AL duleemy (44), Alkhashb *et al.* (45), Al-Hamdany and AL-arajee (46) and Mustafa *et al.* (47) in their studies of different types of birds.

Conclusion

This study presents several significant contributions to embryonic growth and development in domestic chicks and ducks. Firstly, it offers a comprehensive and detailed description of the developmental phases, offering new insights into the embryological growth of these fowl classes. Secondly, it elucidates the morphological variances among chicks and duck embryos hatched in similar environments, thoroughly characterizing these variations. Lastly, studying an embryonic development structure for the small intestine in chicks and ducks presents novel models for studying waterfowl growth. The well-defined growth periods identified in this study will serve as valuable resources for future research, including molecular investigations into the morphological modifications of the small intestine in chicks and duck embryos.

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Conflict of interest

The authors declare that there is no conflict of interest in the publication of this work.

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الوصف الخارجي والمقارنة الشكلية القياسية لتطور المعي المتوسط في أجنة الدجاج المستأنس والبط المحلي

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الخلاصة

تعتبر أجنة الطيور الداجنة أحد النماذج الرئيسية لدراسة التطور ما قبل الولادة. يقدم هذا العمل التطور الكلي ويقارن نمو الأمعاء الوسطى في الدجاج والبط المحليين. تم الحصول على مائة وأربعة بيضات دجاج مخصبة ومائة وأربعين بيضة بط ملقحة من مدينة الموصل ووضعت في حاضنة أوتوماتيكية ذات تهوية ورطوبة ستون بالمئة ودرجة حرارة ٣٧,٧ درجة مئوية للدجاج و ٣٧,٥ درجة مئوية للبط. تم في الدراسة الشكلية القياسية قياس طول الأجنة بعد فصلها عن الأغشية الجنينية، كما تم قياس طول أجزاء الأمعاء الدقيقة باستخدام المسطرة الإلكترونية. أظهرت النتائج تطورا عيانيا متطابقا بين النوعين خلال المراحل المبكرة. في الثلث الأول من الحضانة، تكون الأمعاء الدقيقة على شكل أنبوب صغير، حيث لا يمكن التمييز بين أجزاء الأمعاء الثلاثة. خلال الثلث الثاني من الحضانة، استمرت الأمعاء في البروز والدوران والامتداد خارج تجويف البطن من ساق الصفار. في الثلث الثالث من الحضانة، تبدأ الأمعاء في التراجع إلى تجويف البطن. خلال فترة الحضانة ظهرت فروق معنوية بين أطوال الأجنة، وبين أطوال أجزاء الأمعاء الدقيقة الثلاثة، باستثناء اليومين الأخيرين من فترة الحضانة حيث لم تظهر أي فروق معنوية. في الختام، فإن أهم الاختلافات والتطور الجسدي والجنيني السريع للطيور وأمعائها الوسطى حدثت في الثلث الثاني والثالث من فترة الحضانة في كلا الطائرين.