Comparative light and scanning electron microscopic study of the lingual papillae in three different mammalian animals; *Hemiechinus auritus* (Erinaceomorpha: Erinaceidae), *Cavia porcellus* (Rodentia: Caviidae) and *Mustela nivalis vulgaris* (Carnivora: Mustelidae)

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Abstract: The present study was carried out to describe the histological structure of the tongues of three different mammalian animals which having different diets; *Hemiechinus auritus* (insectivorous), *Cavia porcellus* (herbivorous) and *Mustela nivalis vulgaris* (carnivorous). Also, this study aimed to investigate the morphology of the lingual papillae of the tongues of these animals by the scanning electron microscope. Tissue samples taken from the tongues of five adult healthy animals from each specimen were fixed in the appropriate fixatives for light and scanning electron microscopic investigations. Light microscopy observations showed that the dorsal surface of the tongues of the three animals are formed of three consecutive layers; mucosa, submucosa and muscularis. The mucosal layer consists of stratified squamous epithelium with variable degrees of keratinization and contains different types of papillae. SEM observations revealed that there are three types of papillae (filiform, fungiform and foliate) in *Cavia porcellus*'s tongue. But, there are four types of papillae (filiform, fungiform,vallate and foliate) in the tongues of *Hemiechinus auritus* and *Mustela nivalis vulgaris*. The filiform papillae are leaf-like simple conical or branched in *Hemiechinus auritus* and *Cavia porcellus*, but they take hand-like shape with finger-like processes in *Mustela nivalis vulgaris*. The fungiform papillae are mushroom-like in shape in the three animals. They are aggregated in two clusters in the anterior part of *Cavia porcellus*' s tongue. Two vallate papillae are observed in *Mustela nivalis vulgaris*' s tongue, but there are three vallate papillae in *Hemiechinus auritus*' s tongue. Pair of foliate papillae is found in the latero-posterior parts in the tongues of *Hemiechinus auritus* and *Mustela nivalis vulgaris*. In conclusion, the results of the present study added to the previously recognized studies of the dorsal lingual papillae of different mammalian animals which having different diets.

[Samia M.I. Sakr, Fatma M.A. Taki-El-Deen and Hanaa R. Aboelwafa. **Comparative light and scanning electron microscopic study of the lingual papillae in three different mammalian animals; *Hemiechinus auritus* (Erinaceomorpha: Erinaceidae), *Cavia porcellus* (Rodentia: Caviidae) and *Mustela nivalis vulgaris* (Carnivora: Mustelidae).** *Life Sci J* 2013;10(4):3082-3093]. (ISSN:1097-8135). http://www.lifesciencesite.com. 411

Keywords: *Cavia porcellus*; *Hemiechinus auritus*; light microscopy; lingual papillae; mammals; *Mustela nivalis vulgaris*; SEM; tongue.

1. Introduction

Feeding mechanism is an important factor that determines the success of adaptation of vertebrates to their environment (Darwish, 2012). The tongue is often considered a key innovation in the evolution of a terrestrial lifestyle as it allows animals to transport food particles through the oral cavity (Iwasaki, 2002). Moreover, there are fairly strong correlations between tongue anatomy and its functional roles (e.g., food transport and manipulation), and the environmental conditions in which animals use their tongues or hyobranchial system (i.e., water vs. air) (McClung & Goldberg, 2000; Schwenk, 2000; Iwasaki, 2002; Darwish, 2012).

The shape and structure of the tongue differ significantly among animal species, reflecting the various functions of each respective tongue (Iwasaki, 2002; Santos *et al*., 2011). Tongues of several species of animals were studied not only for their relation to taste but their participation in the assessment of palatability of food, sucking, intake of liquid food, mastication and mixing food with saliva, deglutition, and speech (Stevens & Lowe, 2005; Kulawik & Zdrojewska, 2006). The tongue is a highly muscular organ covered with squamous epithelium and partly oral and partly pharyngeal in position (Stevens & Lowe, 2005). The dorsal surface of the mammalian tongue is covered by specialized structures called lingual papillae. Morphological and functional studies of various species indicated a close correlation of the lingual form and the histological structure of the lingual epithelium with their feeding habits (Emura *et al*., 2008, 2009). Furthermore, Yoshimura *et al.* (2009) stated that the morphology of the tongue, the mucosa of the lingual papillae on its dorsal surface and the distribution of these papillae reflect dietary habits and living environment of the vertebrate animals.

In mammals, four types of tongue papillae (filiform, fungiform, circumvallate and foliate) can be found on the dorsal surface (Emura *et al*., 2006), but

the structure of the tongue reveals a variability of morphological features related to the type of food, habit and taxonomy (Jackowiak & Godinicki, 2005). From a comparative point of view, this variability is significant between high systemic units, such as orders and families, although frequently there are also interspecies differences (Iwasaki, 2002; Kobayashi *et al*., 2005; Emura *et al*., 2001, 2006; Jackowiak *et al*., 2004; Jackowiak & Godynichi, 2005).

Accordingly, many mammalian species have been studied specially for their lingual papillae structure and distribution. Those include primates (Kobayashi *et al*., 2004; Jackowiak, 2006; Kulawik & Godynicki, 2007a,b), rodents (Iwasaki *et al*., 1999; Toprak, 2006; Nasr *et al*., 2012) and bats (Park & Lee, 2009; Ramteke *et al*., 2013; Taki-El-Deen *et al*., 2013).

Therefore, this study has been carried out to describe the structure and distribution of the lingual papillae on the dorsal surfaces of the tongues in three different animals from three different species of mammals, which are feed almost different types of food using light and scanning electron microscopy. Also, this research aimed to clarify and compare the relationship between the morphological features of the tongue of these animals and their dietary habits and life styles and also to complement the previous studies on other mammalian species.

2. Material and Methods

2.1. The experimental animals

In the present work, specimens of three different mammalian animals living in different habitats in Egypt; *Hemiechinus auritus* (long-eared hedgehog), *Cavia porcellus* (guinea pig) and *Mustela nivalis vulgaris* (least weasel) were used.

2.2 Light microscopy preparations

Three animals from each specimen were anaesthetized with ethyl ether and their tongues were dissected from the mandible, removed immediately, cut into small pieces, fixed rapidly in Bouin`s fluid. After routine processing, sections of 4-6 μm were cut and stained with haematoxylin and eosin (Bancroft & Gamble, 2002), microscopically examined and photomicrographs were made as required.

2.3. SEM preparations

For SEM examination, the tongues of two animals from each specimen were placed into 3% glutaraldehyde with phosphate buffer (pH 7.3). Then, the tongues were dehydrated in a graded series of ethanol (70-100%), and subsequently dried with critical-point-dryer (Russell & Daghlian, 1985). The dried material was coated by gold sputter coater (SPL-Module) and samples examined by JEOL-JSM-5500 LV reflection scanning electron microscopy in the central laboratory of Schistosoma Biological Supply Program (SBSP) Theodor Bilharz Research Institute, Cairo, Egypt.

3. Results

3.1. Light microscopy observations

3.1.1. The tongue of *Hemiechinus auritus* (Long-eared hedgehog)

Examination of the histological sections obtained from the tongue of *Hemiechinus auritus*, revealed that it consists of three consecutive layers; mucosa, submucosa and muscularis (Figs. 1A&1B). The first layer consists of very thick stratified squamous epithelium which contains four types of papillae; filiform, fungiform, vallate and foliate papillae. Each type of lingual papillae is covered by stratified squamous epithelium and has a core of connective tissue. Also, keratinization of the covering epithelium is markedly observed (Figs. 1A-1D).

The filiform papillae are the most abundant and scattered all over the dorsal surface of the tongue. They appear as a single or double branched directed backward (Figs. 1A&1B). The anterior aspect of the filiform papilla consists of clear cells with weakly stained cytoplasm in the dorsal part as illustrated in Figure 1C. Fungiform papillae are scattered among the filiform papillae. They are discoid or mushroom-like in shape (Figs. 1A-1C). The vallate papillae are the largest and least common type of papillae, project above the surface of the tongue (Fig. 1B). They are encircled by a deep cleft. The stratified epithelium lining the papillary wall contains numerous taste buds as obviously seen in Figure 1D. The foliate papillae are situated in the latero-posterior part of the root of hedgehog tongue.

The second layer is submucosa which appears as a thin layer and consists of dense connective tissue (Figs. 1A&1B). The third layer (muscularis) is well represented by muscle fibers arranged in many directions (longitudinal, circular and oblique) as illustrated in Figures 1A and 1B.

3.1.2. The tongue of *Cavia porcellus* (Guinea pig)

This tongue is formed likewise of three distinct layers; mucosa, submucosa and muscularis. The mucosa consists of thick stratified squamous epithelium and contains three types only of papillae; filiform, fungiform and foliate papillae (Figs. 2A&2B). The filiform papillae are distributed over almost the entire dorsal surface of the tongue. All of these papillae are bent slightly backwards (Fig. 2B). As seen in Figure 2D, the filiform papilla is a conical process of stratified squamous epithelial cells, it is a slender sharp pointed structure. Fungiform papillae are found between the filiform papillae over the dorsal and lateral surfaces. They are well represented and being aggregated together in the anterior part of the tongue (Fig. 2A). The foliate papillae are found latero-

posteriorly on the root of the tongue. The submucosa is a wide and thick layer, built up of dense connective tissue rich with blood vessels (Figs. 2C). The muscularis layer is formed of striated muscle bundles that arranged in different directions as illustrated in Figures 2A and 2B. A median lingual sulcus is found at the dorsum of this tongue (Fig. 2B).

3.1.3. The tongue of *Mustela nivalis vulgaris* (Least weasel)

The histological sections of the tongue of least weasel showed that it is composed of the same three consecutive layers; the mucosa, submucosa and muscularis (Figs. 3A&3B). The mucosa is formed of stratified squamous epithelium that contains four types of papillae; filiform, fungiform, vallate and foliate papillae (Figs. 3A-3D). The filiform papillae are observed all over the dorsal surface of the tongue, being cone in shape with weakly keratinized stratified epithelium (Fig. 3C). The fungiform papillae possess dome-like shape, and their outermost stratified squamous epithelia are covered by thin cornea. They are found embedded between the filiform papillae (Fig. 3C). The vallate papillae are located at the posterior part of the tongue. They are the largest of all papillae types, appeared circular in shape with a depression around it (Fig. 3D). The foliate papillae are located at the postero-lateral part of the tongue. The submucosal layer consists of connective tissue rich with blood vessels. The muscularis layer is constructed of striated muscle bundles that arranged in different directions as illustrated in Figures 3A and 3B.

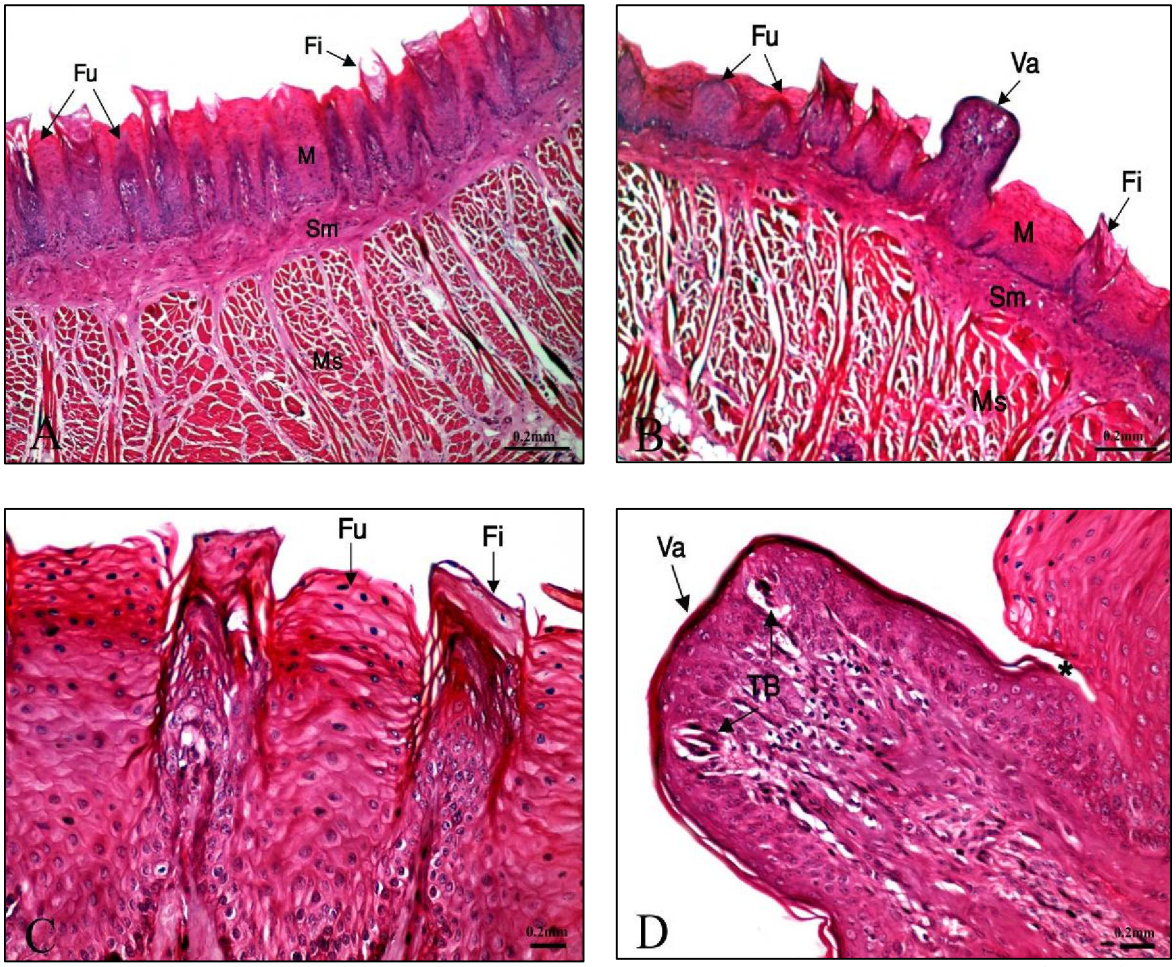

Fig. 1: Photomicrographs (A-D) of transverse sections of the tongue of hedgehog stained with H&E. A: The anterior region of the tongue showing the three consecutive layers; the mucosa (M) with double branched filiform (Fi) and discoid-like fungiform (Fu) papillae, submucosa (Sm) and muscularis (Ms). **B:** The mucosa (M) contains single branched filiform (Fi), mushroom-like fungiform (Fu) and vallate (Va) papillae in the posterior part of the tongue. **C:** Filiform papillae (Fi) appeared as a single branched directed backward, mushroom-like fungiform papillae (Fu) are found in-between the filiform papillae. **D:** Vallate papilla (Va) is encircled by a deep cleft (*) and the stratified epithelium lining the papillary wall contains numerous taste buds (TB). Scale bars=0.2mm

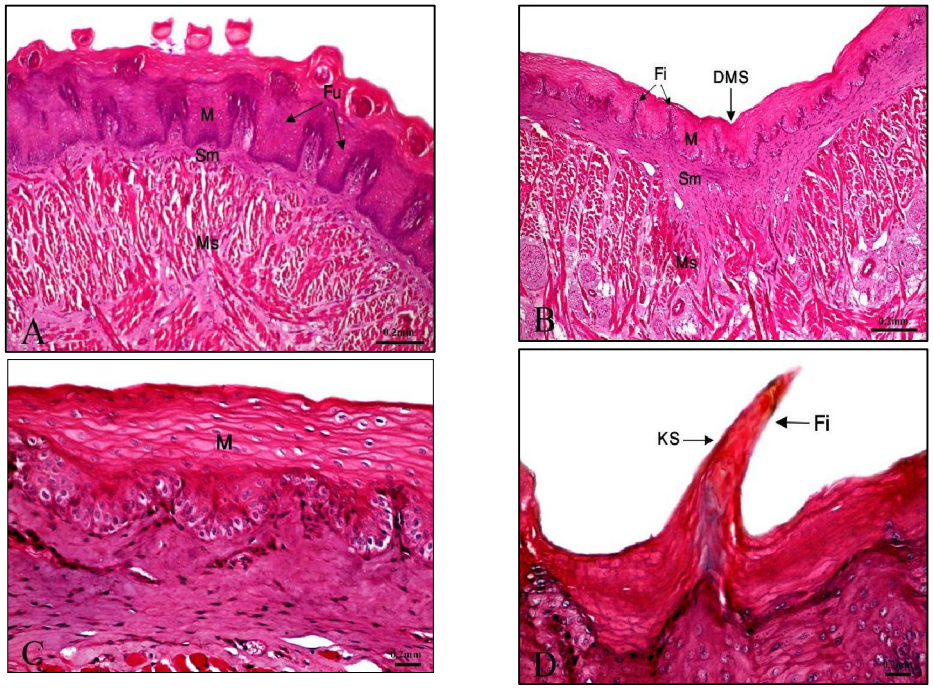

Fig. 2: Photomicrographs (A-D) of transverse sections of the tongue of guinea pig stained with H&E. A: The anterior part of the tongue revealing its three distinct layers; the mucosa (M), submucosa (Sm) and muscularis (Ms). The mucosa consists of thick stratified squamous epithelium which contains aggregated fungiform papillae (Fu). **B:** The dorsal part of the tongue showing a dorsal median sulcus (DMS). Note, the presence of filiform papillae (Fi). **C:** High magnification of the mucosa (M) with its heavily stratified squamous epithelium. **D:** Simple filiform papilla (Fi) consists of dense supporting tissue core and a thick keratinized spine (KS). Scale bars=0.2mm

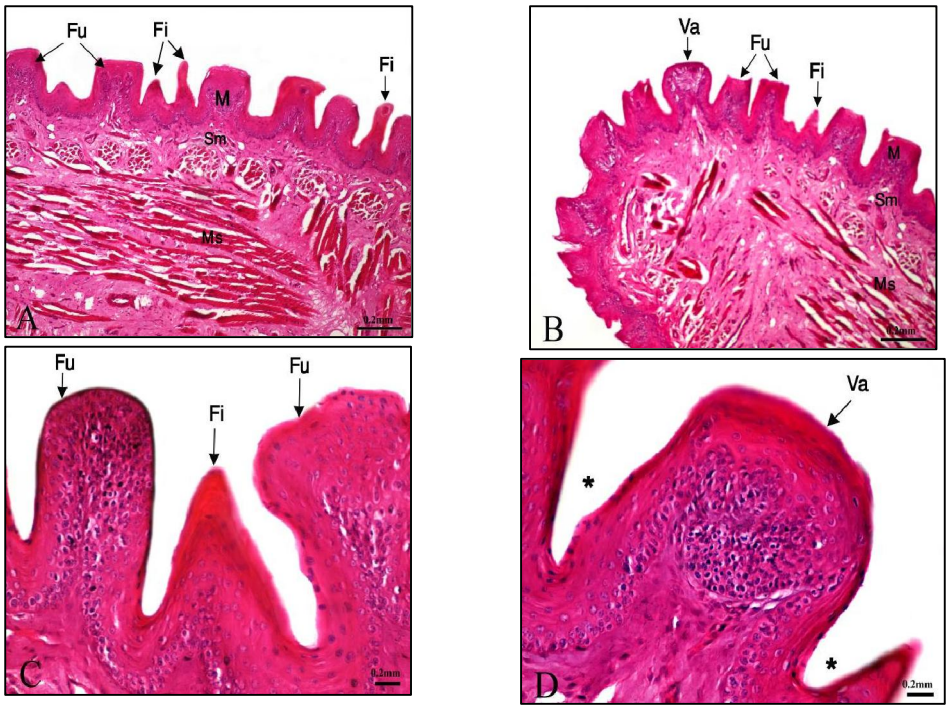

Fig. 3: Photomicrographs (A-D) of transverse sections of the tongue of least weasel stained with H&E. A: The anterior part of the tongue revealing the three consecutive layers; the mucosa (M) contains fungiform (Fu) and filiform (Fi) papillae, submucosa (Sm) and muscularis (Ms). **B:** Fungiform (Fu), filiform (Fi) and vallate (Va) papillae are clearly observed in the mucosa (M) of the posterior part of the tongue. **C:** High magnification of dome-shaped fungiform papillae (Fu) and cone-shaped filiform papillae (Fi). **D:** Vallate papilla being circular in shape with a depression around it (*). Scale bars=0.2mm

3.2. SEM observations

3.2.1. The tongue of *Hemiechinus auritus* (Long-eared hedgehog)

The tongue of hedgehog is elongated with somewhat symmetrical width and rounded anterior end. It can be distinguished into three regions; the anterior (tip), the middle (body) and the posterior (root) as shown in Figures 4A and 4B. Examination of SEM figures obtained from the tongue of the hedgehog, showed that there are four different types of papillae observed on the dorsal surface; filiform, fungiform, vallate and foliate.

Filiform papillae are the most numerous, extending over the whole dorsal surface of the tongue up to the root (Figs. 4A&4B). They are leaf like in shape with directed posteriorly pointed tips. They are simple conical or branched, divided into two to four accessory processes. Filiform branched papillae lie in rows and are compactly distributed over the tongue. They have two accessory processes from the tip to the anterior third and two or four at the posterior two third (Figs. 4C&4D).

Fungiform papillae are observed over the entire surface scattered between the filiform papillae. They are mushroom-like in shape and some of them being dome in shape. They are more abundant on the first third of the tongue and are shorter in length and larger in diameter when compared with the filiform papillae. Fungiform papillae on the anterior region were greater than those in the medial and posterior region. Several taste pores are observed on the dorsal surfaces of the fungiform papillae (Fig. 4C).

Vallate papillae are observed on the posterior-lateral area of the tongue, there are three papillae in an inverted triangle form. One of these vallate papillae is located at the central mid-line, while the other two are located laterally at both sides. Each papilla has a circular or elliptical form with a depression around it. The body of each vallate papillae is surrounded by a continuous trench and dense mucosal folds. It has several taste pores (Fig. 4E).

Foliate papillae are found in the latero-posterior part of the root of hedgehog tongue. There are a pair of foliate papillae, each is crescent in shape and has some parallel projections (microridges) separated by grooves. On their surfaces, there are several taste pores and 4-5 fissures situated bilaterally (Fig. 4F).

3.2.2. The tongue of *Cavia porcellus* (Guinea pig)

The tongue of guinea pig is relatively short with a rounded tip. It is divided into three zones; the anterior, the middle and the posterior. It has an intermolar eminence at about the posterior third (median dorsal groove) (Fig. 5A). Three different types of lingual papillae are observed in the dorsal surface of this tongue; filiform, fungiform and foliate papillae. Filiform papillae are distributed over almost the entire dorsal surface of the tongue except for the narrow zone of the lingual root. In the anterior part of the tongue, branched filiform papillae are distributed densely on the dorsal surface and sparsely on the lateral surfaces. All of these papillae are bent slightly backwards, and each is branched into two processes; one principle and one accessory. Some filiform papillae are simple in shape, having only one pointed process (Figs. 5B-5D).

Fungiform papillae are well represented in the anterior part of the tongue. They are aggregated in two clusters in the anterior part. Also, few fungiform papillae are scattered among the filiform papillae all over the dorsal and lateral surfaces. Each fungiform papilla is elliptical or circular in shape and taste pores are distributed on the top of it (Figs. 5B&5C).

Foliate papillae are observed in the latero-posterior part of the root of the tongue. They have parallel projections or microridges forming network and parallel patterns that are widely distributed on the dorsal surface of the intermolar eminence (Fig. 5E).

3.2.3. The tongue of *Mustela nivalis vulgaris* (Least weasel)

The tongue of least weasel is elongated with somewhat rounded anterior end. It is divided into three parts; the anterior, the middle and the posterior as illustrated in Figures 6A and 6B. There are four types of lingual papillae on the dorsal surface of this tongue; filiform, fungiform, vallate and foliate.

The filiform papillae are the most numerous extending all over the whole dorsal surface of the tongue (Figs. 6A&6B). They have hand-like shape with finger-like processes; most of them are directed posteriorly or posterior-medially toward the sulcus medianus linguale (Fig. 6C). Each papilla composes of main cone-shaped process and accessory finger-like processes. These processes are apparently arising from the base and both lateral surfaces of the papilla. These accessory processes seemed originated at different levels of the filiform papillae main bodies. The main body of each filiform papilla has a centrally running groove along almost all of the length of the papilla body. The accessory finger-like processes exhibited various relations to each other and to the main body. They vary in size, number and length. They either tightly embarrassing the main body of the papilla or leaving a small narrow space between them and the main body.

The fungiform papillae are few in number and located in the anterior part of the tongue compressed between the filiform papillae. They are dome-like in shape with minute taste pores (Fig. 6D).

There are two obvious vallate papillae observed postero-laterally in the tongue. Each papilla has a circular form with a depression around it. The body of each vallate papilla is surrounded by a continuous

trench and dense mucosal folds. Its upper surface mucosa is irregular and has many taste pores (Fig. 6E). There are a pair of foliate papillae found in the latero-posterior part of the root of this tongue, each is crescent in shape and has some parallel projections (microridges) separated by grooves. Several taste pores are found on its surface (Fig. 6F).

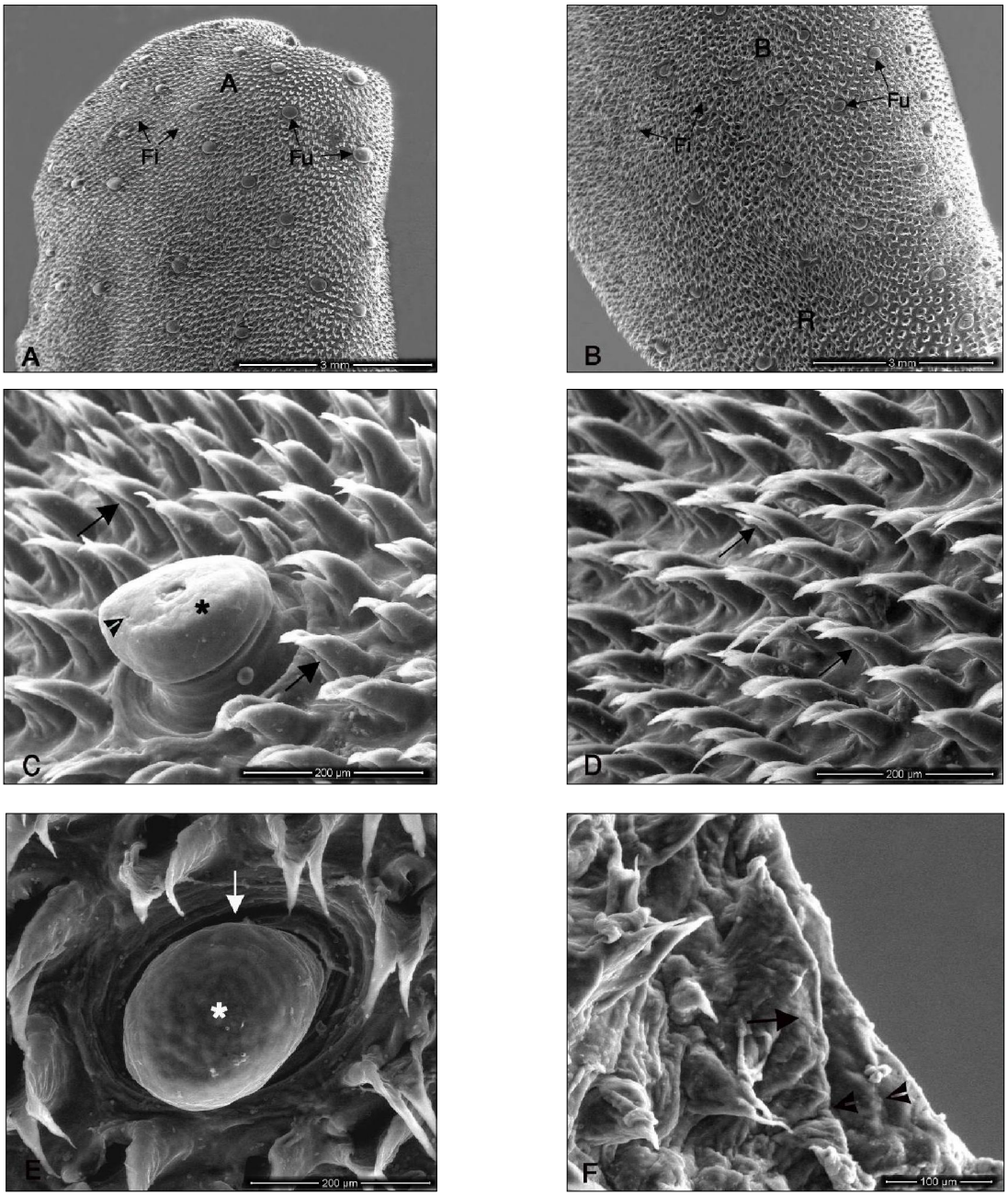

Fig. 4: SEM micrographs (A-F) of the dorsal surface of the tongue of hedgehog. A: The anterior part (A) of the tongue with relatively large and numerous fungiform papillae (Fu) scattered between filiform papillae (Fi). Scale bar=3mm. **B:** Part of the body (B) and the root (R) of the tongue showing fungiform (Fu) and filiform (Fi) papillae. Scale bar=3mm. **C:** A mushroom-shaped fungiform papilla (*) with minute taste pores (arrow head) between filiform papillae that looks like a forceps (arrows) in the anterior region of the tongue. Scale bar=200µm. **D:** Filiform papillae in the middle region of the tongue are relatively tall having two pointed processes (arrows). Scale bar=200µm. **E:** A round flat vallate papilla with central pore (*) is observed in the posterior region of the tongue and is surrounded by a prominent groove (arrow). Scale bar=200µm. **F:** A crescent shaped foliate papilla (arrow) separated by grooves (arrow heads) is seen in the posterio- lateral region of the tongue. Scale bar=100µm.

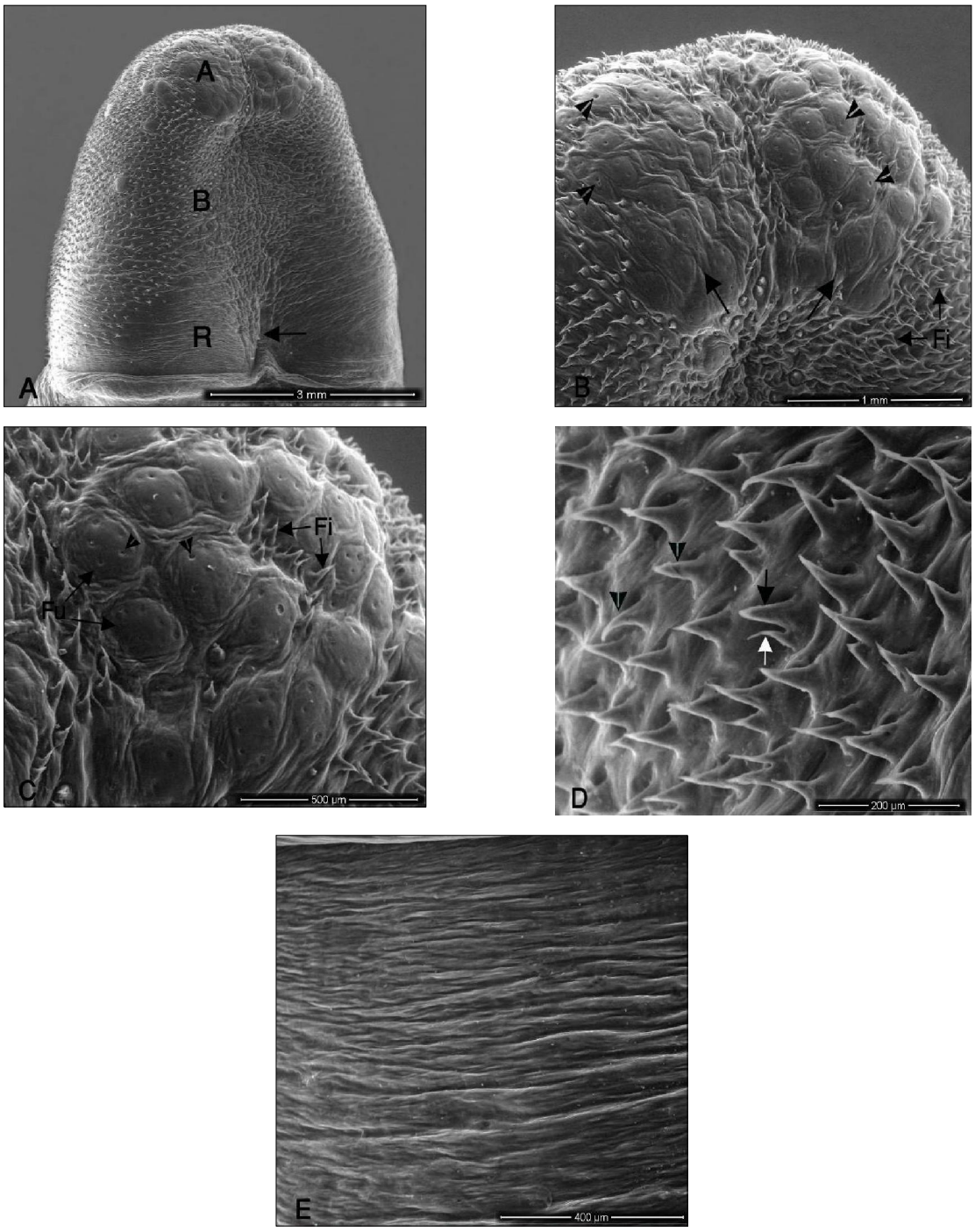

Fig. 5: SEM micrographs (A-E) of the dorsal surface of the tongue of guinea pig. A: The tongue is short with somewhat rounded anterior end. It is divided into three regions; the tip (A), the body (B) and the root (R). Note, the sulcus medianus linguale (arrow). Scale bar=3mm. **B:** The anterior part of the tongue with abundant rounded fungiform papillae which aggregated in two clusters (arrows), having several minute pores (arrow heads). Filiform papillae (Fi) are also seen. Scale bar=1mm. **C:** High magnification of the previous image illustrating clusters of fungiform papillae (Fu) with taste pores (arrow heads). Scale bar=500µm. **D:** Branched filiform papillae divided into two processes; one principle (black arrow) and one accessory (white arrow). Some of them being simple, having only one process (arrow heads). Scale bar=200µm. **E:** Foliate papillae are distinct and prominent in the posterior region of the root. Scale bar=400µ.

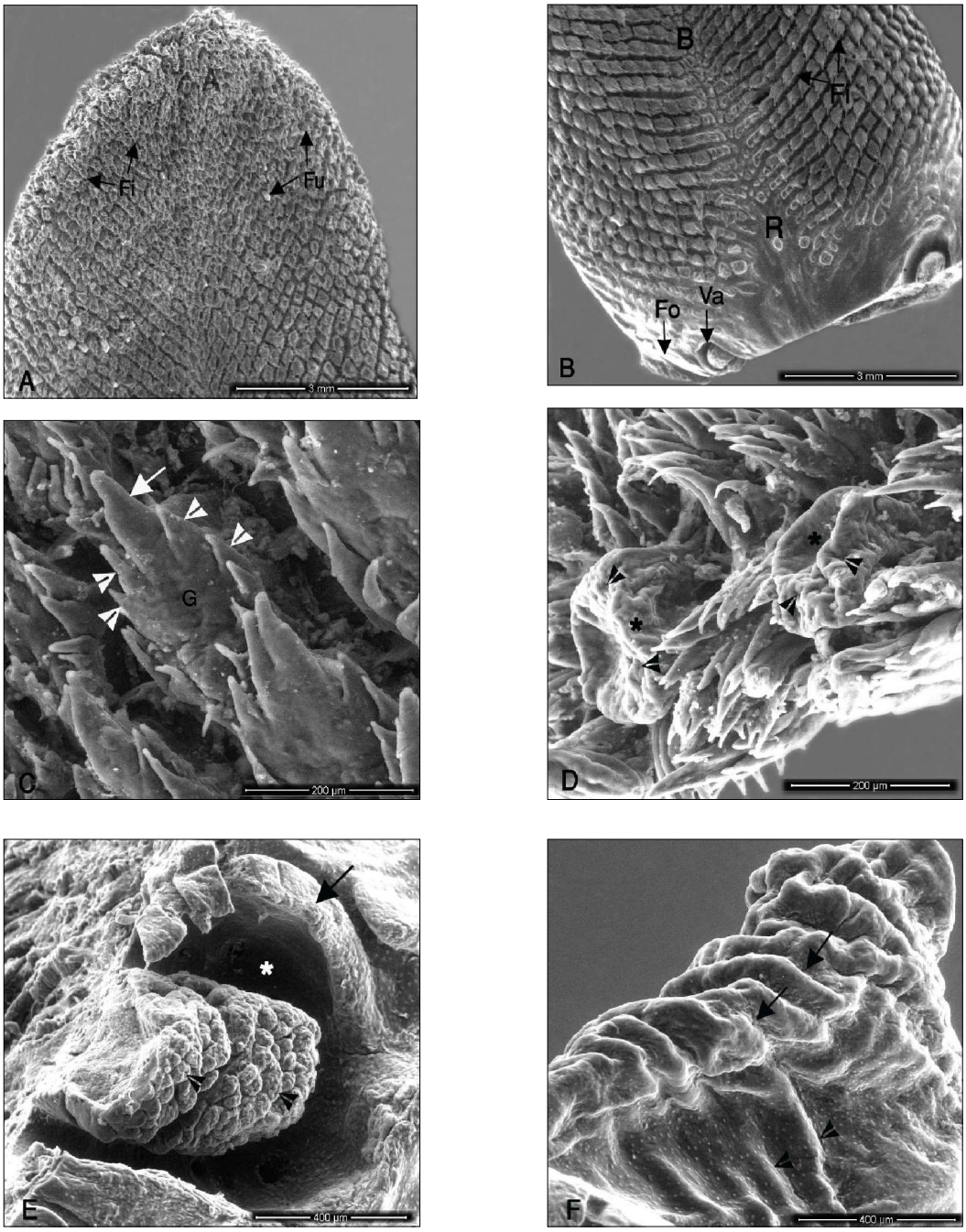

Fig. 6: SEM micrographs (A-F) of the dorsal surface of the tongue of least weasel. A: The anterior part (A) of the tongue with relatively small and less dense fungiform papillae (Fu) embedded between more dense longer filiform papillae (Fi). Scale bar=3mm. **B:** Part of the body (B) of the tongue with its special type of filiform papillae (Fi) and the root (R) with its prominent vallate (Va) and foliate (Fo) papillae. Scale bar=3mm. **C:** Filiform papilla in the middle part of the tongue, looks like a hand composed of main cone-shaped primary process (arrow) that being relatively tall with a centrally running groove (G) and accessory finger-like processes that being relatively short (arrow heads). Scale bar=200µm. **D:** Dome-shaped fungiform papillae (*) with minute taste pores (arrow heads) are found in the anterior region of the tongue. Scale bar=200µm. **E:** Circular vallate papilla is clearly observed in the posterio-lateral part of the tongue. Its body is surrounded by a continuous trench (*) and dense mucosal folds (arrow). Its upper surface mucosa is irregular, having several taste pores (arrow heads). Scale bar=400µm. **F:** Distinct and prominent foliate papillae separated with grooves (arrows) and having parallel projections (arrow heads) are seen in the latero-posterior part of the root of the tongue. Scale bar=400µm.

4. Discussion

Results of the current study showed morphological variations of the tongues of the investigated animals that belong to three different mammalian species which are feed almost different types of food; the long-eared hedgehog, *Hemiechinus auritus*, the guinea pig, *Cavia porcellus* and the least weasel, *Mustela nivalis vulgaris*. The tongue is differing in shape and size among the three animals and this probably due to the differences in body size and their taxonomy (Taha, 2013; Taki-El-Deen *et al.,* 2013).

In the present study, histological observations of the tongues of hedgehog, guinea pig and least weasel revealed that they are formed of three consecutive layers; the mucosa, submucosa and muscularis. The mucosa consists of stratified squamous epithelium and contains three or four types of lingual papillae; filiform, fungiform, vallate and foliate papillae. Most of the papillae are covered by stratified squamous epithelia that differed only in thickness and degree of keratinization as previously mentioned by Nasr *et al.* (2012) and Taha (2013). The submucosa forms of dense connective tissue rich with blood vessels. The muscularis composes of a mass of interlacing bundles of skeletal muscle fibers which permit an extensive range of tongue movements. These observations provided similar results to those observed by Iwasaki *et al.* (1996) in the mouse, Kobayashi *et al.* (2004, 2005) in selected primates and selected ruminantia respectively, Nasr *et al.* (2012) in rats, Taha (2013) in lizard and long-eared hedgehog, Ramteke *et al.* (2013) and Taki-El-Deen *et al.* (2013) in bats.

The present light and scanning electron microscopic results illustrated that the dorsal surfaces of the tongues of *Hemiechinus auritus*, *Cavia porcellus* and *Mustela nivalis vulgaris* are covered by various types of papillae. These tongue papillae differ in shape, size, number, nomenclature and distribution among different groups of vertebrates. These differences depend on diet variety, feeding habits and mouth handling of the food (Iwasaki *et al*., 1996; Iwasaki, 2002; Darwish, 2012; Taki-El-Deen *et al.,* 2013). It was found that, the tongue of *Hemiechinus auritus* and *Mustela nivalis vulgaris* covered by four types of lingual papillae; the filiform, fungiform, vallate and foliate papillae. The presence of four types of papillae as revealed by the scanning electron microscopic observations is a morphological pattern basically similar to that described for other mammalian species (Silva *et al*., 2002; Emura *et al*., 2006; Nasr, 2012; Nasr *et al*., 2012). On the contrary, only three types of lingual papillae were found on the dorsal surface of *Cavia porcellus*'s tongue; namely the filiform, fungiform and foliate papillae. The vallate papillae are absent and this observation agrees with the results obtained by Kobayashi (1990). Also, Ciuccio *et al.* (2010) reported the presence of only three types of papillae in the armadillo's tongue; namely the filiform, fungiform and vallate papillae.

Filiform papillae:

The filiform papillae are distributed on the tongue dorsum in the three investigated animals, but there are marked variations in their size and shape. Apparently, these differences depend on dissimilarities in diet, feeding habits, mastication and handling of the food in the mouth. Filiform papillae are considered to have a mechanical function. They form the primary pathway of food transport which comes into contact with the palate during mastication and swallowing. They provide the tongue with a rough surface suited for the movement and grinding of food (Trzcielinska *et al*., 2009; Karan *et al*., 2010). The absence of taste pores from filiform papillae suggested that they have only mechanical function during mastication process, while its abundance and distribution confirmed their protective role for the dorsal surface (Emura *et al*., 2001, 2006; Karan *et al*., 2010).

In the tongue of *Hemiechinus auritus* many forms of filiform papillae are observed. They are leaf-like in shape with directed posteriorly pointed tips, being simple conical or branched divided into two to four accessory processes. The length and number of the accessory processes vary throughout the surface of the tongue. In the posterior third, the length of processes decreased. The different shapes of the filiform papillae which changed gradually from the apex to the caudal part of the tongue have also been mentioned by Iwasaki and Miyata (1990) in the mongoose and by Nasr *et al.* (2012) in rats. This morphology of filiform papillae is also comparable to that reported for armadillos (Estecondo *et al*., 2004; Ciuccio *et al*., 2010), although some inter-specific differences in the size and in the number of branches were found. These variations may be due to mastication methods and/or dietary habits as has been claimed for other mammals (Yoshimura *et al*., 2002). The pattern of filiform papillae covering the entire dorsal surface of the tongue of *Hemiechinus auritus*, with the number of branches increasing to the middle third of the organ, seems to be common in insectivorous. This result agrees with those presented by Ciuccio *et al.* (2010) in armadillos, Nasr (2012) in hedgehog and Taha (2013) in lizards and hedgehog.

The light and scanning electron microscopic observations of dorsal surface of the tongue of *Cavia porcellus* revealed that the conical filiform papillae underwent gradual changes from the apex to the posterior part, i.e. from a branched type in the anterior area to a non-branched type in the posterior area. This change in the papillary form was somewhat different from this exists in the tongue of *Hemiechinus auritus*. Examination of the tongue of *Cavia porcellus* also

revealed the presence of median lingual sulcus of the apex tongue. This characteristic feature found in many rodents, although its length and width are species-specific (Jackowiak & Godynicki, 2005). The presence of a median lingual sulcus in the rostral and central parts of the guinea pig tongue is similar to findings in mouse (Iwasaki *et al*., 1996), common quail (Parchami *et al.*, 2010), blind mole rat (Kilinc *et al*., 2010) and rat (Nasr *et al*., 2012).

Also, results of this research highlight the presence of especial type of filiform papillae in the tongue of *Mustela nivalis vulgaris*. In this type, each filiform papilla is composed of main cone shaped process and accessory finger-like processes. These processes are apparently arising from the basal and both lateral surfaces of the papilla. These accessory processes seemed originated at different levels of the filiform papilla main body. This structure of filiform papillae was also found in the tongues of raccoon dog and fox (Emura *et al*., 2006) and in Egyptian dog (Essawy, 2008).

The presence of the finger-like processes arising from the basal and the lateral surfaces of the filiform papillae, all together may be acting in prehension of food fragments by their different morphological inter relationship. However, another possible explanation for these arising finger-like processes is to help the main conical form of the papillae to withstand the applied forces, as previously mentioned by Emura *et al.* (2006) and Essawy (2008). In every conical filiform papilla, a centrally placed groove governed by numerous finger-like processes was reported in the results of this study. This phenomenon was previously mentioned also by Emura *et al.* (2006) and Essawy (2008). Similarly, Agungpriyono *et al.* (1995) described these grooves of the filiform papillae in the tongue of the lesser mouse deer, however without the associated finger-like processes. These grooves are most likely used as a pathway for holding fluids and pushing them backward for drinking.

Fungiform papillae:

The size and number of fungiform papillae also vary according to animal species (Yoshimura *et al.*, 2008; Takemura *et al*., 2009). Their gustatory function is clear in view of the multiple taste pores on their surfaces. As mentioned by Delheusy *et al.* (1994), the role of these taste buds on the anterior papillae might be tasting the palatability of the prey when contacts with the tongue occur during capture. Roper (2009) mentioned that taste buds are the peripheral sensory organs of gestation, these structures have the task of monitoring the chemical environment of the oral cavity and particularly of sensing ingested foods. The distribution of filiform papillae surrounding the fungiform ones, suggests a protective role (Jackowiak, 2006).

The current results showed that the tongue of *Hemiechinus auritus* contains various shaped fungiform papillae. Some of them have a mushroom-shaped appearance, while the others being dome in shape. The distribution of mushroom-shaped fungiform papillae was dense especially in the medial region among the longer filiform papillae. The manner of this distribution had also been reported on the dorsal lingual surface in Japanese marten (Emura *et al*., 2007). Dome-shaped fungiform papillae were also observed in the tongue of armadillos (Estecondo *et al*., 2004; Ciuccio *et al*., 2010).

In the tongue dorsum of *Cavia porcellus,* the fungiform papillae are localized in the anterior part. They are elliptical or circular in shape embedded between higher filiform papillae and bear taste buds. These characteristics were reported in rabbits (Ojima *et al*., 1997; Silva *et al*., 2002) and in rats (Nasr *et al*., 2012). Particularly, in the apex of the tongue, fungiform papillae aggregated in clusters. The array of gustatory fungiform papillae in clusters on the apex of the tongue of guinea pig was also observed by Emura *et al.* (2001) in the tongue of the nutria. The function of this special system of papillae is probably related to the preliminary analysis and tasting of food.

The fungiform papillae in the tongue of *Mustela nivalis vulgaris* are dome in shape and also scattered among the filiform papillae, especially at the lingual apex. Similar results had been reported on the dorsal lingual surface of the raccoon dog and fox (Emura *et al.*, 2006).

Vallate papillae:

The vallate papillae are the largest and least common type of papillae on the tongue. It is well known that the number and morphology of vallate papillae varied between species, from absent, as in Cape hyrax, to abundant, as in ruminants (Yoshimura *et al*., 2008). These variations depend on the types of food consumed.

Current investigation illustrated that vallate papillae of the hedgehog tongue is rounded or oval in shape and surrounded by a furrow. The body of the vallate papilla is separated from the wall of the tongue by a continuous deep trench. This large circular trench seems to enhance the accessibility of food to the taste buds present at the papillae s sides. Distribution of the vallate papillae in this animal shows a triangular pattern; one is on the mid-line of the posterior area of the tongue and the other two are situated at the antero-lateral sides. This result agreed with those reported by Nasr (2012). Despite of the insectivorous hedgehog has three vallate papillae, the armadillos have only two papillae as shown by Estecondo *et al.* (2004) and Ciuccio *et al.* (2010).

While, the tongue of guinea pig has no vallate papillae. This result coincides with those reported by

Kobayashi (1990). On the other hand, two obvious vallate papillae are observed postero-laterally in the tongue of least weasel. Each papilla has a circular form and is surrounded by a continuous depression and dense mucosal folds. The surface of this vallate papilla is irregular and has many taste pores. The same results referenced by Emura *et al.* (2004) in the tongue of tiger and by Emura *et al.* (2006) in the tongue of raccoon dog and fox.

Foliate papillae:

In the present study, a pair of foliate papillae was located on the postero-lateral margin of the hedgehog tongue. Each papilla composed of 4-5 microridges separated by deep grooves. This structure is similar to that found in armadillo (Estecondo *et al*., 2004). Both the location and the structure of foliate papillae are similar to those in the bank vole (Jackowiak & Godynicki, 2005) and in golden-headed lion (Buirty *et al*., 2009). Iwasaki (2002) suggested that, these microridges may act as a supporting structure for food-uptake, mastication and swallowing. Also, the present study revealed the presence of foliate papillae in guinea pig tongue. Our observations confirmed the characteristics of foliate papillae reported by Kobayashi (1992), which presented some parallel projections (ridges) separated by grooves and three laminar sheets of connective tissue called groove folds or septal folds.

There are a pair of foliate papillae illustrated in the latero-posterior part of the tongue of least weasel, each is crescent in appearance and has some parallel projections separated by grooves. Their surfaces contain several taste pores. This observations was confirmed in the study of the bush dog that presented by Emura *et al.* (2000).

In conclusion, the comparison of the morphology of the tongues of the three different investigated mammalian animals which feed different diets; particularly the structure and distribution of their lingual papillae using light and scanning electron microscopy revealed marked differences between them. Such variations are probably due to environmental conditions in which animals use their tongues, and reflect adaptations respond to their feeding pattern. Also, these dissimilarities may be correlated with the kinds of food in their habitats. Finally, the results of the present study added to the previously recognized studies of the dorsal lingual papillae of the tongues of different mammalian animals which having different diets.

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