



Original Research Paper

Comparative Anatomical and Histological Adaptations of Lingual Papillae in Camels and Dogs

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Abstract

The present study provides a comprehensive comparative analysis of the anatomical and histological features of the tongue and papillae in the dromedary camels and household dogs of the species *Canis lupus familiaris* and is focused on the unique adaptations that evolved in connection with their diets and habits in the environment. The analysis included twenty individuals from both analyzed groups (ten representatives of each species) and aimed at comparing the data obtained from the experiments performed with the assistance of such techniques as gross anatomical dissection, light microscopy, histochemical staining (Hematoxylin and Eosin, Periodic Acid-Schiff), and scanning electron microscopy. Based on morphometric assessment, the camels were revealed to have the bigger tongue dimensions than dogs at a significance level of $P < 0.05$. From the point of histology, camels' tongues were characterized by severe hyperkeratosis, thick stratum corneum, high amounts of keratin pearls in the epithelium, and few values of gustatory papillae nosed. On the other hand, the canine tongue is notable for its ability to have a lot of sensory specialization, high density of both fungiform and vallate papillae with taste buds, and many Krause's end bulbs situated in connective tissue core as well as specific arrangement of papillae. The analysis through the scanning electron microscope has enabled significant differences in ultrastructure of keratinization patterns and papillae shapes in the studied species. The study suggests lingual structural variations as evolutionary adaptations to certain environmental and dietary challenges. This research can provide important information of the relationship between the tongue structure, feeding behavior, and the ecological niche of the species involved in the comparative morpho-anatomical studies and may have some possible applications in veterinary and zoological worlds.

Keywords: Lingual papillae, taste buds, camel, dog, comparative anatomy, histological adaptations, scanning electron microscopy, dietary specialization.

Introduction

The tongue is a specialized muscular structure that is one of the important parts of the mouth and performs many imperative functions of the mammalian body including chewing, swallowing, tasting food, and food processing (Madkour et al., 2023). The identification of different flavors happens through the activity of food particles with the taste receptors on the lingual papillae enabling scientists to learn much about the feeding patterns and nutrition practices of mammals (Dyce et al., 2018). It can be said that in terms of anatomy the mouth is located below the mobile tongue through the movable muscles, on top through the hard and soft palates, on the sides through the cheeks, at the front through the lips, and at the back through the isthmus of the oropharynx. The vestibule of the mouth is the area between the lips, cheeks, and teeth, while the oral cavity refers to the area inside of the dental arch. (Alexander et al., 2019)

The anatomy of the tongue encompasses the tip, body, and root; the last division of the tongue being connected to the hyoid bone (Dyce et al., 2018). From the physiological perspective, the tongue plays an important role in licking, grooming, bolus movement, and food mixing with saliva (Trautmann and Fiebiger, 2002). The

tongue has a lot of different types of lingual papillae which are categorized into two main types: mechanical (filiform, conical, lenticular) and gustatory (fungiform, vallate, foliate) papillae (Dellmann, 2006; Stinson and Calhoun, 1993). It is worth noting that various environmental conditions and diet of the animal influence the morphology and structure of the lingual papillae, as it can be seen from the fact that the morphology of the lingual area is changed due to food intake and mastication process, which influences the choice of feed and food palatability for ruminants (Ginane and Favreau-Peigné, 2011). Therefore, lingual characteristics of the animal can be used for evaluating the dietary preferences of the animal (Meier et al., 2016).

The anatomy and histology of tongues in mammals vary a lot. Depending on their diet, mammals are classified into three major groups: herbivores, carnivores, and omnivores. These differences are thought to be caused by dietary habits as well as environments of mammals (Hassan et al., 2018). The mouth cavity along with the tongue undergoes morphological and histological changes in accordance with feeding habits of the species involved. Camels (Old World camels) are unusual

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herbivores adapted to consuming the high-salt diet as they are able to eat plants from Asteraceae and Chenopodiaceae families, which means they consume eight times more salt during the day than cows and sheep do (Fitak et al., 2025). Besides, they can eat some poisonous plants such as *Cynanchum* or *Stellera* (Fitak et al., 2025). For instance, the tongue of Bactrian camels differs in many characteristics from that of common domestic ruminants, which is essential for their adaptation to harsh environment with tough, inorganic plants (Eerdunchaolu et al., 2001).

As far as carnivorous species are concerned, they have special features of language that reflect their dietary patterns. Experimental studies have proved that dogs possess unique abilities. Thanks to their special sensory organ, dogs have a big number of taste buds on the tongue, especially along fungiform and vallate papillae (Plewa et al., 2026). The number of taste buds in dogs is quite high, as the majority of taste buds, that is 93% located on the lingual apex and the caudal part of a tongue, that are crucial for food selection and tasting (Plewa et al., 2026). The size of fungiform papillae in dogs is varying in size, where the amount of the taste buds can be 29 per papilla (Plewa et al., 2026).

There is significant literature on the lingual biology of mammals; however, there is a dearth of comparative studies that focus on the variations in tongue design and function in herbivorous camels and carnivorous dogs. Since tongue adaptations are necessary to comprehend how tongue anatomy is related to the feeding habits of the mammals and their evolution, this study aims to be a comparative analysis of the anatomical, histological, and ultra-structure of the tongues of camels and dogs to evaluate how the structure of the tongue is related to the animals' diet and habitat.

Objectives of the Study

1. To compare the gross anatomy and histology of the tongue of dogs and camels.
2. To identify and explain the basic anatomical distribution of lingual papillae of both animals.
3. To compare the structural capacities of different types of papillae in camels and dogs.
4. To establish a connection between the structural variations found during the study and the features of the diet and the environment.

Materials and Methods

Sample Collection and Morphometric Measurements

This research employed a total of twenty adult animals aged 1–3 years representing two species: *Camelus dromedarius* (n=10) and *Canis lupus familiaris* (n=10), irrespective of sex. The tongue tissue samples were taken from healthy animals immediately post-mortem in Basrah Governorate, Iraq. Once extracted, the tongues were washed thoroughly with tap water to remove any residues and contaminants. Total weight was taken on a highly sensitive electronic balance (accuracy ± 0.01 g), while the length and breadth were recorded using a standard calibrated digital caliper (accuracy ± 0.01 mm).

The breadth was measured at three different points: the apex, mid-body, and the base (root) of the tongue.

Histological and Histochemical Processing

For the preparation of light microscopic samples, all tongue tissues were treated with bisected 10% neutral semiformalin for two days at room temperature. After the fixation process was completed, samples underwent a washing process in running tap water for 24 hours and then dehydrated with consecutive ethanol treatments involving concentrations of 70%, 80%, 90%, 95%, and 100%. After the dehydration process, the tissues were completed using standard histological processes of clearing with xylene and embedding in paraffin wax blocks (Bancroft and Layton, 2019). The tissue was sliced with rotary microtome (Leica RM2125) yielding tissue sections of 5–6 μm thickness. These sections were then mounted in gelatin-coated slides and stored overnight at 40°C (Alquraishy et al., 2026).

To examine the structure and architecture of cells, the histological sections were stained with Hematoxylin and Eosin (H&E) following standard protocols (Luna, 1968; Kadhim et al., 2026). The sections underwent periodic acid recipient staining (PAS) to identify the mucopolysaccharides and carbohydrate substances present in tissues (Pearse, 1985). In the end, the stained sections were viewed and captured under a light microscope (Olympus BX430) equipped with a digital camera (Olympus DP27) (Jasim et al., 2025; Mohsin et al., 2025).

Scanning Electron Microscopy (SEM)

The tissue samples from the tongue apex, body, and base were fixed with 2.5% glutaraldehyde for ultrastructural investigations. Samples were fixed for 24 hours at 4°C in 0.1 M phosphate buffer (pH 7.4). Specimens were post-fixed with 1% osmium tetroxide for 2 hours, dehydrated in an ethanol series, subjected to critical-point drying in CO₂, mounted on aluminum stubs, and sputter-coated with gold-palladium. The scanning electron microscope (Hitachi S-4700) was utilized at 10–15 kV for examination and photographing samples.

Digital image analysis was performed using ImageJ software for morphometric analysis of the micropictures. Measurements of the diameter, height and density of taste buds and papillae were made on stained sections. At least 10 fields of those selected randomly were analyzed in each specimen at 400 $\times$ magnification. The density of papillae was defined per unit area (mm²).

Statistical Analysis

All quantitative data were expressed as Mean $\pm$ Standard Deviation (SD). Statistical comparisons between the two species (camels and dogs) were analyzed using the Independent Student's t-test. For comparisons among different anatomical regions within the same species, One-way Analysis of Variance (ANOVA) followed by Tukey's post-hoc test was performed. Statistical significance was set at $P < 0.05$. All statistical analyses were conducted using SPSS

software (Version 25.0; IBM Corp.) (Field, 2018; Abduljaleel et al., 2025).

Results

Gross Morphological Features

A gross anatomical assessment showed that the camel tongue differed in morphology from that of the dog although both species follow the same division into different regions (tip, body and root). The camel tongue was long, thick and muscular with its different areas well-defined (Figure 1). The color of the dorsal surface was dark notably in the tip and the body regions. The lingual prominence (torus linguae) is absent in camels in agreement with the previous reports about the anatomy of the dromedary tongue.

As to the dog tongue it was long, compressed dorsally and very flexible. It was marked by a pronounced median sulcus appearing as a narrow line running the entire length of the dorsal tongue (Figure 2). The lingual frenulum of the dog tongue was quite large running from the underside of the tongue to the bottom of the mouth cavity. The outer surface of the dog tongue was coarse due to the presence of a large number of keratinized filiform papillae. The median sulcus is the biggest in the tip and body parts of the tongue getting smaller as it approaches the base.

Table 1: Morphometric measurements of the tongue in camels and dogs (Mean $\pm$ SD)

Parameter	Camel (n=10)	Dog (n=10)	P-value
Tongue length (cm)	28.4 $\pm$ 2.1	21.1 $\pm$ 0.1	<0.001*
Tongue width at apex (cm)	5.8 $\pm$ 0.6	2.9 $\pm$ 0.5	<0.001*
Tongue width at body (cm)	7.2 $\pm$ 0.8	3.2 $\pm$ 0.6	<0.001*
Tongue width at base (cm)	6.5 $\pm$ 0.7	4.5 $\pm$ 0.3	<0.001*
Tongue weight (g)	425.6 $\pm$ 32.5	378.3 $\pm$ 28.5	0.002*

*Statistically significant at $P < 0.05$

Filiform Papillae

Filiform papillae were plentiful in both animals' dorsal lingual surfaces; nevertheless, the way they were structured and developed differed. In camels, filiform papillae covered the entire dorsal region of the tongue uniformly and appeared as separate conical structures with their apexes pointing backward and enabling food to be moved toward the pharynx (See Figure 1). They had a complicated structure, and their branches formed the main body subjecting food to mechanical treatment. In dogs, filiform papillae were squeezed together in large numbers and became heavily keratinized at their tips; hence, dogs' dorsal lingual surface was characterized by its rough texture (See Figure 2). The papillae were found to be arranged in a strict manner and were already observable in separate lines on a low magnification. At the same time, the apex portion of dogs' filiform papillae appeared sharper than those of

camels since dogs should have their food processed properly.

Fungiform Papillae

In both species, the fungi-form papillae were observed and similar differences in their distribution and number were noted. In camels, they are mushroom-shaped and located between filiform papillae; however, they are more concentrated at the lateral borders of the tongue (Figure 1). Fungiform papillae are characterized as rounded and elevated structures which have one taste pore on their apical surface. In camels, the number of these structures is small (around 12–15 papillae per cm^2) as compared to dogs.

In dogs, fungiform papillae can be found on the dorsal surface of the tongue and distributed over the entire length; however, they are more concentrated at the lingual apex and lateral borders of the tongue (Figure 2). These papillae in dogs are larger than in camels and have 3–8 taste buds in each of them with taste pores being visible through the papillae's surface (Plewa et al., 2026).

Vallate Papillae

A vast difference was noted in regard of the vallate papillae sizes, numbers, and arrangement among different species. In the camel, the shape of the vallate papillae was represented as two identical rows of papillae located symmetrically on the right and left sides of the posterior dorsal surface with each row containing from 8 to 12 cambrian papillae. Each vallate papilla is rather large in size and provided a deep trench around it wherein lies a bulk of taste buds located along with the lateral epithelial part of the vallate papillae. Vallate papillae of the camel were found to be placed before the lingual tonsil forming a circular pattern as a whole group.

In dogs, the number of vallate papillae is rather small comprising from 4 to 6 papillae in the shape of a letter V and directed toward the pharynx. Vallate papillae in dogs can be found in the posterior dorsal part of the tongue before its base. Each individual papilla was found to be smaller than one found in camels and had an identical arrangement, likewise, all vallate papillae consist of central papilla covered with round trench full of taste buds.

Lenticular and Conical Papillae

Lenticular papillae were seen in camels on the back side, specifically in the part of the tongue that is called the root of the tongue. These papillae were flat discs with a rough surface and had a major mechanical role. Also in camels, conical papillae existed on the back side and sides with more keratinization than the other types of papillae.

In dogs, lenticular papillae were not present and conical papillae were less common and less defined than in camels, which is a reflection of the special needs of the herbivorous feeding technique compared to carnivorous feeding methods.

Figure 2: Gross anatomical and macroscopic features of dog and camel tongues showed that (a picture) An in situ overview of the dog tongue demonstrating the main

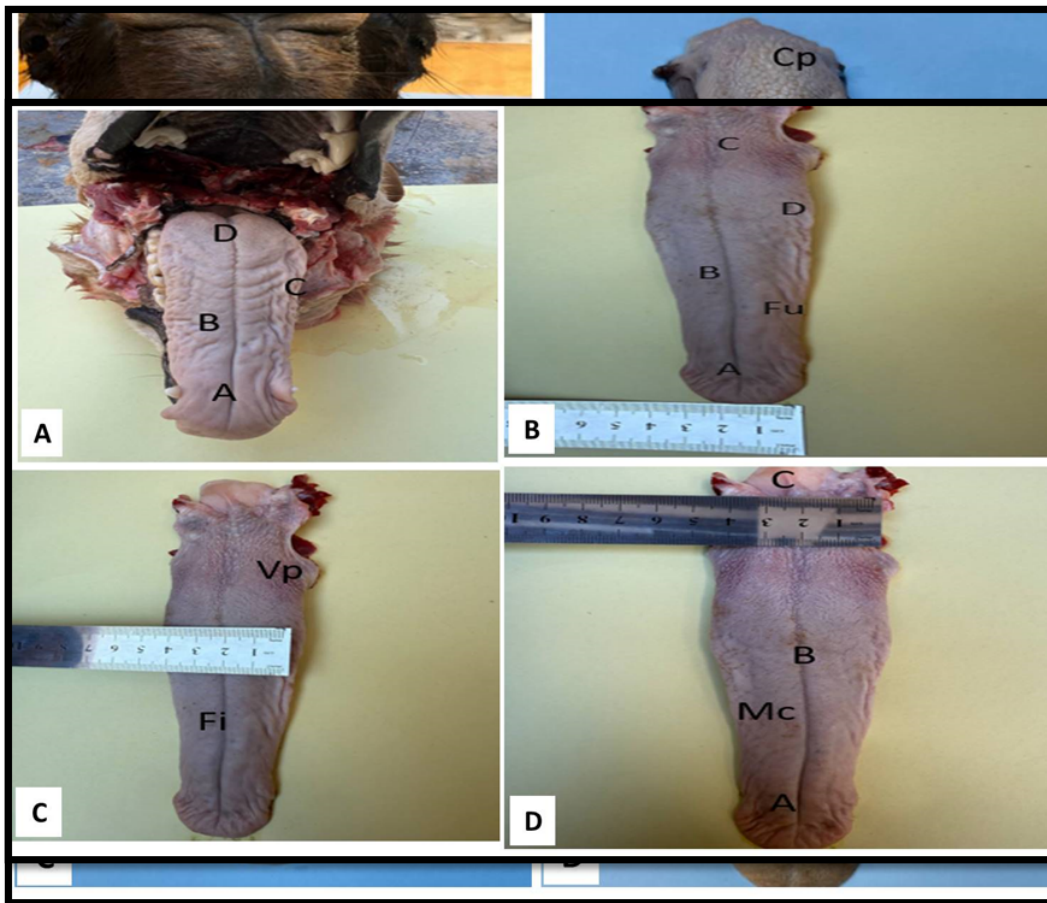


Figure 1: Gross anatomical and macroscopic features of the dorsal surface of the camel tongue showed that, (a picture) An overview of the tongue illustrating the apex (A), body (B), and base (C), with the general distribution of filiform (Fi) and fungiform (Fu) papillae; (b picture) The apex region showing scattered fungiform papillae (Fu) interspersed among the dense filiform papillae (Fi); (c picture) The body region demonstrating the dense distribution of mechanical filiform papillae (Fi) and interspersed gustatory fungiform papillae (Fu); and (d picture) The base region showing the prominent lingual tonsil (LT) flanked by symmetrical rows of vallate papillae (Vp).

landmarks including the apex, body, median sulcus, and base; (b picture) Macroscopic view of the dog tongue apex illustrating a prominent median sulcus (MS) and the distribution of fungiform papillae (Fu); (c picture) Dorsal surface of the dog tongue showing heavily keratinized filiform papillae (Fi) transitioning toward the posterior region containing vallate papillae (Vp); and (d picture) Anatomical features of the camel tongue base showing the prominent lingual tonsil (LT) surrounded by vallate papillae (Vp), lenticular papillae (Lp), and mechanical filiform papillae (Fi).

Histological Features

The light microscopic analysis showed that the structure of the lingual mucosa was similar in dogs and camels, indicating the structure comprised a stratified squamous epithelium, a prominent layer of connective tissue lamina propria and a core of skeletal muscle (Figures 3-4). However, important adaptations associated with

protection from mechanical injuries and sensory functions were noticed.

Camel tongue: Histological analysis of the camel tongue showed a strong degree of hyperkeratosis of the epithelium on the dorsal surface, with the epidermis being characterized by a well-thickened stratum corneum and a presence of intra-epithelial keratin pearls (Figure 3). The thickness of the stratified squamous epithelium was quite impressive too, reaching to 150-200µm in the area of papillae and in the middle of the tongue. At the same time, the presence of pronounced rete pegs increased the area of interaction between the epithelial layer and the lamina propria.

Camels possessed few taste receptors, located deep under the thick layer of keratinized epithelium. The number of these receptors was relatively small, averaging between two to four taste buds per fungiform papilla while there were about 15 to 20 of them in the vallate papilla. The taste buds were mainly located in the sides of the vallate papillae while they were almost absent in the fungiform papillae.

Dog Tongue: A dog's tongue, on the contrary, is not so keratinized and has more intricate sensory features, as shown in Figure 4. The stratified squamous epithelium on the tongue is thinner (80-120 µm) than that of the camels. There is some keratinization, but it only occurs in the surface layer of the filiform papillae. The lamina propria is well-blooded and has many nerves and sensory endings.

It was found that the number of fungiform and vallate papillae having working taste buds in dogs is bigger than in camels. The average amount of fungiform papillae in dogs is between 25-35 papillae per cm², with every papilla having around three to eight taste buds. Vallate papillae consist of fifty to one hundred taste buds per each papilla, which is way higher than in camels. Mostly, taste buds are located in the non-keratinized epithelial borders of the papillae which indicates higher ability of dogs for sensing.

Ultrastructural Features (Scanning Electron Microscopy)

Scanning electron microscopy proved that the two species have different ultrastructural characteristics especially keratinization and the three-dimensional topography of the lingual papillae.

Anterior Region (Apex): The tongue apex in camels is formed by keratinized filiform papillae that have lots of small secondary processes (Figure 5). The secondary

processes are thin finger-like structures, which increase the surface area. Between the filiform papillae, there are big fungiform papillae with visible taste pores on their tops.

In dogs tongues, the apex shows regular array of filiform papillae along with moderate size fungiform papillae having distinct periapical grooves (Figure 6). The filiform papillae in dogs are also sharper and thicker than in

Mid-lingual region: In camels, mid-lingual shows presence of smooth epithelium with thick keratinized strata that covers the filiform papillae as seen in figure 5. Fungiform papillae are found to be scanty in this mid-lingual region with taste pores being visible on some of the papillae.

The same area in dogs shows presence of distinct taste pores with a thin keratinized layer covering them as depicted in (figure 6). The number and size of fungiform papillae were high and their histological section of figure shows presence of taste buds. The high concentration of taste pores in this area indicates the significance of this mid-body area in taste perception while consuming food.

Posterior region: The posterior region of the camel shows presence of large, highly keratinized conical papillae with multiple gland openings (figure 5). The mucosal folds are thick and prominently folded showing presence of numerous mucosal pores confirming presence of lingual glands. Moreover, presence of such keratinization indicates that this area provides protection during consumption of roughage.

In dogs, these characteristics in this posterior area were found to be reduced both in size and structural complexity (figure 6). In posterior section of tongue, papillae found were reduced in numbers and size.

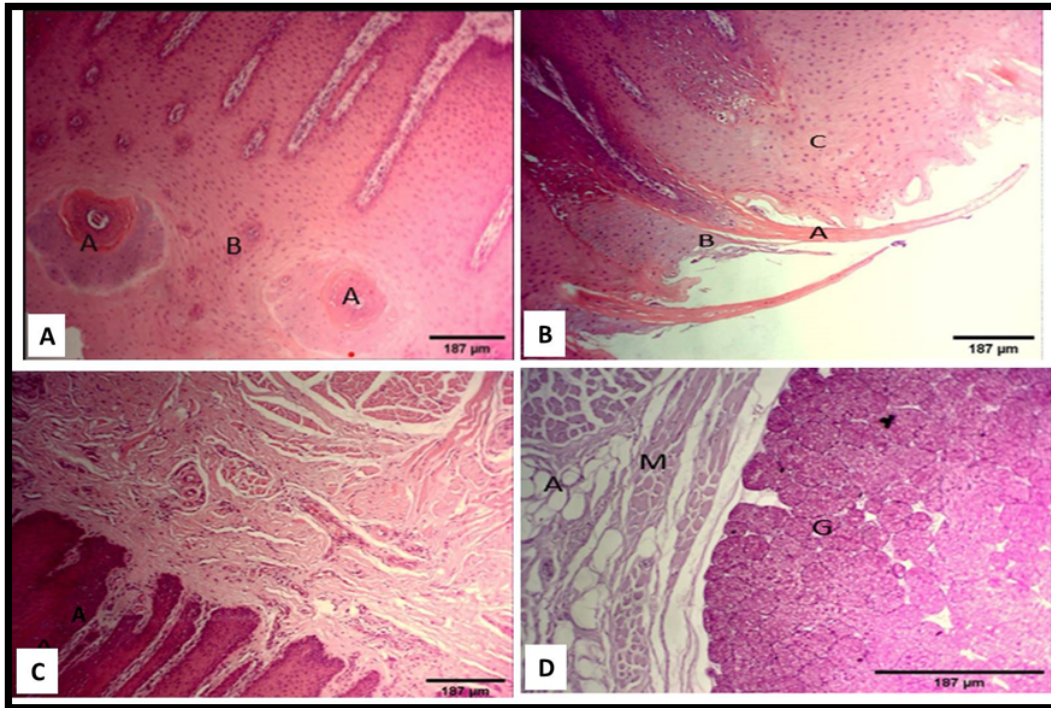
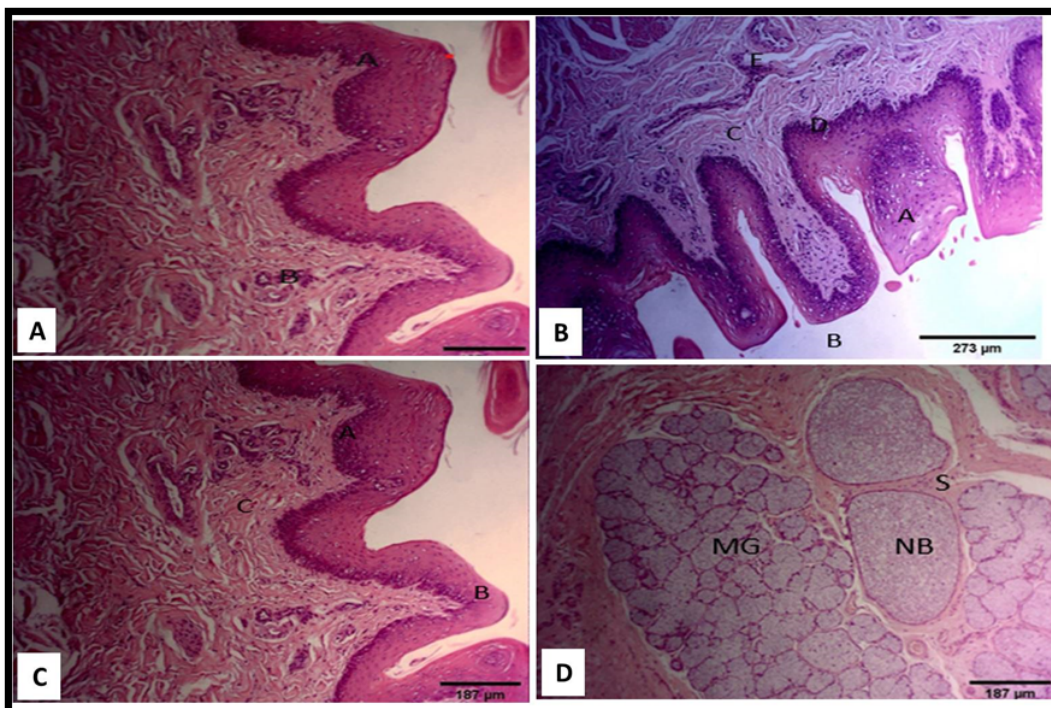


Figure 3: Histological sections of the camel tongue dorsal surface showed that (a picture) Dorsal surface demonstrating hyperkeratosis, prominent keratin pearls (A), and deep epithelial pegs (B); (b picture) The tongue apex showing keratinized filiform papillae (A) lined by a thick keratin layer (B) and stratified squamous epithelium; (c picture) The lingual body showing a dorsal surface lined by thick keratinized stratified squamous epithelium (KST); and (d picture) The tongue base showing a dense accumulation of mucous lingual salivary glands organized into distinct lobules (G) separated by thin connective tissue septa. (H&E stain, scale bar = 187 µm).

Figure 4: Histological sections of the dog tongue dorsal surface was showed that, (a picture) The tongue body appeared keratinized stratified squamous epithelium (A) and rete pegs tightly interlocked with the lamina propria (B); (b picture) The tongue apex showing sharp tipped conical filiform papillae (A) lined by thick keratinized stratified squamous epithelium (B) resting on the lamina propria (C), with the basal layer (D) and underlying



blood vessels (E) indicated; (c picture) The lingual body showed a dorsal surface lined by keratinized stratified squamous epithelium (A) forming numerous simple filiform papillae (B) supported by the underlying lamina propria (C); and (d picture) The base of the tongue showing well-defined lobules of mucous lingual salivary glands (MG) compartmentalized by thin interlobular connective tissue septa (S) adjacent to large nerve bundles (NB). (H&E stain, scale bar = 187 μ m).

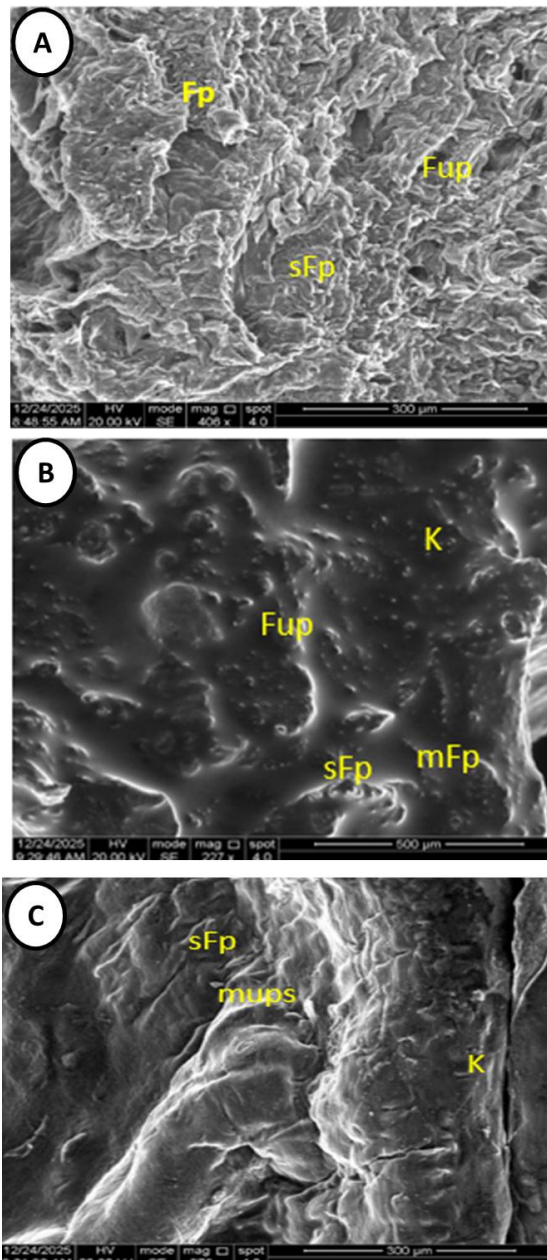


Figure 5: Scanning electron micrographs (SEM) of the dorsal surface of the camel tongue showed that, (A picture) the apex region displaying a dense, highly keratinized surface with mechanical filiform papillae (Fp), secondary filiform papillae (sFp), and interspersed fungiform papillae (Fup) (magnification 406 $\times$, scale bar = 300 μ m); (B picture) showed the body region demonstrating a smoother epithelial surface with keratinized layers (K), main filiform papillae (mFp), secondary filiform papillae (sFp), and gustatory fungiform papillae (Fup) (magnification 227 $\times$, scale bar = 500 μ m); and (C picture) was appeared the root region showing thick mucosal ridges with keratinized folds (K), mucosal pores (mup), and secondary filiform structures (sFp) (magnification 378 $\times$, scale bar = 300 μ m).

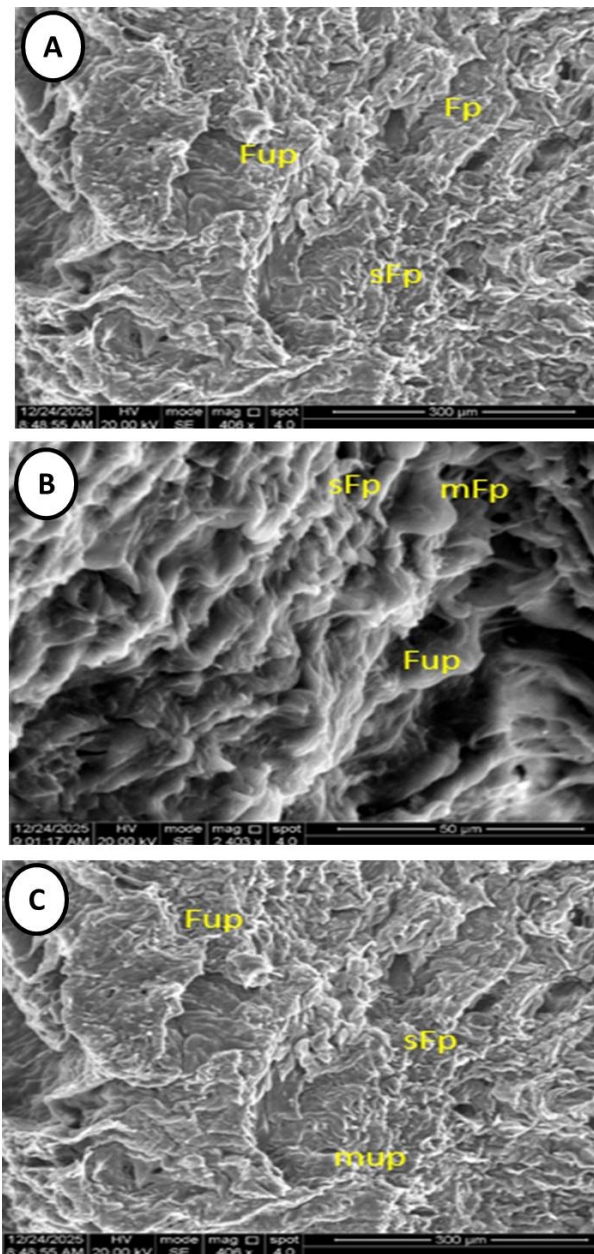


Figure 6: Scanning electron micrographs (SEM) of the dorsal surface of the dog tongue showed that, (A picture) the apex region displaying numerous filiform papillae (Fp), secondary filiform papillae (sFp), and scattered gustatory fungiform papillae (Fup) (magnification 400×, scale bar = 300 µm); (B picture) the body region appeared that main filiform papillae (mFp), secondary filiform processes (sFp), and prominent fungiform papillae (Fup) (magnification 2475×, scale bar = 50 µm); and (C picture) the root (base) region showed that large fungiform papillae (Fup), secondary filiform papillae (sFp), and mucosal surface micro-folds (muf) (magnification 400×, scale bar = 300 µm).

Discussion

This study shows that anatomical, histological, and ultrastructural properties that characterize the tongues of camels are considerably different from those of dogs, indicating how evolution has resulted in tongue adaptations that suit different diets and environments (Dyce et al., 2018; Hassan et al., 2018). Based on the results presented in this study, it can be concluded that the marked morphological variations in lingual papillae structure, keratinization degree, and taste bud incidence confirm the existing functional differences between herbivorous and carnivorous feeding styles.

The high degree of hyperkeratosis in the camel tongue can be viewed as an important adaptation to the need to consume coarse and fibrous vegetation of deserts. This reflects the data on Bactrian camels indicating that, unlike gustatory papillae, the keratinization of the covering stratified squamous epithelium of mechanical lingual papillae is greater (Eerdunchaolu et al., 2001; Ye et al., 2008). The above-mentioned keratin layer serves a number of important functions including the prevention of mechanical damage from the tough plant materials that need to be processed while eating. A particular attention should be given to the fact that camels are associated with eating plant families of the Asteraceae and Chenopodiaceae, with their high silica and salt content (Fitak et al., 2025).

The observation of keratin pearls and deep epithelial pegs (rete pegs) in camels is indicative of this buffering function, which aligns well with the findings in other ruminants that can withstand extreme environments, like sheep and goats (Abumandour & Kandyel, 2023; Madkour et al., 2023). The broad keratinization in the rear area of the camel tongue that has huge conical papillae as well as several openings of glandular choruses can be explained too, as it meets the functional needs for processing rough, dry plants prior to swallowing. One more protective mechanism comes with the fact that high level of neutral mucopolysaccharides revealed in camel epithelium with the help of PAS staining contributes to improving the viscoelastic properties of this epithelial surface as

mucopolysaccharides provide lubrication for food during its entry.

On the other hand, the canine tongue exhibited less keratinization but possessed greater sensory sophistication. The presence of Krause end bulbs in the connective tissue and higher frequency of fungiform and vallate papillae serves to facilitate the dog's carnivorous feeding habits. Recent 3D microstructural studies demonstrated that dogs actually possess many taste buds (93% of which are present at the apex and caudal portion of the tongue – the areas where food is preselected and tasted during predation). In dogs, fungiform papillae were observed to grow in diameter and number of taste buds in a caudal direction, with a maximum of 29 taste buds per one papilla. The presence of such a gradient may mean that the tongue is able to process food in two successive steps: initial taste processing at the tip of the tongue during food intake, followed by detailed taste examination at mid-tongue during mastication.

The differences in arrangement of vallate papillae in different species are remarkable, with camels having two symmetrical rows on the body's dorsum, and dogs having a V arrangement with 4–6 papillae (Alsafy et al., 2013; El Sharaby et al., 2014). This difference is probably due to the different feeding habits, given that the role of vallate papillae is related to bitterness perception, which allows them to avoid harmful substances (Meier et al., 2016). The small number of vallate papillae in camels compared to what is present in dogs suggests that camels can consume plants harmful for other mammals, indicating the presence of a mechanism different from taste to allow the selection of food types. Alternatively, camels may require that increased number of functioning vallate papillae in order to make up for the decreased number of functioning fungiform papillae.

The results of the current investigation match findings reported in past studies in mammalian species (Kobayashi et al., 1988; Pastor et al., 2008; Jackowiak and Godynicki, 2005). In dogs, the organized pattern of filiform papillae with clear periapical grooves ensures effective mechanical processing of meat-based food. In camels, the presence of complex secondary structures in filiform papillae and considerable keratinization in the rear area suggest that these animals may have adapted their tongues to grasp and handle tough vegetation growing in desert. These ultrastructural changes demonstrate a close relation between tongue morphology and feeding behavior. Thus, it can be concluded that lingual features can be effectively used as indicators of dietary ecology.

The histological differences in the distribution of taste buds and their numbers in the two species reflect their different sensory needs. Camels have rather low density of taste receptors, which means that they rely more on mechanical processing than on taste perception when animals are selecting food for themselves (Madkour et al., 2023; Abumandour and Kandyel, 2023). This type of adaptation is especially useful in desert ecosystems

where food is scarce, while palatability plays a secondary role in food acquisition.

The structure of the lamina propria also exhibited differences in relation to species. In the case of camels, previously reported evidence (Ye et al., 2008) for the presence of large lymph nodes in the lamina propria located in the tongue root further substantiates the immune functions necessary for handling potentially harmful desert vegetations. In dogs, on the other hand, highly developed blood vessels and nerve bundles within the lamina propria make for fast nerve transmission of important signals necessary for acute sensory perception (Dellmann, 2006; Stinson and Calhoun, 1993).

The results acquired may contribute to the gathering evidence that demonstrates lingual morphology as a sensitive information reflecting adaptation to feeding behavior. Differences in structure observed in camels and dogs echocardiography findings should indicate that the differences may yield some benefits in terms of the elimination of harmful and easily recognizable food substances (Hassan et al., 2018; Meier et al., 2016).

The findings of this research are significant for veterinary practice and comparative zoology. The background information collected on thenormal anatomy and histology of tongues in both camels and dogs can aid in diagnosis of diseases of the oral cavity. Furthermore, knowledge of the connection between tongue structure and feeding habits can help in managing and conserving different animal species, including both domestic and wild animals in terms of fulfilling their food needs and preserving their habitats. Subsequent studies utilizing modern methods such as three-dimensional reconstruction, immunohistochemistry for various taste receptors, and molecular research of the gustatory pathway will help to understand the reason for the mentioned morphological differences (Plewa et al., 2026). Comparative studies involving various mammals, including other herbivorous, carnivorous, and omnivorous animal groups, can help understand the evolution of tongue modifications in relation to food diversification.

Conclusion: This extensive comparative research highlights the differences in structural, histological and morphological aspect of camel and dog tongue based on the evolutionary adaptation of these animals in their feeding habits and their living environment. Camel tongue has a lot of hyperkeratosis, thick stratified squamous epithelium, extensive mechanical papillae, but few taste buds, which is perfect for overcoming tough desert vegetation. Dog tongue, on the other hand, is moderately keratinized, has numerous fungiform and circumvallate papillae populated with numerous taste buds, and possesses multifaceted sensory system facilitating carnivorous taste demands. These discoveries bring important understanding of tongue structure and its function in the case of mammals' dietary ecology.

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