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Article

Histomorphometric and Microscopic Assessment of Gastric Mucosa in Guinea pig and White Rat Models

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Abstract: The understanding of rodent gastrointestinal morphology is important for several medical applications, including experimental surgical procedures, the diagnosis of gastric disorders, and providing information about diet adaptation and gut physiology. Therefore, the present study aimed to investigate the anatomical, morphometric, and microscopic characteristics of the gastric mucosa in adult guinea pigs and white rats. Stomachs from five healthy adult guinea pigs (Cavia porcellus) and five white rats (Rattus norvegicus) were collected and preserved in 10% formalin. The samples were later processed, sectioned, and stained with Harris Hematoxylin and Eosin. Microscopic measurements were made for the depth of gastric pits, diameter of gastric glands, and the thickness of the gastric mucosa, tunica submucosa, tunica muscularis, and tunica serosa. The number of parietal and chief cells was counted in the fundic and pyloric regions of both animals. The rat stomach was crescent-shaped, with distinct non-glandular and glandular regions. While the stomach of guinea pig was pear-shaped, totally glandular. The mucosal microstructure exhibited variations in thickness and morphology. The rat's non-glandular mucosa had keratinized squamous epithelium, while the guinea pig lacked a non-glandular region. Histologically, gastric pits and glands differed in size, density, and cellular composition, with guinea pigs showing thicker muscular layers and larger, less dense glands, while rats had more parietal and chief cells in the fundic and pyloric regions. This study enhances the understanding of how dietary habits shape gastric anatomy and physiology. Future research could explore enzymatic activity, gut microbiota interactions, developmental anatomy, and the mechanisms underlying these adaptations.

Keywords: : Anatomy, Histology, Guinea pig, Rat, Stomach.

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1. Introduction

Digestive diseases, represent a significant portion of clinical emergencies worldwide. According to the centers for disease control and prevention (CDC), diagnostic visits for these conditions reaching 7.9 million annually [1, 2]. Rodents, due to their genetic, physi ological, and anatomical similarities to humans, considered as the best animal models for studying human diseases [3, 4]. Among rodent, laboratory rats and guinea pigs recognized as an optimal biological model for studying the pathological mechanisms in various gastrointestinal disorders [5].

The understanding of rodent's gastrointestinal morphology is important in several medical applications, including experimental surgical procedures and transplantation [6]. Morphometric studies of the gastric mucosa are important in the diagnosis of gastric ulcers [7]. furthermore, quantitative analyses of gastric muscle and its arrangement contribute to the diagnosis of a range of disorders, including gastric reflux, dyspepsia, gastroparesis, pyloric stenosis, and rapid gastric emptying [8,9]. The microscopic features of the stomach provide valuable information in diet adaptation and gut physiology [10]. Studies on stomach morphology in rats and guinea pigs provide vital understanding in acidity-related gastric cancers and in vivo nitrosocarbamates formation in the human stomach [11].

Both rats and guinea pigs, which belong to the order Rodentia and the families Muridae and Caviidae, respectively, exhibit distinct feeding practice: rats are omnivorous, while guinea pigs are strict herbivores [12]. The morphology and functionality of the stomach are influenced by nature of food, food intake frequency, food storage mechanisms, and overall body shape and size [13] .

Basic study for stomach morphology, among different rodent species were conducted by [11], but Ghoshal & Bal study overlooked several important morphometric and microscopic details. Other studies were conducted among Muridae (rats and mice) [14], Leporidae (rabbits) [15], and Caviidae (guinea pigs) [16].

However, there has been a lack of comparative studies addressing the microscopic and morphological characteristics of the stomachs across different rodent species. Such studies help to choose the best animal model in gastric medical research, and highlight the different digestive adaptations among rodents, understanding the evolutionary history, and improve the medical and nutritional applications among animals.

Therefore, the current study intended to investigate the structural, morphometric and microscopic features of the gastric mucosa in the adult guinea pigs (*Cavia porcellus*) and white rats (*Rattus norvegicus*).

2. Materials and Methods

Study animals

Five (n.=5) healthy adult guinea (Cavia porcellus) pigs and five (n.=5) white rats (Rattus norvegicus) were employed in this study with weights ranged between (532-612 g) and (200-235 g) respectively, obtained from certified animals' breeders in the city of Mosul-Iraq, the animals housed during the investigation in appropriate cages with free food and water access, the study performed in the laboratory of Anatomy Department, College of Veterinary Medicine ,University of Mosul-Iraq, during October 2024 - December 2025 . Sex differences were not considered in this study.

Animal preparation and ethical approvement

The experimental animals handled with care adhering to animal rights ethics. Euthanasia achieved by intraperitoneal injection of 130 mg sodium thiopental in the lower right quadrant of the abdomen in both types' animals, corresponding with (AVMA) guidelines [17], the study approved by Animal Care and Use Committee in the College of Veterinary Medicine- University of Mosul,Iraq under Ref no. UM.VET.2024.019.

The animal were weighed using sensitive weighing scale (EK-IEW-I, Japan), than animal fixed with pins penetrated through the limbs, incision was made from the neck anteriorly to the genital area posteriorly, and other transvers incision made perpendicularly along the length of limb and skin was folded laterally, incision through the abdominal wall proceeded laterally on both sides to cut the ribs cage, the abdominal viscera exposed ,and stomach photographed and examined in situ and the whole digestive system were evacuated outside of the body [18] .

Histological processing

After fixation with neutral buffered formalin 10% for 72 hours, the specimens subjected to dehydration by immersing in ethyl alcohol solutions with concentrations of 70%, 80%, and 95% for 30 minutes each. Subsequently, they were placed in 100% alcohol for 45 minutes.

Next, the specimens cleared in xylene for 50 minutes and were then embedded in wax (paraffin) two changes for 1.5 hour each. Subsequently, the specimens were molded into a paraffin block and sliced into 4 µm thick sections using a rotary microtome (BIOBASE BK-2218, China).

The sections were stained with Harris hematoxylin and eosin. Then, the slides mounted by DPX and cover slipped. later, the stained slides were assessed under a light microscope (Olympus-CX21, Japan) [19].

Histomorphometric measurements

A series of images was captured for the selected tissue sections. These images were obtained using an 18.0 MP OMAX digital camera equipped with the light microscope. Afterwards, measurements and image processing were carried using Image J software (version 1.53, NIH, USA). Eight histological sections were randomly chosen for analysis, and measurements conducted across 15 microscopic fields. These measurements included the depth of gastric pits, dimeter of gastric glands, thickness of the gastric mucosa, tunica submucosa, tunica muscularis and tunica serosa, The cells counted manually in 100 µm2 fields at 40X magnification in the fundic and pyloric regions in both animals.

Statistical analysis: the data from macroscopic and microscopic measurements were organized and summarized as a mean and standard error of the mean (M ± SEM), Furthermore. Significant differences of the gastric morphological parameters analyzed between both animal (rat and guinea pigs) using Student's t-test for independent variables, the statistical analysis performed using (IBM .Spss V27,UK) software at $p \leq 0.05$.

3. Results

The rat stomach exhibited crescent shape, located in the left upper region of the abdominal cavity. It was situated caudal to the diaphragm and dorsal to the medial lobe of the liver, aligned with the first lumbar vertebra. On the other hand, the guinea pig stomach was a curved pear shape, occupying the upper left abdominal cavity. and positioned dorsal to the liver, cranial and medial to the small intestine, and caudal to the diaphragm. The rat stomach was characterized by two distinct regions: a non-glandular portion, which appeared thin-walled and white, and a glandular portion, which was thicker and gray in color. In contrast, the guinea pig stomach was entirely glandular and uniformly grayish in color (Figure 1A & B).

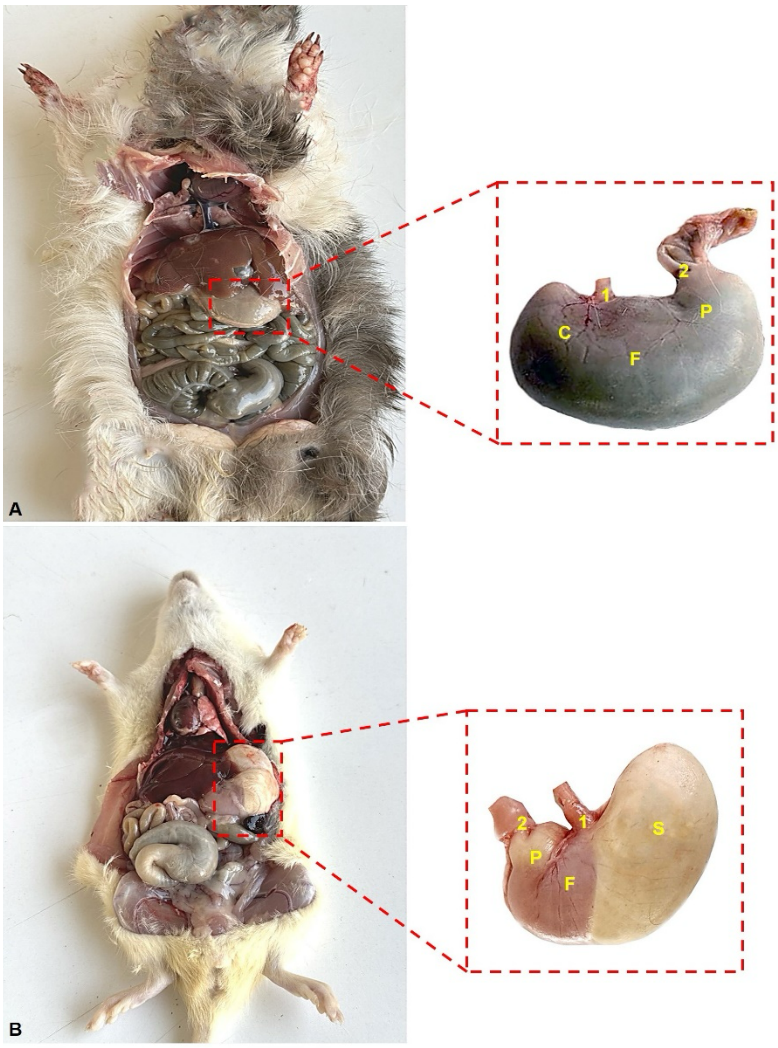

Figure 1. The figure illustrates the position of the stomach within the abdominal viscera in the rat (A) and guinea pig (B), and the different gastric regions, including the cardia (C), fundus (F), pylorus (P), and forestomach (S), along with the cardiac opening (1) and pyloric opening (2).

The total weight of the stomach was between 3-4.5 grams in both animals, showing no significant differences, but the relative weight of the rat stomach was significantly greater than the guinea pig stomach at ($P \leq 0.05$) (Table 1). The gastric mucosa in the rat stomach showed prominent short folds (rugae) near the cardiac opening and in the fundic region. The number of these rugae was fewer than those seen in the guinea pig stomach, where the rugae were longer, more numerous, and higher, covering most of the cardiac region.

Table 1: The relative weight in rat and guinea pig stomach

Animal	Body weight (g.) M ± SEM	Stomach weight (g.) M ± SEM	Relative weight (%.)
Rat	221 ± 14.03	4.60 ± 0.71	2.08 % *
Guinea pig	572 ± 40.01	3.70 ± 0.35	0.64 %

*: indicate significant statistical differences between both animals

The microscopic observations revealed that the wall of the stomach was composed of four main layers or tunics: the mucosa, submucosa, muscularis, and the serosa in most gastric regions in both animals.

The gastric mucosa in rats was covered with thick stratified keratinized squamous epithelium in the forestomach region. The thickness varied from very thick in the limiting ridge to multiple thin layers of cells in the rest of this part. The total thickness of the wall was 212.98 ± 5.65 µm, the thickness of stratified squamous epithelium was 92.07 ± 1.47 µm, while the thickness of submucosal layer was 52.50 ± 3.91 µm, the thickness of muscular layer was 51.12 ± 1.11 µm and the thickness of serosal layer was13.62 ± 0.73 µm (Figure 2).

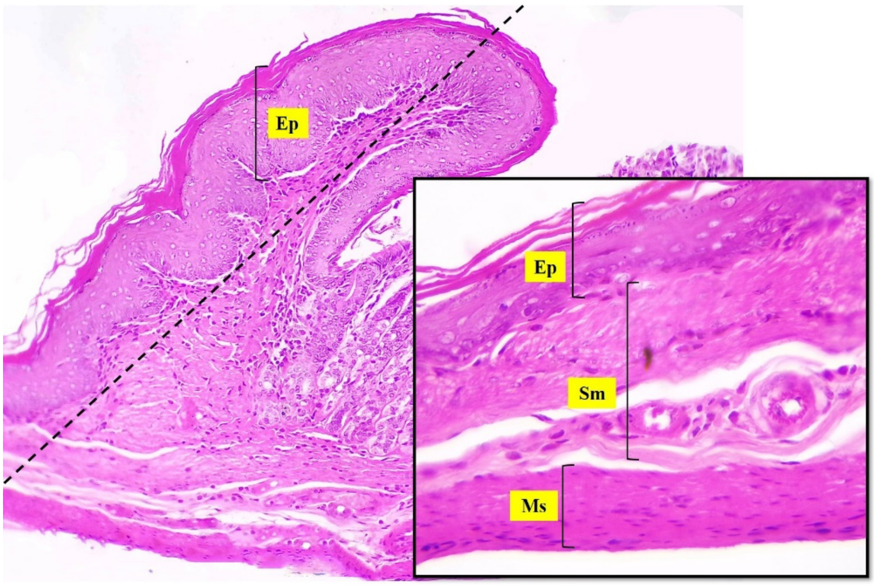

Figure 2. The microphotograph shows the limiting ridge (dashed line) between glandular and non-glandular stomach in rat, covered with thick keratinized stratified squamous epithelium (Ep), the magnified figure shows the forestomach histological layers including: the mucosal epithelium (Ep), submucosa (Sm), and the muscular layer (Ms), (H&E, 100X, magnified fig, 400X)

The glandular mucosa in of the fundic and pyloric regions was lined with a simple columnar epithelium that extended into gastric pits. The pits varied in depth, being shorter in the fundic region and deeper in the pyloric region. The lamina propria contained branched and simple tubular gastric glands, with lower density in the apical region and higher density in the basal region. These glands were composed of four cell types: zymogenic, large eosinophilic parietal, mucous neck and enteroendocrine cells.

The muscularis mucosae present beneath the mucosa, and constituted from thin layer of smooth muscle fibers, while, the submucosa was a thin layer of loose connective tissue containing blood and lymph vessels.

The muscular layer consisted of an inner circular and an outer longitudinal layer. This layer was thicker in the glandular regions compared to the non-glandular regions. The serosal layer was composed of mesothelial epithelium (Figure 3 A &B).

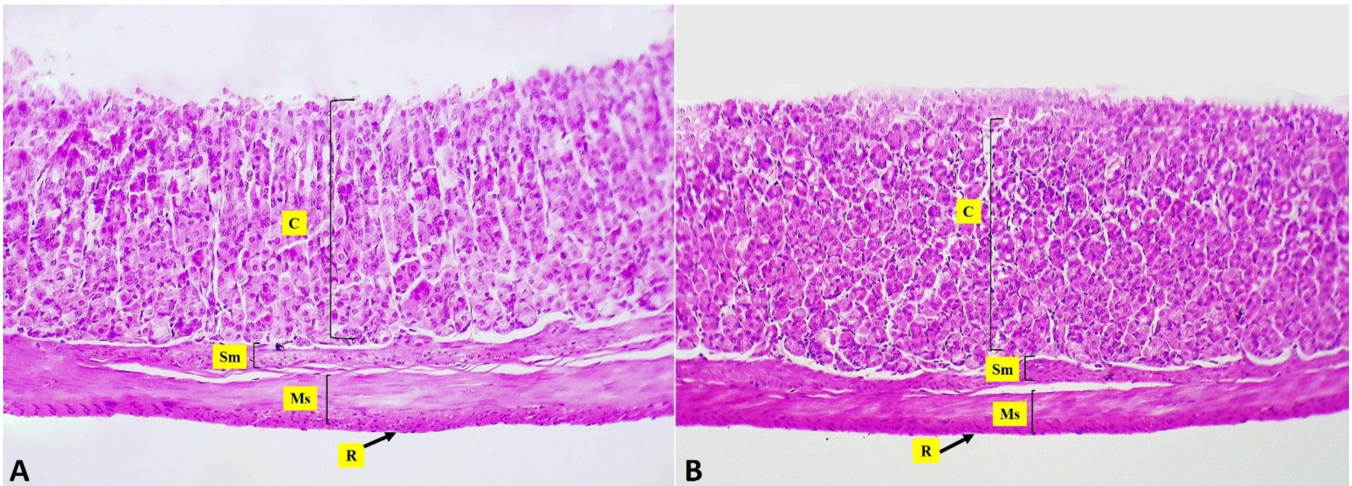

Figure. 3. The microphotograph shows the fundic (A) and pyloric regions (B) of the rat stomach. The figure focus on the histological layers of the glandular stomach, including the mucosa (C), submucosa (Sm), muscular layer (Ms), and serosa (R). (H&E, 100X).

The microscopic structure of guinea pig stomach was similar to that of rats, except that the non-glandular portion was absent with presence of small cardiac region (Figure 4 A &B).

The histomorphometric measurements of gastric microcomponents revealed that the total thickness of the gastric wall was significantly thicker in the fundic and pyloric regions of the guinea pig stomach compared to rats. In the fundic region, the mucosal layer was thicker in rats than in guinea pigs ($P \leq 0.01$), while the muscular and serosal layers were significantly greater in the guinea pig stomach than in rats. The diameter of the gastric glands was wider ($P \leq 0.01$) in the guinea pig stomach than in the rat stomach. However, the gastric pits showed no statistical differences (Table 2 and Table 3).

Table 2: Total thickness of the fundus and pylorus in rat and guinea pig stomachs

Parameter	Rat (M ± SEM)	Guinea Pig (M ± SEM)	Significance (*P*.value)
Total thickness of the fundus wall (μm)	515.97 ± 5.64	604.65 ± 5.58	Yes ($p < 0.01$)
Total thickness of the pylorus wall (μm)	408.88 ± 5.23	525.25 ± 2.82	Yes ($p < 0.05$)

Table 3: Thickness of histological layers in the fundic region of the rat and guinea pig stomachs

Parameter	Rat (M ± SEM)	Guinea Pig (M ± SEM)	Significance (*P* .value)
Thickness of mucosal layer (µm)	373.73 ± 6.71	297.91 ± 2.82	Yes (p < 0.01)
Thickness of submucosal layer (µm)	73.40 ± 4.76	81.51 ± 1.28	No
Thickness of muscular layer (µm)	79.66 ± 2.51	192.06 ± 1.60	Yes (p < 0.01)
Thickness of serosal layer (µm)	15.35 ± 0.73	20.64 ± 1.03	Yes (p < 0.01)
Diameter of gastric glands (µm)	39.39 ± 2.15	45.92 ± 2.09	Yes (p < 0.01)
Length of gastric pits (µm)	74.65 ± 2.99	81.85 ± 3.14	No

In the pyloric region, the mucosal layer exhibited significant differences (P ≤ 0.01) between rats and guinea pigs. The submucosal layer was similar in both animals. The muscular layer was thicker in the guinea pig's pyloric region compared to the rat stomach. And the gastric glands were wider in the guinea pig, and the gastric pits were deeper than in rat (Figure.5) (Table 4).

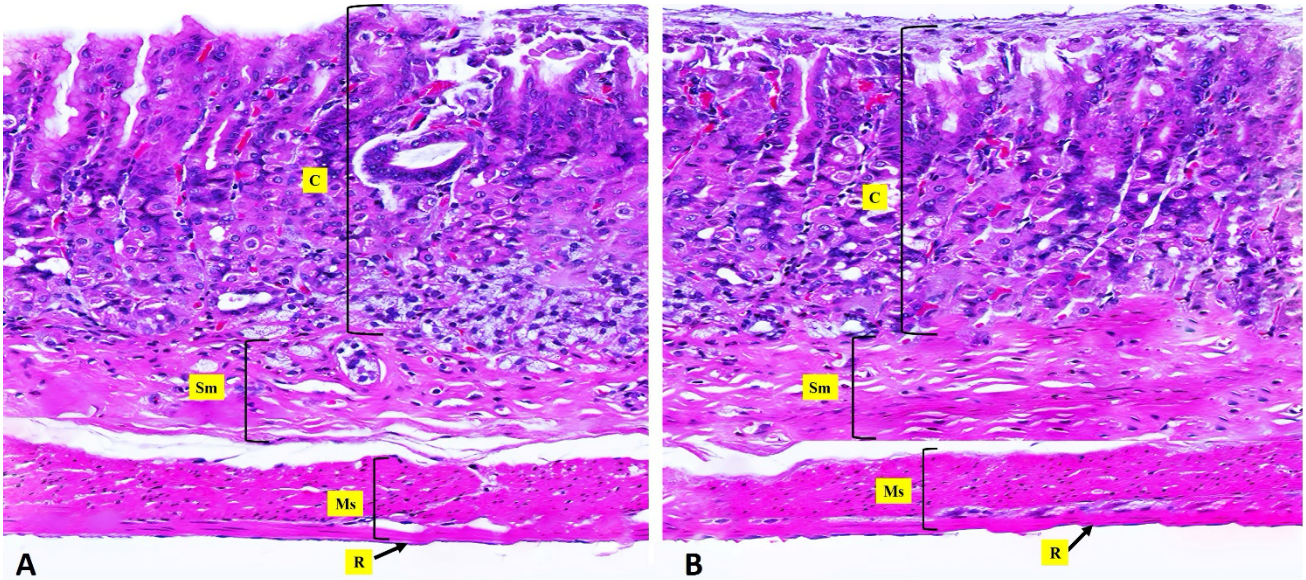

Figure. 4. The microphotograph shows the fundic (A) and pyloric regions (B) of the guinea pig stomach. The figure shows the histological layers of the glandular stomach, including the mucosa (C), submucosa (Sm), muscular layer (Ms), and serosa (R). (H&E, 100X).

Table 4: Thickness of histological layers in the pyloric region of the rat and guinea pig stomachs

Parameter	Rat (M ± SEM)	Guinea Pig (M ± SEM)	Significance (P .value)
Thickness of mucosal layer (µm)	395.93 ± 5.15	240.90 ± 1.21	Yes (p < 0.01)
Thickness of submucosal layer (µm)	72.03 ± 4.76	82.18 ± 1.28	No
Thickness of muscular layer (µm)	54.04 ± 3.66	161.67 ± 1.65	Yes (p < 0.01)
Thickness of serosal layer (µm)	14.84 ± 1.67	17.91 ± 1.03	No
Diameter of gastric glands (µm)	39.13 ± 1.19	58.05 ± 2.09	Yes (p < 0.01)
Length of gastric pits (µm)	120.72 ± 2.98	192.21 ± 5.10	Yes (p < 0.01)

The density of gastric glands varied in the fundic and pyloric regions between the two animals. In the rat stomach, the glands were densely arranged within the mucosal layer, while in the guinea pig stomach, the glands were larger and exhibited lower density.

The number of parietal and chief cells in the gastric glands also showed a significant difference between rat and guinea pig stomach, the parietal cells were slightly higher in the fundic and pyloric region in the rat stomach compared with guinea pig, while the chief cells were higher in the fundic region and evenly matched in the pyloric region (Figure.5) (Table 5).

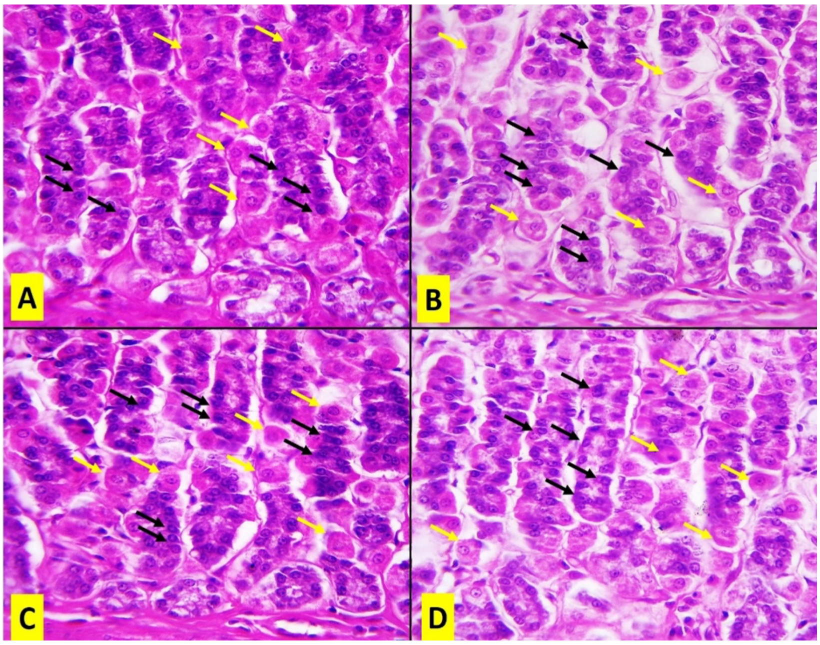

Figure. 5. The microphotograph shows the gastric glands in the fundic (A) and pyloric (B) regions of the rat stomach, as well as the fundic (C) and pyloric (D) regions of the guinea pig stomach. The figure highlights the parietal cells (yellow arrows) and chief cells (black arrows). (H&E, 100X).

4. Discussion

The present study intended to investigate the anatomical, morphological and microscopic aspects of the stomach in the adult guinea pigs and white rats. The gastric shape, location and division in rat and guinea pig in our study were Similar to the observations of Di Natale et al. (2022) [20], and Matsukura et al. (1985) [21] in rat, and Similar to the observations of Raja (2022) [22], and Stan (2018) [23], in guinea pigs. Vdoviaková et al. (2016) [13] and Raja (2022) [22] summarized differences in stomach shape between rats and guinea pigs. They found that the stomach in rats was slender and thinner, while it was wider, broader, and more curved in guinea pigs. The dimensions of the guinea pig stomach were also slightly larger compared to those of rats. These differences are attributed to the total body size differences between the two animals. Bülbül and Nawaz., 2020 [24]. noted that the ability of animal to store a greater quantity of food for prolonged periods, as well as differences in diet type and energy requirement, affects the stomach size in these rodents.

The present study showed that the relative weight of the rat stomach was significantly greater than the guinea pig stomach, with a similar value recorded by Vdoviaková et al. (2016) [13], in rat and by Al-Shreefy (2024) [25], in guinea pig stomach. The differences come from differences in total body weight and size between both animals. The bigger and heavier animal shows the smaller relative gastric weight.

Microscopic observations in the current study revealed that the histological components of the gastric wall were similar in both animals. except that mucosa in the rat's forestomach (non-glandular) region was covered with a thick cornified squamous epithelium. While, the glandular region was lined by a single row of simple cuboidal and columnar epithelia. Corresponding observations reported by [21,26].

The histomorphometric measurements of the total thickness of the gastric wall were significantly thicker in the fundic and pyloric regions of the guinea pig stomach. In the fundic region, the mucosal layer was thicker in rats than in guinea pigs, whereas the muscular and serosal layers were significantly thicker in the guinea pig stomach than in rats. The measurement data were closer to those of [27], in adult rats and [24] in guinea pigs. Histological differences were attributed to the functional and evolutionary developmental characteristics of both animals. Bülbül and Nawaz., 2020 [24] was noted that herbivorous guinea pigs require ten times the quantity of food compared to other omnivorous rodents to meet their nutritional needs for proteins, carbohydrates, and vitamin C. This dietary requirement is reflected in their histological development.

The gastric glands were wider in the guinea pig than in the rat stomach. These variances attributed to the secretary activity and dietary specialization, since fibrous plant material requires more extensive enzymatic digestion in guinea pigs' stomach [28,25]

The density of the gastric glands varied in the fundic and pyloric regions between the two animals. In the rat stomach, the glands were smaller and densely arranged within the mucosal layer, whereas in the guinea pig stomach, the glands were larger and exhibited lower density. Similar finding mentioned by [26] in albino rat and by [25] in guinea pigs, authors mention that nucleus-glandular index and glandular cell density was great within mucosal area in the rat stomach compared with guinea pig.

5. Conclusions

The present study provides a detailed comparative analysis of the anatomical, morphological, and microscopic features of the stomach in adult guinea pigs and white rats aligned with their dietary adaptations. The findings showed that guinea pig's stomach is entirely glandular, larger, and structurally suited for its herbivorous grazing habits, while the rat's stomach has both glandular and non-glandular regions, adapted for omnivorous feeding. Microscopic analysis showed variations in layer thickness and glandular arrangement, this study enhances understanding of how dietary habits shape gastric anatomy and physiology in nutrition planning, and the use of these species as research models. Future research could explore enzymatic activity, gut microbiota interactions, developmental anatomy, and molecular mechanisms underlying these adaptations. These findings also pave the way for comparative evolutionary studies, disease modeling and their impacts on gastrointestinal health.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. CDC. Centers for Disease Control and Prevention. National hospital ambulatory medical care survey: 2010 emergency department summary tables. Centers for Disease Control and Prevention, Atlanta, Georgia. 2013. Updated March 29, 2012. Accessed May 2, 2013. www.cdc.gov.
2. CDC. Centers for Disease Control and Prevention. National ambulatory medical care survey: 2010 outpatient department summary tables. 2010. Updated March 29, 2012. Accessed May 2, 2013. www.cdc.gov.
3. Guo Y, Bao Y, Meng Q, Hu X, Meng Q, Ren L, Li N, Zhao Y. Immunoglobulin genomics in the guinea pig (Cavia porcellus). PloS one. 2012 ;7(6):e39298. https://doi.org/10.1371/journal.pone.0039298.
4. Szpirer C. Rat models of human diseases and related phenotypes: a systematic inventory of the causative genes. J. Biomed. Sci. 2020;27(1):84. https://doi.org/10.1186/s12929-020-00673-8.
5. Musser G. rodent. Encyclopedia Britannica. 2024. https://www.britannica.com/animal/rodent
6. Natale G, Lazzeri G, Blandizzi C, Gherardi G, Lenzi P, Pellegrini A, Del Tacca M. Seriate histomorphometry of whole rat stomach: an accurate and reliable method for quantitative analysis of mucosal damage. Toxicol. Appl. Pharmacol. 2001 ;174(1):17-26. https://doi.org/10.1006/taap.2001.9193.
7. Tack J., & Pandolfino JE. Pathophysiology of gastroesophageal reflux disease. Gastroenterol. 2018; 154(2): 277-288. https://doi.org/10.1053/j.gastro.2017.09.047.
8. Keller J, Bassotti G, Clarke J, Dinning P, Fox M, Grover M, Hellström PM, Ke M, Layer P, Malagelada C, Parkman HP. Advances in the diagnosis and classification of gastric and intestinal motility disorders. Nature reviews Gastroenterol. hepatol. 2018;15(5):291-308. https://doi.org/10.1038/nrgastro.2018.7.
9. Nwafor JA, OM'Niabohs FA. Comparative histomorphological study of the stomach of Rattus norvergicus, Agama agama, and Bufo marinus. Annal. Bioanthropol. 2014;2(2):54. http://dx.doi.org/10.4103/2315-7992.153817.
10. Rickard RW, Dorough HW. In vivo formation of nitrosocarbamates in the stomach of rats and guinea pigs. J. Toxicol. Environm. Heal. Part A Current Issues. 1984; 14(2-3):279-90. https://doi.org/10.1080/15287398409530580.
11. Ghoshal NG, Bal HS. Comparative morphology of the stomach of some laboratory mammals. Lab. Anim. 1989 ;23(1):21-9. https://doi.org/10.1258/002367789780886911.
12. Igbokwe C, Obinna S. Oesophageal and gastric morphology of the African Rope Squirrel Funisciurus anerythrus (Thomas, 1890). J. Appl. Life Sci. Int. 2016;4(2):1-9. https://doi.org/10.9734/JALSI/2016/21794.
13. Vdoviaková K, Petrovová E, Maloveská M, Krešáková L, Teleky J, Elias MZ. & Petrášová D. Surgical anatomy of the gastrointestinal tract and its vasculature in the laboratory rat. Gastroenterol. Res. Pract. 2016; 2016(1): 2632368. https://doi.org/10.1155/2016/2632368.
14. Khalel EM, Ghafi HD. Anatomical and histological study of stomach in adult local rabbits Oryctolagus cuniculus. Al-Mustansiriyah J Sci. 2012;23(7):1-22.
15. Florin ST. Comparative study of the stomach morphology in rabbit and chinchilla. AgroLife sci. J. 2013 ;2(2). 73-78. https://www.cabidigitallibrary.org/doi/pdf/10.5555/20143039519.
16. Abd AL-Rhman SA. Morphological and histological study of the stomach in local rodent species (Guinea pig) Cavia porcellus. J. Bio. Agri. and Heal. 2016;6(6):74-86. https://www.journalijar.com/article/8149/morphological-and-histological-study-of-the-stomach-in-local-rodent-species(guinea-pig)-cavia-porcellus/
17. Underwood W. and Anthony R. AVMA guidelines for the euthanasia of animals: 2020 edition. 2020; 2013(30): 2020–1
18. Johnson-Delaney CA. Anatomy and physiology of the rabbit and rodent gastrointestinal system. InProc. Assoc. Avian Vet. 2006 ;10 (1): 9-17).
19. Carson, FL. and Cappellano, CH. Histotechnology. a self-instructional text. In Fixation, Eds. Carson, F.L. and Cappellano, American-Society, ASCP press. Chicago, USA, 2015;12–15
20. Di Natale MR, Patten L, Molero JC, Stebbing MJ, Hunne B, Wang X, Liu Z, Furness JB. Organisation of the musculature of the rat stomach. J. Anat. 2022 ;240(4):711-23. http://dx.doi.org/10.1111/joa.13587.
21. Matsukura N, Shirota A, Asano G. Anatomy, histology, ultrastructure, stomach, rat. InDigestive system Berlin, Heidelberg: Springer Berlin Heidelberg. 1985: 281-288. https://doi.org/10.1007/978-3-642-96910-2_49.
22. Raja K, Ushakumary S, Rajathi S, Ramesh G, Ramesh S. Histological and Histochemical Studies on the Stomach of Guinea Pig (Cavia porcellus).2022;12(3): 407-413. http://dx.doi.org/10.30954/2277-940X.03.2022.14.
23. Stan FG. Comparative macroscopic anatomy of the stomach morphology in laboratory rat and guinea pig. Lab Anim. 2018; 23(1): 21-9. https://doi.org/10.1258/002367789780886911.
24. Bülbül T, Nawaz S. An overview about laboratory rodents, digestive physiology and important issues regarding their nutrition. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi. 2020 Dec 15;3(2):219-27.
25. Al-Shreefy MN. Histomorphological and Histochemical Study of Esophagus and Stomach in Adult Guinea Pigs (Cavia porcellus). Wasit J. Pure Sci. 2024;3(2):306-314. https://doi.org/10.31185/wjps.412.

26. Ofusori DA, Caxton-Martins EA. A comparative histomorphometric study of the stomach of rat (Rattus norvegicus), bat (Eidolon helvum) and pangolin (Manis tricuspis) in relation to diet. Int. J. Morphol. 2008 ;26(3):669-74.http://dx.doi.org/10.4067/S0717-95022008000300026.
27. Zhu L, & Wang JL. Sexual dimorphism in histological structure of normal rat stomach. Int. J. Morphol., Temuco. 2016; 34(4), 1461-1464. http://dx.doi.org/10.4067/S0717-95022016000400046.
28. Kararli TT. Comparison of the gastrointestinal anatomy, physiology, and biochemistry of humans and commonly used laboratory animals. Biopharmaceutics & drug disposition. 1995;16(5):351-80. https://doi.org/10.1002/bdd.2510160502.