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Comparative Study of Duodenal Histology in Three Type of Birds and Two Different Rations

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Abstract

General Background: The avian duodenum is the primary site of enzymatic digestion and nutrient absorption, and its morphology reflects dietary specialization and metabolic demands. **Specific Background:** Passerine birds such as the Canary (*Serinus canaria*), Zebra Finch (*Taeniopygia guttata*), and White-eared Bulbul (*Pycnonotus leucotis*) exhibit distinct feeding habits, including granivory and frugivory/insectivory, which may be associated with differences in duodenal microarchitecture. **Knowledge Gap:** Comparativehistomorphological data on the duodenum of these small passerines remain limited. **Aims:** This study aimed to compare the gross morphology, histological organization, and morphometric characteristics of the duodenum in the three species. **Results:** In all species, the duodenum formed a characteristic U-shaped loop surrounding the pancreas and consisted of four tunicae: mucosa, submucosa, muscularis, and serosa. The muscularis mucosa was absent in all birds. The White-eared Bulbul showed the greatest mucosal thickness and the highest goblet cell ratio (33.1%), whereas the Canary exhibited the longest villi and the thickest tunica muscularis. The Zebra Finch had the lowest mucosal thickness and shortest villi. Crypt depth was greatest in the Bulbul and Zebra Finch. **Novelty:** This study demonstrates species-specific duodenal histological patterns linked to contrasting dietary strategies in three passerine birds. **Implications:** These findings provide baseline anatomical and histological data that improve understanding of digestive adaptation and supportfuturecomparative and veterinary investigations in avian species.

Highlights:

- All species exhibited a U-shaped duodenal loop enclosing the pancreas and lacked muscularis mucosa.
- White-eared Bulbul had the highest goblet cell proportion and greatest mucosal thickness.
- Canary showed the longest villi and the thickest tunica muscularis among the examined birds.

Keywords: Avian Duodenum, Comparative Histology, Passerine Birds, Goblet Cells, Digestive Adaptation

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1. Introduction

Aves is class characterized by remarkable biological diversity , with Passeriformes being the largest and most ecologically successful order containing over half of all currently existing bird species [1].These birds , known as passerines or perching birds have evolved specialized physiological and anatomical adaptations that enable them to flourish in a variety of environments [2] . Iraq boasts a particularly rich avian fauna, and over the past hundred years numerous researchers have thoroughly documented the distribution and ecology of both indigenous and migratory species [3] .The digestive system of these birds serves as a primary interface with their environment due to its close relationship with their specific dietary niches. It is essential to comprehend the morphological variations in passerine gastrointestinal tracts , as closely related species can exhibit considerable histological differences depending on their diet : granivores like the Zebra Finch and Canary versus generalist feeders like the White-eared bulbul [4 ,5] .small passerines, in contrast to larger avian orders, have a high metabolic rate that requires a highly efficient digestive mucosal surface for rapid nutrient assimilation [6) . as the segment of the avian small intestine that is most proximal and physiologically active, the duodenum plays a key role . from an anatomical perspective it is defined by its unique U-shaped loop that encircles the pancreas ,serving as the main entry point for pancreatic enzymes and biliary secretions [7]. From a histological perspective, the duodenal mucosa is especially suited for optimal nutrient absorption; it generally features the longest and most developed villi in comparison to the jejunum and ileum, thereby offering a broad surface area for the initial stage of absorption [8].For small passerines such as the Canary, Zebra Finch, and White-eared Bulbul, the micro-architecture of the duodenum must allow for rapid enzymatic hydrolysis in order to compensate for a short intestinal transit time. Villus height and density, important histological markers of the bird's digestive capacity and health. Moreover, the placement of Goblet cells in the duodenal epithelium is crucial for the secretion of protective mucins that safeguard the sensitive mucosal lining from the acidic chyme coming from the gizzard [9].

2. Methods and Materials

During our research data collection, fifteen adult birds were utilized, sectioned into three species (n=5 per species): Canaries (Serinus canaria), Zebra finches (Taeniopygia guttata), and White-eared bulbuls (Pycnonotus leucotis). The specimens were purchased from local markets in Dhi Qar province, Iraq. All birds were maintained under the same environmental conditions and provided with a standardized commercial ration throughout the study period to evaluate the baseline histological characteristics of their digestive systems .At the final experimental timeline, the birds wes euthanized as their total body weight (BW) and body length (BL) were recorded. The abdominal cavity was exposed through a mid-ventral longitudinal incision. anatomical finding included identifying the shape and position of the duodenum within the intestinal tract .Morphometric parameters were calculated ,specifically the relative weight ratio of the small intestine (IW / BW) and the relative length ratio (IL / BL) . for histological analysis, duodenal segments were excised and fixed immediately in 10 % buffered neutral formalin . using a standard paraffin-embedding technique the samples were processed that included dehydration in ethanol ascending grades and xylene clearing . Serial sections were cut at a thickness of 6\ \mu m using a rotary microtome. The sections were Hematoxylin stained the with eosin [10] (H & E). Quantitative histological observations ,such as villus height and crypt depth, were performed using a calibrated ocular micrometer to compare the duodenal micro-architecture among the three avian species .

3. Results

the morphological study revealed that in the Canary (Serinus canaria) ,White-eared Bulbul (Pycnonotus leucotis)and Zebra Finch (Taeniopygia guttata) ,the duodenum constitutes the initial segment of the small intestine ,originating at the ventriculo- duodenal junction .In all examined species, the duodenum exhibited a characteristic U -shaped loop consisting of descending (ventral) and ascending (dorsal) limbs that encircle the pancreas . in the Canary , the duodenum appeared pinkish ,shaped like a comma or an incomplete " U " arising directly in front of the junction of ventriculo duodenal then caudally extending toward the gizzard (Fig . 1 ,2) . In the Bulbul, it appeared as pink pale structure that closely associated with the abdominal right wall partially concealed by the right lobe of the liver (Fig.3,4). Regarding the Zebra Finch, the duodenum was distinguished by its compact U-loop and a distinctive pale-creamy to light pink coloration (Fig.5,6).

Histologically, the duodenal wall in studied birds was composed of four distinct tunicae: mucosa, submucosa, muscularis, and serosa (Figs.7,8,9). The tunica mucosa was lined with simple columnar epithelium organized into finger like villi. These cells possessed oval nuclei situated near the basal membrane, with numerous Goblet cells interspersed among them(Fig10). The thickness of the mucosal layer in duodenal exhibited significant variation among the three studied species (Table 1), The highest values were recorded in the White-eared Bulbul and Canary, which showed closely comparable results, while the significantly lowest mucosal thickness was observed in the Zebra Finch .

The villus length exhibited significant variation across the studied species (, with the longest villi recorded in the Canary, followed by the Bulbul, while the shortest length was observed in the Zebra Finch. Within the lamina propria, the Lieberkuhn Crypts was identified as simple tubular invaginations extending from villi base toward the underlying tissue. The depth of these crypts varied significantly among the three birds (Table 2), reaching its maximum value in the Bulbul and its minimum in the Canary. These crypts were lined with simple columnar epithelium similar to the duodenal lumen (Fig.10,11),While shows Regarding the villus diameter, the results showed significant variations among the studied species ($p<0.05$), as detailed in ,The greatest diameter was recorded in both the White-eared Bulbul and Canary while the Zebra Finch exhibited values. These differences in villa dimensions reflect the adaptive capacity of the intestinal mucosa to maximize the absorptive surface area according to the metabolic needs of each bird . Notably, the duodenal mucosa in all

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three species lacked a muscularis mucosa, placing the lamina propria in direct contact with the submucosa(Fig9,10,11) .The Goblet cells appeared rounded or oval, though they were not highly visible in all sections(Fig 10). The Goblet cells ratio within the villi were significantly higher in the Bulbul (33.1%) compared to the Canary (9.8%) and the Zebra Finch (7.8%), showing a statistically significant difference (P \< 0.05). The tunica submucosa in all species consisted of a very thin connective tissue layer that is loose .the tunica muscularis were organized into a layer of inner circular that's thick and a outer longitudinal layer that's thin, housing Auerbach's plexuses between them. Significant variations were observed in the thickness of this tunic among the species (Table 3); the greatest thickness was recorded in the Canary, followed by the Zebra Finch, while the Bulbul exhibited the thinnest muscular layer. Finally, the tunica serosa was found to be consistently thin across all three species, composed of loose connective tissue covered by a layer of mesothelium.

Figure 1 . Visceral organs of the Canary showing: (1) heart , (2) liver, (3) gizzard, (4) duodenal loop enclosing the pancreas , (5) pancreas , and (6) jejunum

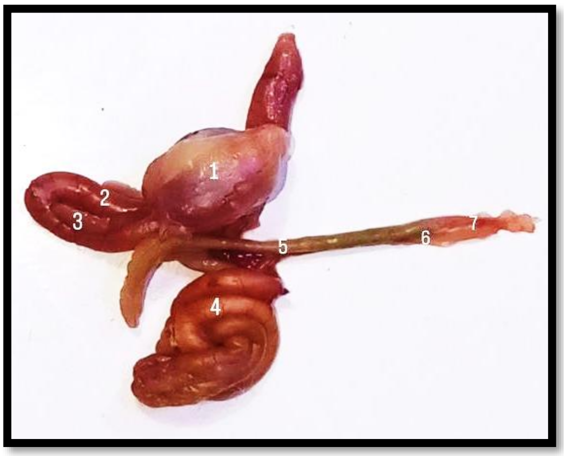

Figure 2 . small intestine and attached organs of the canary showing : (1) gizzard, (2) duodenal loop , (3) pancreas, (4) jejunum , (5) ileum, (6) cecum, and (7) large intestine .

Figure 3 . Visceral organs of the White-eared Bulbul showing : (1) heart, (2) liver , (3) gizzard, (4) duodenal loop, (5) jejunum , (6) ileum, (7) cecum , and (8) large intestine

Figure 4. Small intestine and attached organs of the White eared Bulbul showing : (1) gizzard, (2) duodenal loop , (3) pancreas , (4) jejunum, (5) ileum, (6) cecum, and (7) large intestine

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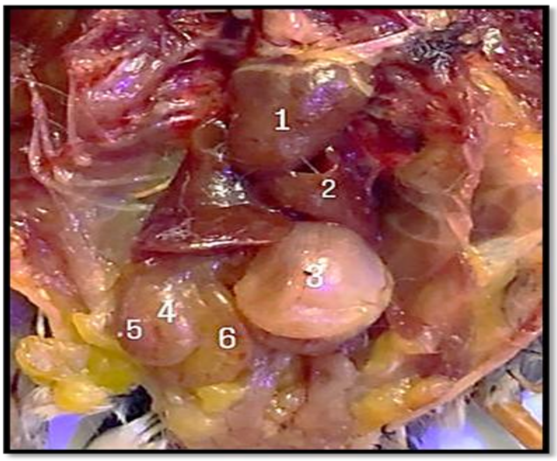

fig (5) Visceral of zebra finch .1. heart 2.liver 3. Gizzard 4. duodenal loop. 5.pancreas 6. Jejunum

fig (6) The zebra finch small intestine and attached organs 1. Gizzard 2. duodenal loop 3.pancreas 4.Jejunum 5..Ileum 6.cecum. . 7 Large intestine

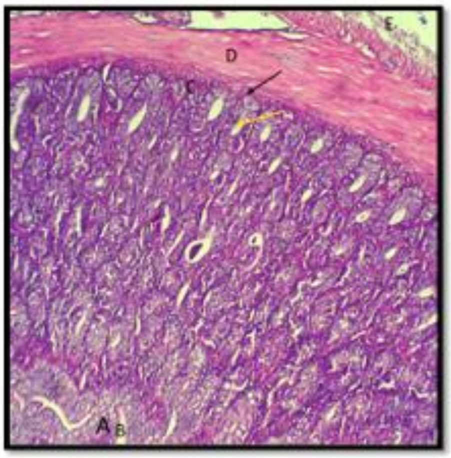

Figure 7. Transverse section of the duodenum of a Canary showing : (A) villi ,(B) intervillous spac (C) lamina propria (yellow arrow) ,intestinal gland (black arrow) ,(D) submucosa ,(E) muscularis externa and serosa (100×, H&E stain).

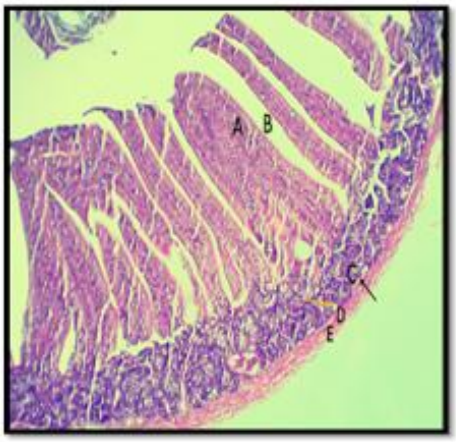

Figure 8. transverse section of the duodenum of the Zebra Finch showing : (A) villi , (B) intervillous space, (C) lamina propria (yellow arrow), intestinal gland (black arrow) , (D) submucosa , (E) muscularis externa, and serosa (100×, H &E stain)

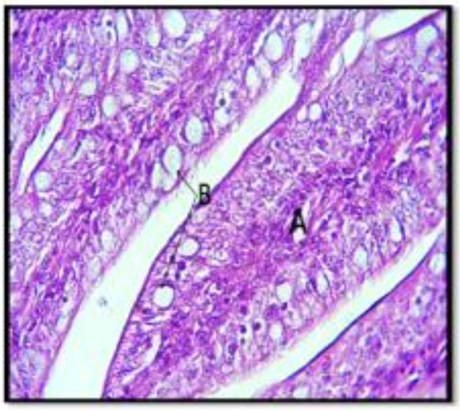

Figure (9) Duodenum villi of white-eared bulbul (A) lamina propria (B)goblet cells (400x)H&E stain

Figure (10) Duodenum villi of canary (A) lamina propria (B)goblet cells H&E stain (400x)

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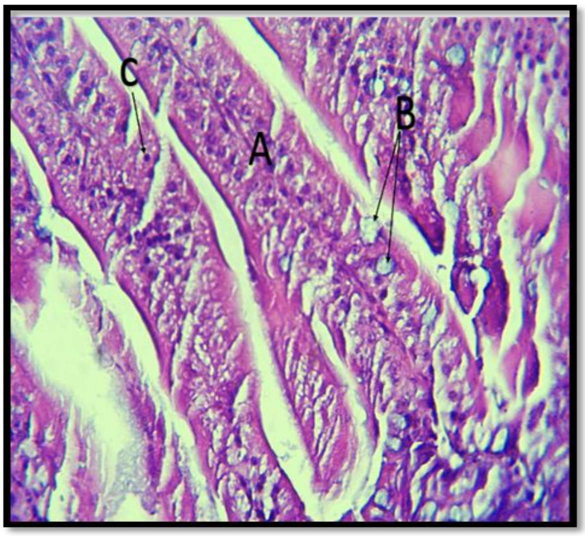

Figure 11 . duodenal villi of the Zebra Finch showing : (A) lamina propria, (B) goblet cells, and (C) lymphocytes (400× H&E stain).

Table 1: The Thickness of tunica mucosa of study birds (µm) in the Duodenum of three bird species

bird species	**thickness of tunica mucosa**
White-eared Bulbul (Pycnonotus leucotis)	(895.766 ±5.773µm)
Canary (Serinus canaria)	(895.75 ±45.018µm),
Zebra Finch (Taeniopygia guttata)	(592.733 ±11.574µm).

Table (2) The length of villi in (µm) of the duodenum of study birds

bird species	**The length of villi**
White-eared Bulbul (Pycnonotus leucotis)	(923.491 ±14.105µm)
Canary (Serinus canaria)	(600.240 ± 71.846µm)
Zebra Finch (Taeniopygia guttata)	(588.160 ±37.386 µm

Table (3) The tunica muscularis (µm) of the duodenum of study birds

bird species	The length of villi
White-eared Bulbul (Pycnonotus leucotis)	(36.566 \pm 15.275 µm)
Canary (Serinus canaria)	(69.9 \pm 10 µm)

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Zebra Finch (Taeniopygia guttata)	43.233 \pm 5.773 µm)

4-Discussion

The morphological results of the duodenum in the three studied species are in agreement with [11, 12], which state that the duodenum forms the first primary small intestine loop in avian species, though the specific curvature in the Canary differs slightly from the observations in [13]. the characteristic " U -shape " encircling the pancreas is a conserved anatomical feature among Passeriformes ,serving to provide an extensive surface area for the initial stages of chemical digestion (12) .

The significant increase in the mucosal thickness and the villus length observed in the canary and bulbul compared to Zebra Finch reflects physiological adaptation to their energy requirements . in the canary the incomplete " U" or comma shape combined with long villi suggests a strategy to maximize nutrient absorption in a relatively compact space (14- 15) . the goblet cells percentage that' s high of the discovered in the duodenum in White eared Bulbul (33.1 %) compared to the Canary (9.8 %) and Zebra Finch (7.8 %) is one of the most striking histological findings . This due to the Bulbul 's diet ,which includes various fruits and insects with high fiber and chitin content and These materials require significant lubrication provided by goblet cell mucin to prevent mechanical damage to the mucosal lining . Conversely the zebra Finch ,being a specialized granivore ,relies on a more muscular duodenum for mechanical processing rather than high mucin production , which explains its lower goblet cell ratio and thicker muscularis relative to its small size. furthermore the depth of thee Lieberkühn Crypts in Bulbul and Zebra Finch was greater than in the canary, which is in agreement with [15] . Deeper crypts are often associated with a higher rate of cell renewal , ensuring that the epithelial lining of the duodenum remains functional despite the abrasive nature of the food (seeds for the zebra finch and fibers for the bulbul) . The absence of the muscalariss mucosa in the duodenum of all three birds suggests a simplified intestinal wall structure ,allowing for closer interaction between the lamina propria and the submucosal vasculature for rapid nutrient transport (16 ,17) .

5. Conclusion

This comparative histological and morphometric study demonstrated that the duodenum of the Canary, White-eared Bulbul, and Zebra Finch shares a common basic anatomical organization, including a characteristic U-shaped loop surrounding the pancreas and a wall composed of mucosa, submucosa, muscularis, and serosa. Despite these similarities, significant interspecies differences were identified in mucosal thickness, villus dimensions, crypt depth, goblet cell distribution, and tunica muscularis thickness. The White-eared Bulbul exhibited the highest goblet cell percentage and deeper crypts, indicating an adaptation to a mixed diet rich in fruits and insects that requires enhanced mucosal protection and epithelial renewal. The Canary showed the thickest muscularis and well-developed villi, reflecting efficient nutrient absorption and mechanical processing of seeds. In contrast, the Zebra Finch displayed a more compact duodenum with comparatively lower mucosal measurements, consistent with its specialized granivorous feeding habit. The absence of the muscularis mucosa in all three species suggests a simplified intestinal arrangement that may facilitate rapid nutrient transport. Overall, the observed structural variations in the duodenum represent species-specific evolutionary adaptations to different dietary strategies and metabolic demands, highlighting the close relationship between gastrointestinal morphology and feeding ecology in passerine birds

References

1. King, A. S., & McLelland, J. (1975). Outline of Avian Anatomy (1st ed., pp. 33–39). London, UK: Bailliere Tindall.
2. اللوس، بشير. (1961). الطيور العراقية: رتبة الدجاجيات (الجزء الثاني، ص 1–13). بغداد، العراق: مطبعة الرابطة.
3. مهدي، شفيق. (1983). الطيور المائية في العراق والوطن العربي. بغداد، العراق: مطبعة وزارة الثقافة والإعلام، دار الرشيد للنشر.
4. Caviedes-Vidal, E., & Karasov, W. H. (2001). Developmental changes in digestive physiology of nestling house sparrows (Passer domesticus). Physiological and Biochemical Zoology, 74(5), 769–782.
5. Naya, D. E., Ebensperger, L. A., Sabat, P., & Bozinovic, F. (2008). Digestive and metabolic flexibility allows female degus to cope with lactation costs. Physiological and Biochemical Zoology, 81, 186–194.
6. Mohammed, H. H. (2017). The morphological and histological features of tongue in black kite (Elanus caeruleus). Basrah Journal of Veterinary Research, 16(1).
7. Hussein, A. J., Hussein, H. A., & Abdulzahra, H. K. (2018). Morphological and histological study of the liver and pancreas of small Indian mongoose (Herpestes javanicus). Basrah Journal of Veterinary Research, 17(3).
8. Igwebuike, U. M., & Eze, U. U. (2010). Morphological characteristics of the small intestine of the African pied crow (Corvus albus). Animal Research International, 7(1), 1116–1120.
9. Yamauchi, K. E., Incharoen, T., & Yamauchi, K. (2010). The relationship between intestinal histology and function as shown by compensatory enlargement of remnant villi after mid-gut resection in chickens. The Anatomical Record, 293.
10. Majeed, M. F., Al-Asadi, F. S., Al-Nassir, A. N., & Rahi, E. H. (2009). The morphological and histological study of the cecum in broiler chicken. Basrah Journal of Veterinary Research, 8(1).
11. Dyce, K. M., Sack, W. O., & Wensing, C. J. G. (2002). Textbook of Veterinary Anatomy (pp. 806–821). Philadelphia, PA: W. B. Saunders.
12. Awad, W., Ghareeb, K., & Böhm, J. (2008). Intestinal structure and function of broiler chickens on diet supplemented with a synbiotic containing Enterococcus faecium and oligosaccharides. International Journal of Molecular Sciences, 9, 2205–2216.

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Vol. 3 No. 1 (2026): July
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13. Sack, W. O., Dyce, K. M., & Wensing, C. J. G. (2002). Veterinary Anatomy. Canada: W. B. Saunders.
14. Jassem, E. S., Hussein, A. J., & Sawad, A. A. (2016). Anatomical, histological and histochemical study of the proventriculus of common moorhen (Gallinula chloropus). Basrah Journal of Veterinary Research, 14(4).
15. von Röhe, I. T., & Breisgau, A. F. (2013). Effects of feed structure on animal performance, gastrointestinal morphology, gut-associated lymphoid tissue and jejunal glucose transport in laying hens. Journal of Nutrition, Berlin.
16. Richardson, K. C., & Wooller, R. D. (1986). The structures of the gastrointestinal tracts of honeyeaters and other small birds in relation to their diets. Australian Journal of Zoology, 34(6), 119–124.
17. Gelis, S. (2012). Evaluating and treating the gastrointestinal system. In Clinical Avian Medicine (Vol. 1, pp. 411–440).

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