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A study of the Histogenesis and development of the pancreas of the Pheasant (*Phasianus colchicus*) embryos

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Abstract

The main objective of this study was to investigate the histogenesis and development of the pheasant's pancreas during embryonic stages. Twenty-five fertilized pheasant eggs were placed in an incubator at 37.5°C and a humidity of 58 to 62%. Three pheasant embryos at ages 13, 15, 17, 19, 21 as well as three one-day-old chicks were collected. After tissue processing including dehydration, clearing and impregnation with melted paraffin samples were sectioned (5 micrometer) and stained with Hematoxylin and Eosin, Masson's Trichrome and Gomori's trichrome stains. The pheasant's pancreas began to form between days 13 and 15 days of the embryonic period. In the 17-day-old pheasant embryo, in addition to the dorsal lobe, the formation of the ventral lobe had also begun. Similar to the 15-day-old pheasant embryo, the pancreas of the 17-day-old embryo consisted of undifferentiated epithelial cells, connective tissue, and underdeveloped ducts, but the number of acinar cells had increased. In the 19-day-old embryos, the acinus was formed and mainly organized. Also, the Langerhans islands were observed at this age. In the 21-day-old embryo, the interlobular ducts were identified, and the formation of the Langerhans Islands had increased. In the 1-day-old pheasant chick, the exocrine part of the pancreas, the acinus, was more developed. The islets of Langerhans were also clearly visible, as these islands in the splenic lobe were more numerous than in the other lobes. In conclusion, the histogenesis of the pheasant (*Phasianus colchicus*) pancreas begins to form between days 13 and 15 days of the embryonic period, and continues until after hatch. The dorsal lobe demonstrated primary by initiating development first. The definitive pancreatic architecture was established through the sequential differentiation of key components. The endocrine islets of Langerhans emerged on day 19, followed by the maturation of the exocrine acinar tissue and the ductal system on day 21, marking the culmination of embryonic organogenesis.

Key words: Pheasant embryo, Pancreas, Histogenesis, Development

Introduction

The pancreas is one of the important exocrine and endocrine glands in vertebrates, holding–a special place in the body's physiology, playing a key role in regulating metabolism and food digestion (Alkhatib, 2024; Ariyaan et al, 2023; Karpińska and Czauderna, 2022; Lee and Lee, 2024; Peyghan et al, 2023). In birds, particularly wild species such as pheasants (*Phasianus colchicus*), the pancreas exhibits unique structural and functional characteristics that distinguish it from other animal classes (Hollwarth and Prieto, 2025). A correct understanding of the

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developmental stages of the pancreas during embryonic development can provide valuable insights into the processes of cellular differentiation, tissue organization, and the evolution of the digestive system in birds, and provide a suitable basis for comparisons between species.

During the embryonic period, the differentiation and development of body tissues are influenced by genetic, hormonal, and environmental factors (Sirard, 2021). Genetic factors, such as the Hox and Pdx1 genes, control signaling pathways that direct the formation of early pancreatic structures and the differentiation of specialized cells (Jensen, 2004). Hormonal factors, including insulin and thyroid hormones, modulate pancreatic growth and differentiation at various stages by regulating cell proliferation and the expression of specific genes (Chen et al, 2018). Environmental factors, such as incubation temperature and maternal nutrition, also influence the speed and accuracy of pancreatic development by altering gene expression patterns and hormone levels (O'Dowd and Stocker, 2013; Reusens and Remacle, 2006).

The pancreas originates from the primary digestive bud. It gradually develops into its mature form at different stages of development, featuring specific structures such as lobes, islets of Langerhans, and excretory ducts (Slack, 1995). The development of the embryonic pancreas typically begins with the formation of primary ductal-endothelial projections from the propancreatic endoderm (Olaniru et al, 2023). These projections then differentiate into individual pancreatic ducts, and through processes of branching and differentiation, they create the tree-like structure of the gland. The initial cell population gradually differentiates into its final fates, namely exocrine (acinar), endocrine (islets of Langerhans), and ductal cells, through induction by neighboring tissues and the expression of specific gene sequences (Ornellas et al, 2020; Rooman and Real, 2012). A detailed study of these developments in a species such as the pheasant, which is of interest to biologists due to its physiological characteristics and high resistance in various habitats, can shed light on the new aspects of the tissue development process.

The pheasant, a native bird of many regions of Asia, including Iran, has high ecological and economic value. Despite its importance, few studies have been conducted on the developmental aspects of this bird's internal organs (Al-Shuwaili et al, 2022; Gheshlagh et al, 2020; Khodadadi et al, 2019; Khodaparast and Nabipour, 2024). Previous studies have focused on behavioral, ecological, and nutritional aspects of the topic. Detailed knowledge of the structure and tissue development of the pancreas can lead to improved breeding methods, improved digestive health and efficiency, and a deeper understanding of its physiology.

Extensive studies have been conducted on the development of the pancreas in various birds, including chickens (Vertiprakhov et al, 2023) and ducks (Pieler and Chen, 2006), which have helped clarify the different stages of this organ's development. Although the processes of pancreatic development and differentiation in mammals and some bird species, such as domestic chickens, have been well studied, there is very limited information on how these processes occur in wild birds, especially pheasants (*Phasianus colchicus*). This knowledge gap is clearly noticeable. There are no systematic histomorphological data on the early stages of pancreatic formation, including the differentiation of acinar, ductal, and islet of Langerhans cells, in pheasant embryos. Additionally, the correspondence or differences between this process and other bird model species have not been precisely determined. Therefore, the main objective of this study is to accurately and systematically characterize the stages of histogenesis and morphogenesis of the pancreas in the

pheasant embryo from the earliest stages of its formation until hatching and in 1-day-old pheasant chick.

Materials and methods

Separation of embryos and sampling

Twenty-five fertilized pheasant eggs were obtained from a pheasant egg production farm and transferred to the histology laboratory of the Faculty of Veterinary Medicine, Ferdowsi University of Mashhad. The eggs were placed in an incubator at 37.5°C and 58-62% humidity.

The incubation period in pheasant is about 23 days. Three pheasant embryos at ages 13, 15, 17, 19, 21 as well as three one-day-old chicks, were collected. Eggs were opened from the air chamber side, and the calcareous shell and membrane shell attached to it were removed. All these membranes were cut into a circle with fine scissors. Then, all the egg contents were poured into a Petri dish, and the embryo was removed from the amniotic sac. Embryos were placed entirely in Bouin's solution. However, in the case of larger embryos, the pancreas was dissected and placed separately in the mentioned fixative.

Histological analysis

The embryos were dehydrated in a series of ascending ethanol concentrations, cleared in xylene, and then embedded in paraffin. 5 µm-thick paraffin sections were obtained with a rotary microtome (Leica RM 2145; Germany). The sections were stained using Hematoxylin and Eosin (H&E) for general tissue morphology, Masson's trichrome for collagen fiber differentiation, and Gomori's for reticular fiber visualization. Following staining, the prepared slides were thoroughly examined and imaged using an Olympus DP2-BSW light microscope equipped with a digital camera DP-12 (Olympus). The histogenesis and development of the pancreatic tissue of pheasant embryos at mentioned ages as well as three one-day-old chicks were studied.

Results

13-day embryo

The primitive gut was observed developing at this age (Figure 1).

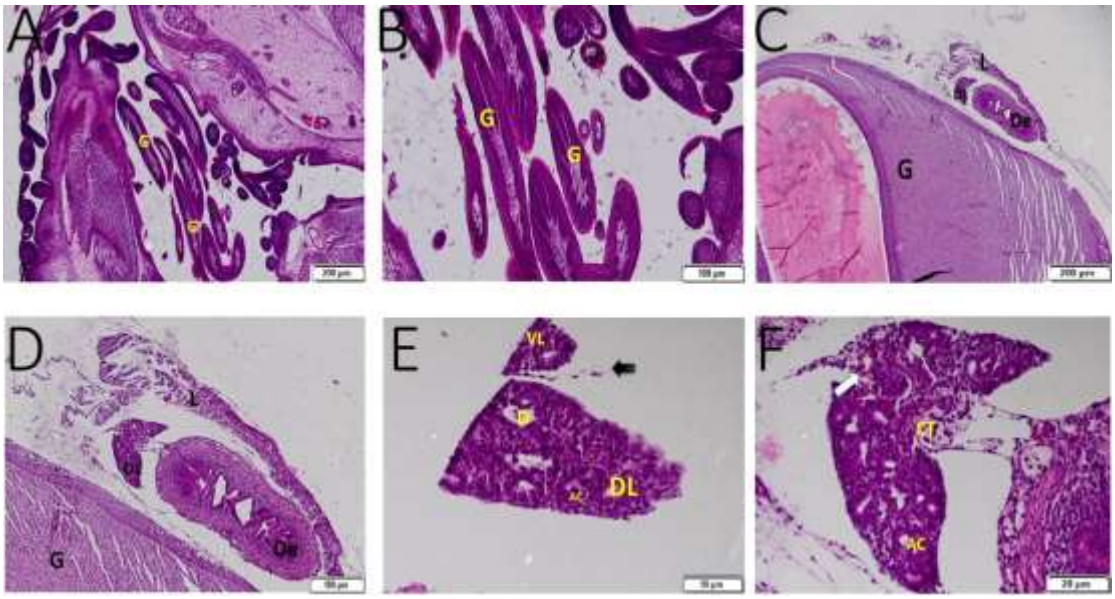

Figure 1: A) Showing the primary intestine in a 13-day-old pheasant embryo. Primary intestine (G). B) Showing the primary intestine (G) in a 13-day-old pheasant embryo. C and D) Showing the formation of the dorsal lobe of the pancreas in a 15-day-old pheasant embryo. Dorsal lobe (DL), duodenum (De), liver (L), gizzard (G). E) This figure shows the histological structure of the pancreas in a 17-day-old pheasant embryo. Dorsal lobe (DL), ventral lobe (VL), mesenchymal tissue separating the two lobes (arrow), duct (D), and acinar cells (AC). F) Showing the histological structure of the pancreas in a 15-day-old pheasant embryo. Connective tissue (CT), red blood cells (arrow), acini (AC). Hematoxylin and Eosin staining

15-day embryo

Early signs of pancreatic formation were observed at this age. Hence, it seems that the pheasant pancreas begins to form between days 13 and 15 of embryonic development. The pancreas was connected to the duodenum via a stalk, and it appears that the dorsal lobe of the pancreas is formed first, and the other lobes were not observed. The formation of the pancreas occurred near the liver. Regarding the histological structure of the pancreas in the 15-day embryo, the acini were not formed or were only partially formed in some areas, and arteries were observed. The pancreas consisted of undifferentiated epithelial cells, connective tissue, and undeveloped ducts. In addition, the islets of Langerhans were not formed in the 15-day embryo (Figure 1).

17-day embryo

In this age, in addition to the dorsal lobe of the pancreas, the formation of the ventral lobe had also begun. The dorsal lobe was noticeably larger than the ventral lobe. Moreover, the histological structure of the pancreas was similar to that of the 15-day embryo, with a decrease in the amount of connective and mesenchymal tissues and ducts. Still, the number of acinar cells had increased from the 15-day embryo. Therefore, the exocrine part of the pancreas develops more at this age. Blood vessels were also clear at this age. In addition, the islets of Langerhans were not observed at a 17-day embryo either (Figure 1).

19-day embryo

Concerning this age, all three lobes of the pancreas, including the dorsal, ventral, and splenic lobes, were observed. Moreover, the acini were largely organized and formed, and the exocrine part of the pancreas had grown. Ducts were observed. The connective tissue had fewer blood vessels compared to the 17-day-old age.

Due to the low connective tissue level, the lobules could not be distinguished. Acinar cells had spherical nuclei at the base of the cells. Signs of Langerhans islet formation were observed in the ventral lobe (Figure 2).

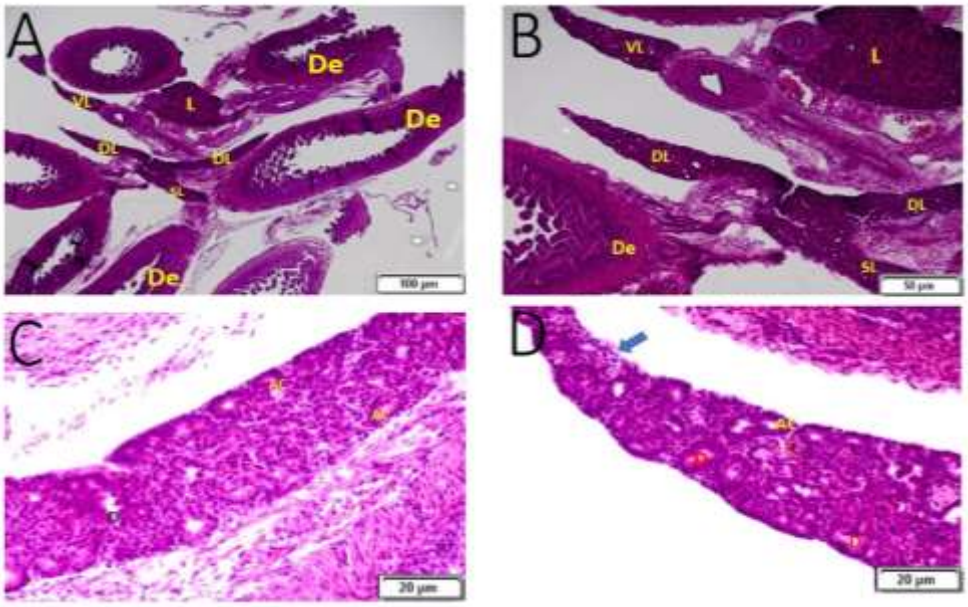

Figure 2: A and B) Represents the pancreas in a 19-day-old pheasant embryo. Dorsal lobe (DL), ventral lobe (VL), splenic lobe (SL), duodenum (De), and liver (L). C) Represents the histological structure of the dorsal lobe of the pancreas in a 19-day-old pheasant embryo. Acini (AC), duct (D). D) Represents the histological structure of the ventral lobe of the pancreas in a 19-day-old pheasant embryo. Acini (AC), ducts (D), islets of Langerhans (arrows), and erythrocytes (E) Hematoxylin and Eosin staining.

21-day-old embryo

In regard to this stage, the interlobular ducts were visible, and the formation of Langerhans islets had increased. However, intralobular ducts, such as intercalated ducts were not observed. The cytoplasm of the acinar cells was completely acidophilic, indicating the formation of zymogen granules containing enzymes. The centroacinar cell was not distinguishable at this age. Therefore, the exocrine part of the pancreas was fully developed (Figure 3).

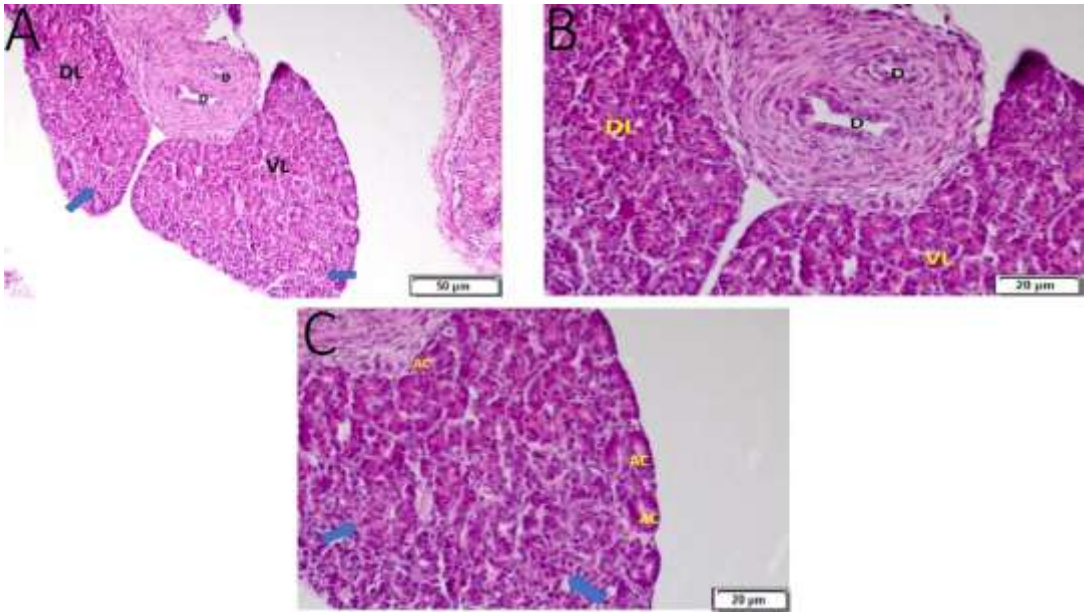

Figure 3: A) Shows the interlobular ducts of the pancreas in a 21-day-old pheasant embryo. Ducts (D), dorsal lobe (DL), ventral lobe (VL), and islets of Langerhans (arrows). B) Shows the interlobular ducts of the pancreas in a 21-day-old pheasant embryo. Ducts (D), dorsal lobe (DL), and ventral lobe (VL). Note the acidophilic cytoplasm of the acinar cells. C) Shows the histological structure of the pancreas in a 21-day-old pheasant embryo. Acini (AC) have cells with acidophilic cytoplasm, islets of Langerhans (arrows). Hematoxylin and Eosin staining.

1-day-old pheasant chick

In a one-day-old pheasant chick, the three pancreatic lobes, including the dorsal, ventral, and splenic lobes, were macroscopically distinct. The dorsal lobe was larger than the ventral lobe, and the splenic lobe was located anterior to the dorsal lobe. The splenic lobe was distinguished from the other two lobes by the greater concentration of Langerhans islets (Figure 4).

In relation to this age, the exocrine part of the pancreas had further developed. The islets of Langerhans were also clearly visible, with the number of these islets in the splenic lobe being higher than in the other lobes. Islets were also seen scattered in the ventral lobe. The amount of connective tissue and intralobular ducts was very low. The centroacinar cell was also not distinguishable at this age (Figure 5).

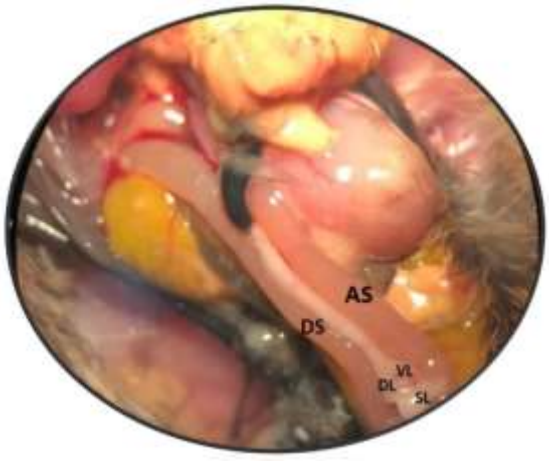

Figure 4: Pancreas in a one-day-old pheasant chick. Ascending duodenum (AS), descending duodenum (DS), dorsal lobe of the pancreas (DL), ventral lobe of the pancreas (VL), and splenic lobe of the pancreas (SL).

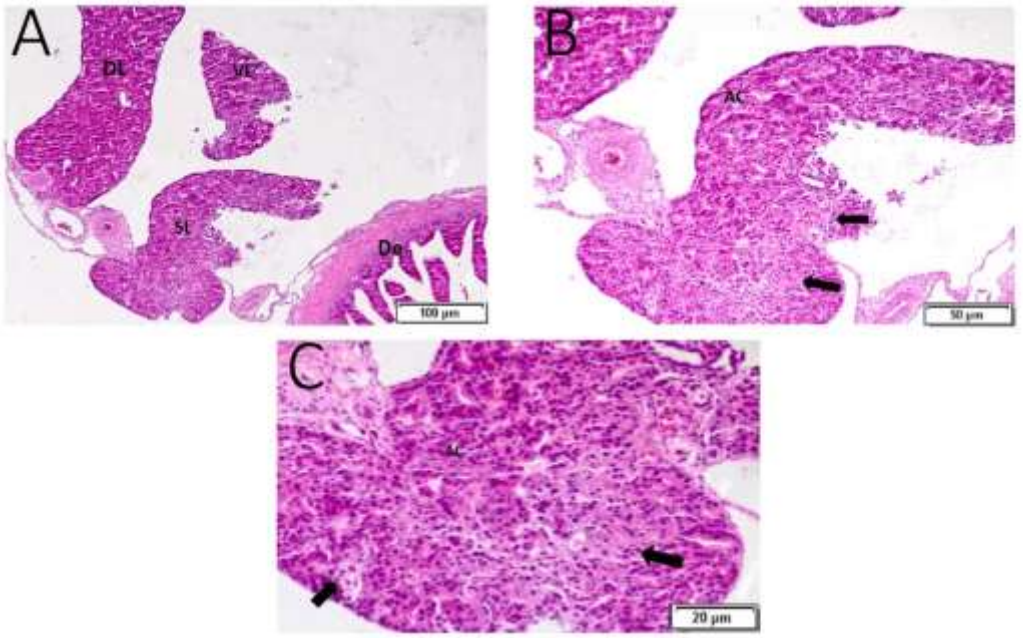

Figure 5: A) Represents the pancreas in a one-day-old pheasant chick. Dorsal lobe (DL), ventral lobe (VL), splenic lobe (SL), and duodenum (De). B and C) Histological structure of the splenic lobe in a one-day-old pheasant chick. Islets of Langerhans (arrows) and acini (AC). Hematoxylin and Eosin staining.

In Masson's Trichrome staining, the histological structure of the pancreas of the one-day-old chick was well differentiated and included dorsal, ventral, and splenic lobes. In the splenic lobe, acini, islet cells of Langerhans, and ducts were recognizable. Connective tissue and structural differentiation in the pancreas were observed. A one-day-old pheasant chick pancreas was histologically and functionally well-organized and active (Figure 6).

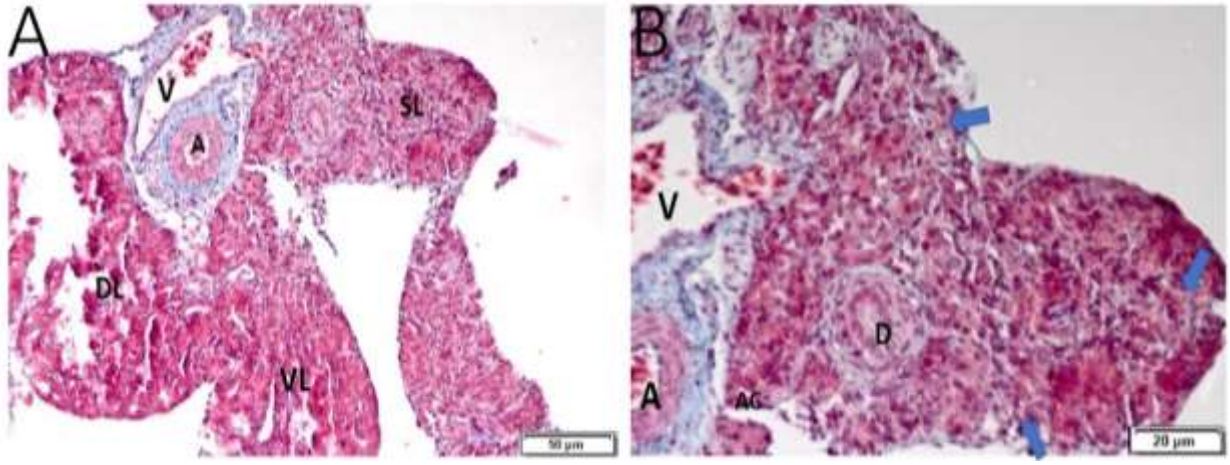

Figure 6: A and B) Shows the histological structure of the pancreas in a one-day-old pheasant chick. Dorsal lobe (DL), ventral lobe (VL), splenic lobe (SL), interlobular ducts (D), artery (A), and vein (V), Acini (AC), cells of the islets of Langerhans (arrows). A small amount of connective tissue is evident within the pancreas. Masson's Trichrome staining.

In Gomori's trichrome staining, the islets of Langerhans were observed in the pheasant embryo at 19 days. Langerhans islets were consisted of alpha and beta islets. The alpha islet cells had a slightly pale pink cytoplasm, and the beta cells were slightly basophilic or pale blue. Additionally, the alpha islets were larger than the beta ones. To ensure the correct functioning of the dye, staining was first performed on the pancreas of another species as a control sample (Figure 7).

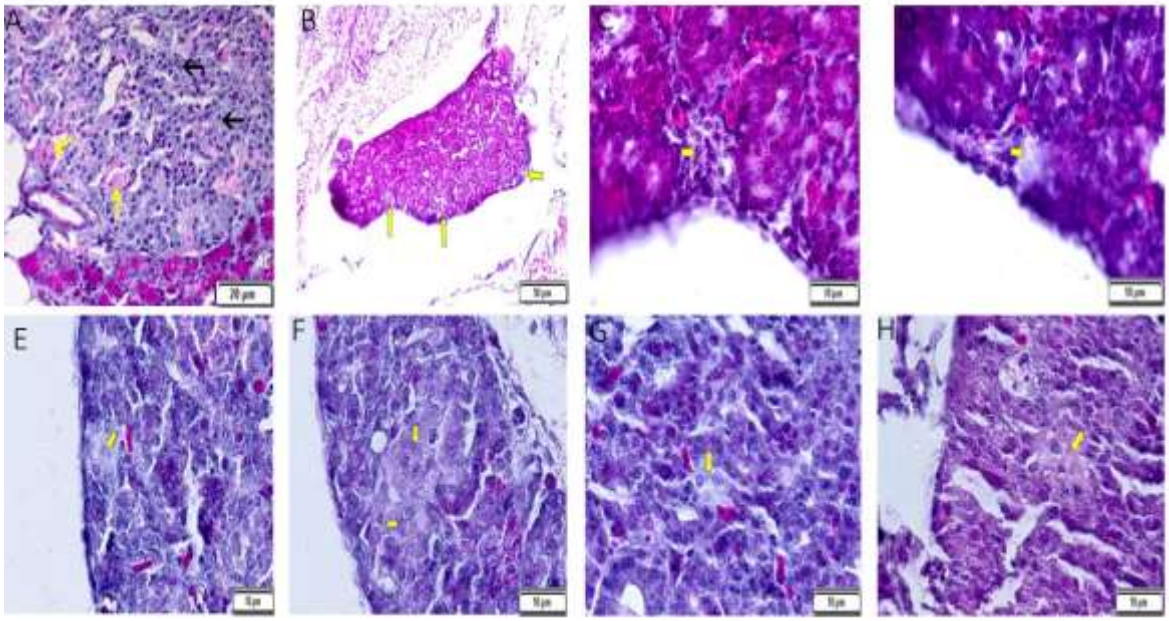

Figure 7: A) Shows the exocrine compartment and the islet of Langerhans in a guinea pig as a control. Acini (AC), alpha cells (yellow arrow), and beta cells (black arrow). B) Shows the islets of Langerhans (arrows) in the pancreas of a 19-day-old pheasant embryo. C) Shows the histological structure of the alpha islet (arrow) in the pancreas of a 19-day-old pheasant embryo. D) shows the beta islet (arrow) in the pancreas of a 19-day-old pheasant embryo. E) shows the beta islet (arrow) in the pancreas of a 21-day-old pheasant. F) Shows the alpha islet (arrow) in the pancreas of a 21-day-old pheasant embryo. G) Depicting the beta islet (arrow) in the pancreas of a one-day-old pheasant chick. H) Depicting the alpha islet (arrow) in the pancreas of a one-day-old pheasant chick. Gomori's trichrome staining.

Discussion

In the present study, the primitive pancreas was formed between days 13 and 15 of the embryonic period. The presence of blood vessels, such as arteries and veins, as well as limited connective tissue, suggested that this organ underwent early development and organization in the one-day-old chick. The pancreas of the pheasant had three lobes, including dorsal, ventral, and splenic, similar to that of the golden eagle (Al-Agele and Mohammed, 2012), guinea fowl (Pourhaji Motab et al, 2015), and ostrich (Stornelli et al, 2006). The pancreas of the goose (Beheiry et al, 2018), red jungle fowl (Kadhim et al, 2010), native chickens (Parchami and Kusha, 2015), crow (*Linnaecus corvus*), and Iraqi black partridge (*Melanoperdix niger*) have four lobes (Naser et al, 2024), including dorsal, ventral, splenic, and caudal. In the goose, the splenic lobe is connected to the ventral or dorsal lobes, or both (Beheiry et al, 2018). The splenic lobe is not connected to the other lobes in the Palam Dove (*Streptoplia selegalensis*) (Saadatfar et al, 2011). In the ostrich, the splenic lobe is not visible macroscopically but is microscopically seen in the anterior part of the dorsal lobe (Stornelli et al, 2006).

In our study, as well as in the red jungle fowl (Kadhim et al, 2010) and the ostrich (Stornelli et al, 2006), the pancreas

completely filled the space between the descending and ascending loops of the duodenum. However, the pancreas does not fill the space between the duodenal loops in the goose (Beheiry et al., 2018) and the golden eagle (Al-Agele and Mohammed, 2012). Moreover, the dorsal lobe was larger than the ventral lobe, and the splenic lobe was an extension of the dorsal lobe, located anterior to it. In the goose, the ventral lobe is larger than the dorsal lobe (Beheiry et al., 2018). In poultry, the ventral and dorsal lobes are of equal size, but in the guinea fowl, the ventral lobe is longer and narrower than the dorsal lobe (Pourhaji Motab et al., 2015). In the ostrich, the dorsal lobe is more developed and is located in the direction of the descending duodenal loop, and the ventral lobe is shorter. It is located adjacent to the ascending duodenal loop (Stornelli et al, 2006).

The exocrine part of the pheasant pancreas consisted of ducts and acini, and in our study, acini began to form on embryonic day 15, and ducts were formed on embryonic day 17. This indicates the early metabolic and secretory function at this stage of development. The acini cells were pyramidal, and the centeroacinar cell was not observed at any age. In the goose (Beheiry et al, 2018) and red fowl (Kadhim et al, 2010), the acini are pyramidal with a narrow lumen, and the acini's central cell, a slightly smaller and lighter cell than the acini, is located in the center of the acini's lumen. In the goose (Beheiry et al, 2018) and turkey (Mobini and Aghaabedi, 2009), the acini have two distinct regions, the apical part having basophilic cytoplasm and the basal part having acidophilic cytoplasm. In the turkey, the acini are pyramidal to cylindrical, with the nucleus at the base (Saadatfar and Asadian, 2009). In the Mynah (*Acridotheres tristis*), the acini are round to oval in shape with large granules, and the acini's central cell is absent (Saadatfar and Asadian, 2009).

Alpha, beta, and delta cells can be identified by immunohistochemistry in the 5-day-old chick embryo, but these cells cannot be identified by hematoxylin and eosin staining (Maňáková and Titlbach, 2007). In another study on the endocrine glands in the chick pancreas, on embryonic day 9, significant alpha and medium beta islets are identified in the splenic lobe and the third lobe (Rawdon and Larsson, 2000). Somatostatin cells are first observed at embryonic stage 26 H&H, and in older embryos, delta cells are located around the large alpha islets and are scattered in the exocrine parenchyma. In the present study, pancreatic islets were identified by hematoxylin and eosin staining and Gomori stains in the pheasant's embryonic stages, forming Langerhans' islets from embryonic day 19. Like other birds, Langerhans's islets of pheasant were composed of alpha and beta, with alpha islets appeared larger and more numerous than beta islets. The largest number of islets was concentrated in the dorsal and splenic lobes, and islands were rarely observed in the ventral lobe.

Most islets in the red jungle fowl are in the ventral lobe (Kadhim et al, 2010). In the mynah, alpha islets are more numerous than beta ones in the dorsal lobe and do not have a clear boundary with the exocrine part. Beta islets are spherical, brighter, and smaller than alpha islets, and are separated from the exocrine part by connective tissue. Beta islets are more numerous in the ventral lobe than alpha islets (Saadatfar and Asadian, 2009). The golden eagle has two types of islets. Alpha islets contain alpha, delta, and a few beta cells, and beta islets contain beta cells and a few delta cells located around the islet (Al-Agele and Mohammed, 2012). In the Palam Dove, beta islets are pale and separated from the exocrine part by a clear border. In the ventral lobe, beta islets are more numerous and smaller than alpha islets, but these islets are seen in all four lobes. Alpha islets are dark and have a more irregular shape. They occupy the periphery of the lobe, and in the third and dorsal lobes, the density of alpha islets is greater than that of beta islets.

Alpha islets are located in the splenic lobe. The islets are not distributed evenly throughout each lobe, so in the ventral lobe, they are concentrated in the central area, and in the dorsal lobe, they are concentrated around the central area (Saadatfar et al., 2011).

The islets of Langerhans in the ostrich are more concentrated in the splenic lobe and have two types of islets, alpha and beta (Stornelli et al, 2006). In ducks, the islets are not uniformly distributed throughout each lobe, with small islets around the ventral lobe and large islets in the central cylindrical region. In the splenic lobe, the islets are darker. In addition, the islets of the dorsal lobe are larger than those of the ventral lobe (McClish and Eglitis, 1969). In domestic fowl, three types of islets are found, with the endocrine part consisting mainly of beta islets, being more abundant in the splenic and third lobes. Alpha islets are absent in the ventral and dorsal lobes in both sexes (Parchami and Kusha, 2015). Mixed islets are not found in the goose (Beheiry et al, 2018), turkeys (Mobini and Aghaabedi, 2009), and golden eagles (Al-Agele and Mohammed, 2012).

Given the findings of this study on the progression of pancreatic histogenesis and histochemistry during the embryonic period of the pheasant, it is suggested that future studies should closely examine the molecular mechanisms and important cellular factors in the differentiation and organization of the endocrine and exocrine compartments of the adnexa, including the role of transcription factors-1, such as NPD. In addition, the use of advanced techniques such as electron microscopy to examine the ultrastructures of acinar cells and islets of Langerhans, as well as immunohistochemical methods to identify and quantify the types of main cells (insulin, glucagon, somatostatin) at different stages, can provide more effective insight into the functional maturation of the pancreas. In addition, comparison with other bird species, especially wild birds with different metabolic patterns, can help to understand the influence of experience and ecology on morphology and function. Investigating environmental factors, such as maternal diet and incubation conditions, on pancreatic development will also be valuable for future research. Ultimately, long-term studies are recommended to assess postnatal changes and their correlation with physiological adaptations in birds.

In conclusion, it seems that the pheasant pancreas begins to form between days 13 and 15 of embryonic development. The dorsal lobe demonstrates primacy by initiating development first. The definitive pancreatic architecture is established through the sequential differentiation of key components: the endocrine islets of Langerhans emerge on day 19, followed by the maturation of the exocrine acinar tissue and the ductal system on day 21, marking the culmination of embryonic organogenesis. It is recommended that the future studies focus on the molecular and hormonal mechanisms involved in cell differentiation and conduct comparative analyses with other bird species.

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Conflict of interest

The authors declare that they have no conflict of interest.

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مطالعه بافت‌زایی و تکوین لوزالمعده در جنین قرقاول

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چکیده

هدف اصلی این مطالعه بررسی بافت‌شناسی و تکوین لوزالمعده قرقاول در مراحل جنینی بود. تعداد ۲۵ تخم قرقاول بارور شده در انکوباتور با دمای ۳۷/۵ درجه سانتی‌گراد و رطوبت ۵۸ تا ۶۲ درصد قرار داده شدند. سه رویان قرقاول در سنین ۱۳، ۱۵، ۱۷، ۱۹ و ۲۱ و همچنین سه جوجه یک روزه قرقاول جمع‌آوری شد. بعد از آماده‌سازی بافت شامل آب‌گیری، شفاف‌سازی و آغشته‌سازی با پارافین مذاب، نمونه‌ها برش داده شد (۵ میکرومتر). برش‌ها با رنگ‌های هماتوکسیلین و ائوزین، ماسون تری‌کروم و گوموری تری کروم رنگ‌آمیزی شدند. لوزالمعده قرقاول بین روزهای ۱۳ تا ۱۵ دوره جنینی شروع به تشکیل کرده بود. در جنین ۱۷ روزه قرقاول، علاوه بر لوب پشتی، تشکیل لوب شکمی نیز آغاز شده بود. مشابه جنین ۱۵ روزه قرقاول، لوزالمعده جنین ۱۷ روزه شامل سلول‌های اپیتلیال تمایز نیافته، بافت همبند و مجاری توسعه نیافته بود، اما تعداد سلول‌های آسینار افزایش یافته بود. در جنین‌های ۱۹ روزه، آسینوس تشکیل شده و عمدتاً سازماندهی شده بود. همچنین، جزایر لانگرهانس در این سن مشاهده شدند. در جنین ۲۱ روزه، بین لوبی و مجاری دفعی اصلی شناسایی شدند و تشکیل جزایر لانگرهانس افزایش یافته بود. در جوجه قرقاول ۱ روزه، قسمت برون‌ریز لوزالمعده، آسینوس، توسعه یافته‌تر بود. جزایر لانگرهانس نیز به وضوح قابل مشاهده بودند، زیرا این جزایر در لوب طحال بیش‌تر از سایر لوب‌ها بودند. نتیجه‌گیری می‌شود بافت‌زایی لوزالمعده قرقاول بین روزهای روز ۱۳ و ۱۵ اتفاق می‌افتد و تا پس از هچ ادامه می‌یابد. تکوین لوب پشتی زودتر آغاز شده بود. ساختار بافتی لوزالمعده از طریق تمایز پی در پی اجزای کلیدی شکل می‌گیرد. جزایر لانگرهانس در روز ۱۹ رویانی ظاهر شدند و به دنبال آن بافت آسینی برون ریز و سیستم مجاری تکوین پیدا کردند که نقطه اوج تشکیل اعضای جنینی را نشان می‌دهد.

کلمات کلیدی: جنین قرقاول، لوزالمعده، بافت‌زایی، تکوین

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