Int. J. Morphol.,
32(4):1407-1417, 2014.

Morphological Comparison of the Filiform Papillae of New Zealand White Rabbits (*Oryctolagus cuniculus*) as Domestic Mammals and Egyptian Fruit Bat (*Rousettus aegyptiacus*) as Wild Mammals Using Scanning Electron Microscopic Specimens

Comparación Morfológica de las Papilas Filiformes de Conejos Blancos Nueva Zelanda (*Oryctolagus cuniculus*) como los Mamíferos Domésticos y los Murciélagos de la Fruta Egipcios (*Rousettus aegyptiacus*) como los Mamíferos Salvajes Utilizando Muestras de Microscopía Electrónica de Barrido

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ABUMANDOUR, M. A. M. Morphological comparison of the filiform papillae of New Zealand white rabbits (*Oryctolagus cuniculus*) as domestic mammals and Egyptian fruit bat (*Rousettus aegyptiacus*) as wild mammals using scanning electron microscopic specimens. ***Int. J. Morphol., 32(4)***:1407-1417, 2014.

SUMMARY: This paper presents a comparison of the morphological structure of the filiform papillae in New Zealand white rabbits as domestic mammals and Egyptian fruit bats as wild mammals. This study was carried out on the tongues of adult healthy New Zealand white rabbits and Egyptian fruit bats of both sexes. There were four types of lingual papillae in both animals. In the Egyptian fruit bats, there were six subtypes of the filiform papillae; three on the anterior part (small, conical and giant), two on the middle part (cornflower and leaf-like papillae) while the posterior part contain rosette shape filiform papillae, in addition to transitional papillae and conical papillae. In New Zealand white rabbits, there were four subtypes of filiform papillae; spoonful conical (on the lingual anterior part), processed (at the anterior edge of lingual prominence), leaf-like (on the posterior area of lingual prominence) and triangular filiform papillae (on the lingual root). The shape, size, number and orientation of the lingual papillae itself and its processes varied according to their location within the tongue (region-specific) in relation to the feeding habits, strategies for obtaining food, climate conditions, and types of food particles.

KEY WORDS: Filiform papillae; Egyptian fruit bat; New Zealand white rabbits; Scanning electron microscope (SEM).

INTRODUCTION

The bat is considered the second largest mammalian order (Altringham *et al*., 1996), has an arboreal character (Ogunbiyi & Okon, 1976). The bats are the only mammals that have the ability of flight, in which the anterior member transforms into wings (Wilson & Reeder, 1993). The bat belongs to the Chiroptera order, suborder Megachiroptera, family Pteropodidae. Pteropodidae were feed on the fruit, flowers, nectar and pollen, and have Rousettus genus, there is only one species in Egypt called *Rousettus aegyptiacus* (Altringham *et al*.).

The New Zealand white rabbits belong to Leporidae family of Lagomorpha order. Once classified as a rodent, the rabbit was given a separate order because of dentition differences, chiefly the incisors. The rabbit was considered one of most a widely distributed mammalian species, used for economical, medical experiments and teaching purposes, and in recent years, kept as pet animals, all these facts put the rabbit in the focus of research (Romer, 1960).

The mammalian tongue varies in shape from species to species. The reasons for this morphological diversity are generally the result of different strategies for capturing and manipulating food, grooming, or vocal modulation. The tongue is a taste organ in the buccal cavity and with its species-specific lingual papillae on the dorsal surface plays an important role in food intake, digestion in many mammals (Iwasaki, 2002; Kobayashi & Shimamura, 1982; Abumandour & El-Bakary, 2013; Pastor *et al*., 1993).

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Previous studies on the distribution of lingual papillae on the dorsal surface of the tongue in the Egyptian fruit bat indicated its considerable species-specific character, resulting from the adaptation of the lingual mucosa to the intake of liquid and semi-liquid food (Jackowiak *et al*., 2009; Emura *et al*., 2012; Trzcielinska-Lorych *et al*., 2009; Abumandour & El-Bakary, 2013). The arrangement and structure of the mechanical lingual papillae, aiding the transfer of food, documented in vertebrates, constitutes general traits typical of individual taxonomic units, for example, orders or families (Azalli *et al*., 1991; Emura *et al*., 2002b; Emura *et al*., 2000; Jackowiak & Godynicki, 2004). On the other hand, an important factor affecting the structure of the lingual papillae is the type of ingestion of food, the method of its grinding in the oral cavity, as well as the method of its passage to further segments of the alimentary tract.

In the end, there is a true question, is there a relationship between the morphological structures of the tongue, feeding habits, geographic position and the type of feed. This research was conducted to show morphostructural studies of the filiform papillae in the New Zealand white rabbits and Egyptian fruit bats fed as herbivorous animals and adapted to geographical distribution. Thus, the results were discussed and compared with those reported by the literature.

MATERIAL AND METHOD

Samples. This study was carried out on the tongues of eight adult normal healthy Egyptian fruit bats of both sexes collected from fruit farms and old houses from Edfina, Rashid, and Behera Governorate, Egypt, and eight a healthy adult New Zealand white rabbits (*Orycotolagus cuniculus*) of both sexes (1 year old, and 5.2±0.4 kg) collected from farms from Desouk, Kafre El-Sheik Governorate, Egypt.

For gross morphology. Five Egyptian fruit bats and five New Zealand white rabbits of both sexes were euthanized to demonstrate the gross morphological features. Two Egyptian fruit bats and two New Zealand white rabbits were used as fresh and three were formalized. The oral cavity was opened; the specimens were then fixed in 10% formalin.

For scanning electron microscopy. A tongue of the three adult Egyptian fruit bats and three New Zealand white rabbit tongue of both sexes, fixed in (2% formaldehyde, 1.25% glutaraldehyde in 0.1 M sodium cacodylate buffer, pH 7.2) at 4°C. Once fixed, the samples were washed in 0.1 M sodium cacodylate containing 5% sucrose, processed through tannic acid, and finally dehydrated in increasing concentrations of ethanol (15 min each in 50, 70, 80, 90, 95 and 100% ethanol). The samples were then critical point dried in carbon dioxide, attached to stubs with colloidal carbon and coated with gold palladium in a sputtering device. Specimens were examined and photographed with a JEOL scanning electron microscope operating at 15 KV, at the faculty of science, Alexandria University.

RESULTS

New Zealand white rabbits

A- Gross anatomical studies of the tongue: Macroscopically, the non-protrusible tongue of rabbit is characterized by an elongated corpus, which relatively flat and ends with a rounded apex. The tongue of the rabbit could be divided into three areas: the anterior (lingual apex), middle (lingual body) and posterior (lingual root) areas (Fig. 1: An, M and P). The characteristic feature of the dorsal surface of anterior part is the presence of a shallow dorsal median groove (Fig. 1: Lg), while the characteristic feature of the dorsal surface of middle part is the presence of the lingual prominence (torus lingua) (Fig. 1: Lp).

B- Scanning electron microscopic studies of lingual filiform papillae: The dorsal surface of tongue contain four types of the lingual papilla; one mechanical (filiform) and three gustatory (fungiform, foliate and circumvallate). There are four subtypes of the mechanical filiform papillae; the anterior lingual part contains only one subtype of the filiform papillae called spoonful conical filiform papillae, and the lingual prominence contains two subtypes of the filiform papillae; processed filiform papillae and leaf-like filiform papillae, while the dorsal surface of the lingual root contains only one subtype of filiform papillae called triangular filiform papillae.

(1) SEM characteristic of spoonful conical filiform papillae. These posteriorly directed papillae (Fig. 1: Sf) were distributed on the dorsal surface of the anterior lingual part. Theses papillae were vertical spoonful, conical-shaped with an oval-shaped base and a body, having a posterior convex surface and anterior concave surface with a slightly posteriorly bent blunt tip. There are high numbers of the spoonful filiform papillae with small number of the fungiform papillae on the rostral round edge of the tongue. There are high number of microridges and microgrooves especially on the convex surface of the body.

(2) SEM characteristic of processed filiform papillae. These anteriorly directed papillae were distributed at the anterior

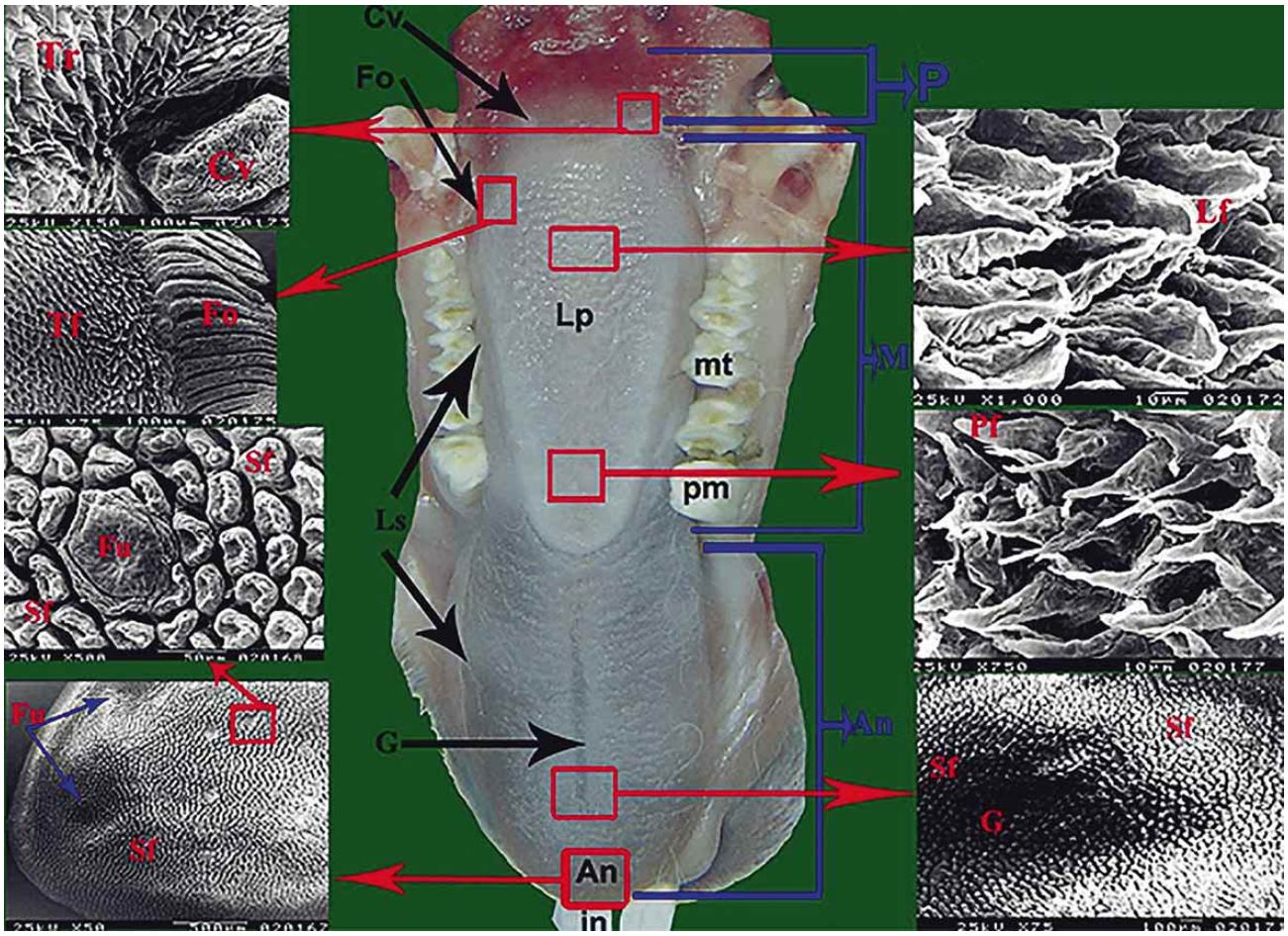

Fig. 1. Dorsal view of the New Zealand white rabbit tongue with Scanning electron micrographs of the some parts; An-anterior part of tongue, M-lingual body, P-lingual root, Lp-lingual prominence, G-dorsal median shallow groove, Ls-lateral surface of tongue, Cv-circumvallate papillae, Fo-foliate papillae, in-incisor teeth, pm-premolar, M-molars, Sf-small filiform papillae, Fu- fungiform papillae, Pf- processed filiform papillae, Lf- leaf-like filiform papillae, Tf-triangular filiform papillae.

narrow part of the lingual prominence (Fig. 1: Pf). These papillae had a pointed long main process with only a pointed tip. There are microridges and microgrooves on its surface.

(3) SEM characteristic of leaf-like filiform papillae. These posteriorly directed papillae (Fig. 1: Lf) were distributed on the posterior wide area of lingual prominence, posterior to the anterior directed long processed filiform papillae. These papillae have a sharp convex ventral surface and sharp concave dorsal surface with two elevated lateral edges. There are high number of prominent microridges and microgrooves on the sharp convex surface of the papillae body.

(4) SEM characteristic of triangular filiform papillae. These posteriorly directed papillae (Fig. 1: Tf) were distributed on the lingual root surrounding the circumvallate papillae rostrally and medially and surrounding the foliate papillae.

Egyptian fruit bats

A- Gross anatomical studies of the tongue: Macroscopically, the Egyptian fruit bat is characterized by the protrusible, elongated flat tongue with a rounded apex. The tongue could be divided into three areas: anterior (lingual apex), middle (lingual body) and posterior (lingual root) areas (Fig. 2: An, M and P), in which each area was divided into three regions; median and two lateral part regions (Fig. 2: 2, 3, 4, 5, 6, 7 and 8), in addition to the apical part to the anterior part (Fig. 2: 1).

B- Scanning electron microscope of the lingual filiform papillae: There are four types of lingual papillae; two mechanical (filiform and conical) and two gustatory (fungiform and circumvallate) were recognized. There are six subtypes of the mechanical filiform papillae were observed throughout the whole tongue. The ones close to

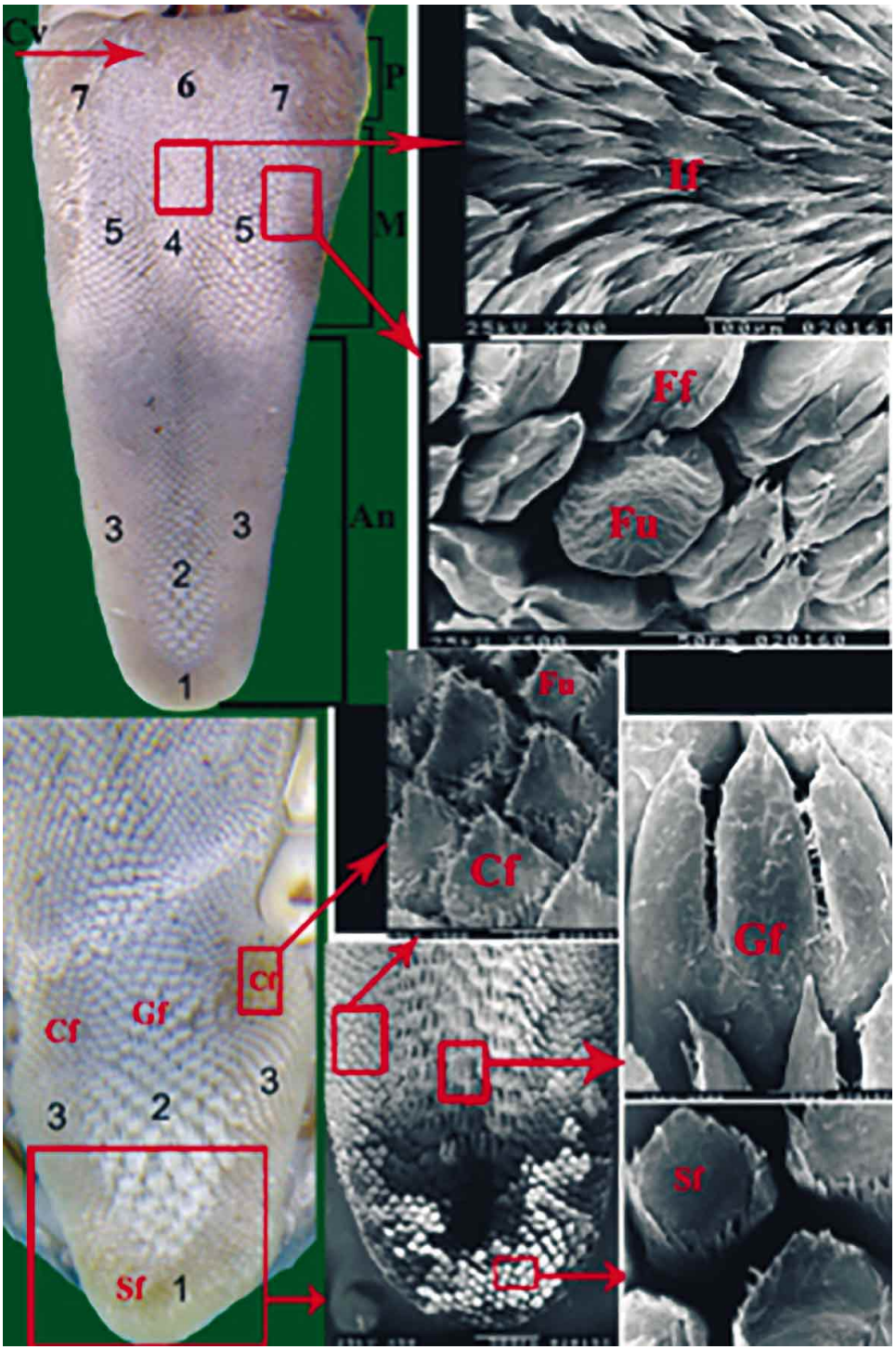

Fig. 2. Dorsal view macrograph of the Egyptian fruit bat tongue with scanning electron micrographs of the some parts; An-anterior part of tongue, M-lingual body, P-lingual root, 1-lingual apical region of the anterior lingual part, 2- median region of the anterior lingual part, 3- lateral region of the anterior lingual part, 4- median region of the medial lingual part, 5- lateral region of the medial lingual part, 6- median region of the posterior lingual part, 7- lateral region of the posterior lingual part, Cv-circumvallate papillae, Sf-small filiform papillae, Cf- conical filiform papillae, Fu- fungiform papillae, Gf- giant (trifid) filiform papillae, Ff- cornflower filiform papillae, Lf- leaf-like filiform papillae, Tf-triangular filiform papillae.

the middle part of tongue were posteriorly directed toward the pharynx, while theses present on the lateral edge of tongue are directed medioposteriorly to help in the collection and gathering of food particles in the middle part region of posterior part of tongue then to pharynx (Fig. 2). The anterior part was subdivided into four region in form of U-shape; apical part, two lateral and median regions (Fig. 2: 1, 2 and 3), there are three subtypes of filiform papillae were region-specific distributed on the four regions of the anterior lingual part; lingual apex contain large number of the posteriorly directed small filiform (Fig. 2: Sf) surrounding a small number of the rectangular fungiform papillae (Fig. 2: Fu), while the two lateral regions contain large number of the medioposteriorly directed conical filiform papillae (Fig. 2: Cf) surrounding a very small number of the fungiform (Fig. 2: Fu), moreover the median region contain large number of the posteriorly directed giant filiform papillae only (Fig. 2: Gf).

The middle part subdivided into three region; two lateral regions (Fig. 2: 5) and one median region (Fig. 2: 4). The middle part contains two subtypes of filiform papillae; the two lateral regions contain medioposteriorly directed cornflower filiform papillae (Fig. 2: Ff) surrounding a small number of round fungiform papillae, while

the median region contain posteriorly directed leaf-like filiform papillae only (Fig. 2: If).

The posterior part of tongue was subdivided into three region; two lateral regions (Fig. 2: 8) and median region (Fig. 2: 7); the two lateral regions contain medioposteriorly directed conical papillae (Fig. 2: Tp). The median region contains posteriorly directed rosette-shape filiform papillae (Fig. 2: Rf).

(1) SEM characteristic of small filiform papillae (Fig. 2: Sf): These papillae were round and small and its dorsal surface have microtubercles and microgrooves, and have posterior directed several pointed processes originated from all anterior, posterior and lateral margin of papillae (25–35 processes), this processes bearing microtubercles and microridges and terminated posteriorly by one or two posterior processes.

(2) SEM characteristic of conical filiform papillae (Fig. 2: Cf):These papillae having posteriorly directed several pointed processes originated from all margins of the papillae (40–45 processes).

(3) SEM characteristic of giant filiform papillae (trifid or tridentate) (Fig. 2: Gf): These papillae were overlap on each other, and reach to about 0.8–1 cm in long and 0.4 cm in wide. Each papilla has 13–18 small posteriorly directed anterior processes. The body terminated posteriorly by three large posteriorly directed posterior processes.

(4) SEM characteristic of cornflower filiform papillae (Fig. 2: Ff): These papillae were characterized by its two lateral edges was bent on the dorsal surface of papillae and the papillae ended by posteriorly directed round end with a secondary one to three posterior processes. Some of these papillae were orientated medioposteriorly and some orientated medially.

(5) SEM characteristic of leaf-like filiform papillae (Fig. 2: Lf): These papillae ended with posteriorly directed main posterior process and posteriorly directed 2 to 4 accessory lateral processes.

(6) SEM characteristic of rosette shape filiform papillae (Fig. 3: Rf) These rosette-shape papillae have round base and its apex ended with posteriorly directed many small posterior processes (10–12 processes).

(7) SEM characteristic of transitional papillae (Fig. 3: Tf). These papillae represent a transitional stage, which present between the rosette shape filiform and conical papillae in the two lateral region of posterior part near the median region, which take the tongue shape with central groove and posterior pointed end. These papillae overlap each other and orientated medioposteriorly.

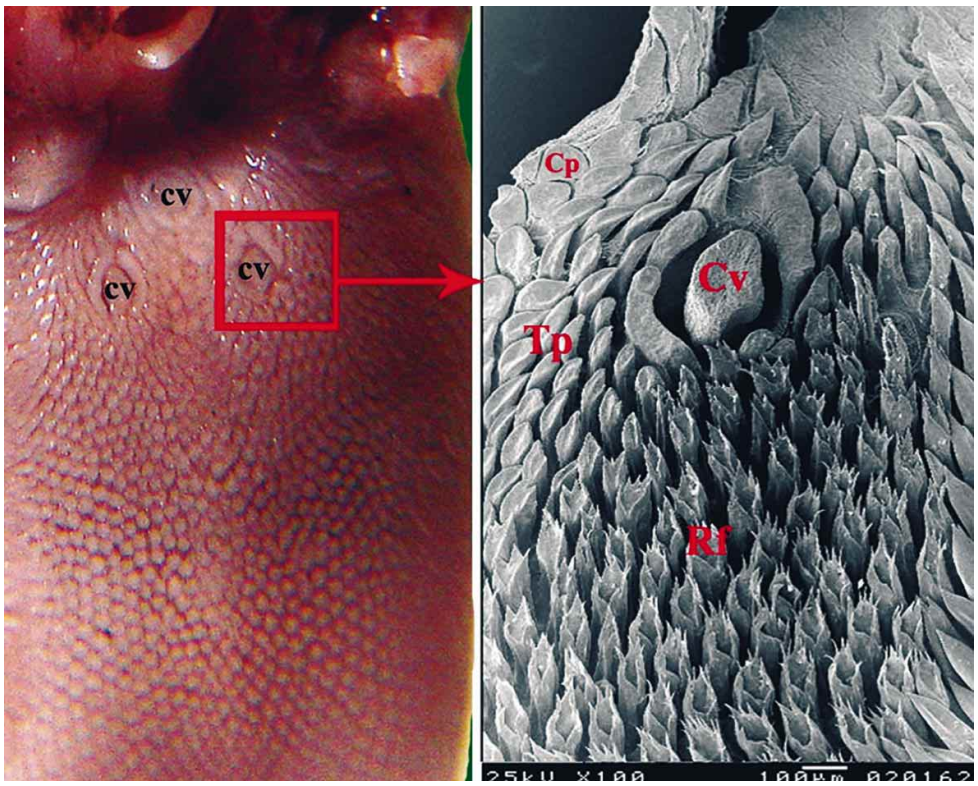

Fig. 3. Dorsal view macrograph of the posterior part of the Egyptian fruit bat tongue with scanning electron micrographs photo to show; Cv- circumvallate papillae, Rf- Rosette shape filiform papillae, Cp- conical papillae, Tp- transitional papillae.

DISCUSSION

Different morphological structures of the vertebrates tongue are specialized to fulfill different functions, such as swallowing, water uptake, capturing and manipulating the food, grooming, vocal modulation, and suckling (Pastor *et al*., 2011; Kilinc *et al*., 2010; Mancanares *et al*., 2012). Morphological differences and variations appearing in the tongue are directly associated with dietary specializations and food type, as well as adaptations to various environmental conditions (Iwasaki). The distribution of the different papillae on the various surfaces of the tongue is characteristic of a genus and may even be distinctive among different species. One of the elements that contribute most to the morphological, distribution, and type of papillae is the diet (Pastor *et al*., 2008; Abumandour & El-Bakary).

In the present study, the Egyptian fruit bat was characterized by elongated protrusible tongue with round long free anterior part to facilitating the movement of tongue while swiping the extracts of fruit pulp, agree with (Birt *et al*., 1997; Abumandour & El-Bakary; Mqokeli & Downs, 2012), while the New Zealand white rabbit tongue is characterized by elongated non-protrusible tongue with thin round apex to be adapted for eating form the ground as in; rabbit (Ojima *et al*., 2000), Japanese Badger (Yoshimura *et al*., 2009).

The lingual median prominence was a characteristic feature in some mammals, which agree with our observation in New Zealand white rabbit tongue, and in; bank vole (Jackowiak & Godynicki, 2005), rabbit (Nonaka *et al*., 2008) and herbivorous artiodactylas (Zheng & Kobayashi, 2006), while omnivorous artiodactylas (pig) and carnivores animals not have a lingual prominence (Emura *et al*., 2006; Kumar & Bate, 2004). While (Pastor *et al*., 1993) in common European bat reported that there was a prominent of intermolar tubercle, moreover, molossid bats have a prominent mid-dorsal lobe as noted by Gregorin (2003), but Emura *et al*. (2001b), Jackowiak *et al*. (2009), Gregorin and Mqokeli & Downs (2012) reported that, there is no typically intermolar tubercle in all bats, while our study in the Egyptian fruit bat noted that, the characteristic feature of the dorsal surface of the middle part of tongue is the presence of a shallow intermolar tubercle, located close to the posterior half area of the tongue. Our study in New Zealand white rabbit confirmed that, the presence of a lingual prominence is regarded as a characteristic of herbivores and this muscle-rich prominence with filiform papillae allows herbivores to grind food by crushing it between the tongue and the upper palate, while in the Egyptian fruit bat, the main function of the filiform papillae to help in catching of foods.

The food habits of the bats are diversified: insectivorous, fruit-eating, flower-eating, vampire and carnivorous feeding. These differences resulted in various adaptations in the number and the morphology of the filiform papillae as noted in different study as in; six species of long-nosed bats (Greenbaum & Phillips, 1974), Japanese long-fingered bat (Kobayashi & Shimamura, 1982), European common bat (Pastor *et al*., 1993), lesser dog-faced fruit bat (Emura *et al*., 2001a), large flying fox (Emura *et al*., 2002b) and Japanese common pipistrelle (Emura *et al*., 2009), in which this clear in our study in the Egyptian fruit bat. The previous studies on the distribution and structure of the mechanical papillae on the dorsal surface of the mammalian tongue constitute general traits typical for individual taxonomic units, such as orders or families, as well as traits characteristic of a particular species (Iwasaki; Abumandour & El-Bakary). Our study noted that the lingual papillae distributed on the Egyptian fruit bat's tongue have some characteristics that are different from those of land mammals.

As in the previous published data, the lingual papillae were species-specific, in which differing in their number among mammalian species, these differences may depend on dissimilarities in diet, feeding habits and handling of food in mouth (Emura *et al*., 2002b; Abumandour & El-Bakary), the previous data clear in; our study in Egyptian fruit bat, this confirmed by presence of four types of lingual papillae; two mechanical and two gustatory as noted in; bats (Selim *et al*., 2008; Abumandour & El-Bakary; Abayomi *et al*., 2009), moreover other mammals have four lingual papillae; as in our study in New Zealand white rabbits; one mechanical (filiform) and three gustatory (fungiform, foliate and circumvallate) as noted in; rats (Nasr *et al*., 2012), bank vole (Jackowiak & Godynicki, 2005), dog and fox (Emura *et al*., 2006). However, three types of lingual papillae; one mechanical (filiform) and two gustatory (fungiform and circumvallate) as noted in; bats (Pastor *et al*., 1993; Emura *et al*., 2001b; Park & Lee, 2009; Masuko *et al*., 2007), however, there were two types only of papillae (filiform and fungiform) in hematophagous bats (Masuko *et al*.).

Our study agrees with the previous published data that, the filiform papillae have some morphological variations according to specialized to fulfill different functions; for example, the filiform papillae are simple in rodents to compound structure in artiodactyls as cattle. This confirmed in the previous articles that, the filiform papillae have many divisions, such as they were classified as seven subtype in; bat by (Park & Hall, 1951), while our study in Egyptian fruit bat and (Kobayashi & Shimamura, 1982;

Emura *et al*., 2002b; Abumandour & El-Bakary, 2013) describe six subtypes of the filiform papillae. Five subtypes were noted in; lesser dog-faced fruit and nectarivorous bats (Emura *et al*., 2001b; Greenbaum & Phillips; Emura *et al*., 2012; Masuko *et al*.) and in cat (Ojima *et al*., 1997). But there were four subtypes as noted in our study in New Zealand white rabbits and in frugivorous bats (Masuko *et al*.; Trzcielinska-Lorych *et al*.; Mqokeli & Downs) and ferret (Takemura *et al*., 2009). While three subtypes as noted in; bats (Jackowiak *et al*., 2009; Pastor *et al*., 1993), rat (Ojima *et al*., 1996), mice (Toprak, 2006), and rabbit (Nonaka *et al*.), moreover there are two subtypes as in; bat (Park & Lee), Porcupine (Karan *et al*., 2011) and (Jackowiak, 2006) in European mole. There is only one types as noted in camel by (Qayyum *et al*., 1988). Functionally in our study in the Egyptian fruit bat, the numerous subtypes of the filiform papillae, suggests the role of filiform papillae in food and liquid intake during the flight and transport toward pharynx, in which this papillae increase the adhesion of food to the surface of tongue; because of eating habits during flight, agree with general information noted by (Ojima *et al*., 2000).

From the previous published data it becomes clear that, the variation in the morphology of the filiform papillae may be related to masticatory methods and dietary habits, as Yoshimura *et al*. and Abumandour & El-Bakary; this confirmed in our study in the Egyptian fruit bat, small filiform papillae with its several pointed posterior directed small processes as in (Jackowiak & Godynicki, 2004), and microtubercles, microridges and microgrooves with the conical filiform papillae on the lateral sides of the anterior part of the tongue help in the catching processing and fixing of food materials during the flight. while the giant filiform papillae with its posteriorly directed small anterior and large trifid processes in the median region of the anterior part of the tongue help in the posterior direction of the food materials caught, with the anterior directed canine; it therefore becomes clear that these filiform papillae on the anterior part of the tongue compensate for the absence of upper and lower incisive teeth which leave the space between the canine teeth, this space was adapted for allowing the elongated tongue to move freely when feeding, this agrees with nectar-feeding bat (Mqokeli & Downs) and fruit bat (Abumandour & El-Bakary). The greater protrusible tongue with the retention of canines of *S. australis*; suggest that it may be more efficient than Pteropus species when collecting nectar from flowers (Birt *et al*.).

The differences in the filiform morphology among the same animals may be related to type of food eaten, which varied according to geographical distribution; as in this study of Egyptian fruit bat (captured from Egypt), there were differences in shape, size, orientation and number of the lingual papillae; there were six subtypes of the filiform papillae, moreover in Egyptian fruit bat (captured from Japan) (Emura *et al*., 2012) noted that there are five subtypes of the filiform papillae, but in Egyptian fruit bat captured from Poland, there are two status; the first noted by (Trzcielinska-Lorych *et al*.) that there were four subtypes, while the second status noted by (Jackowiak *et al*., 2009) that there are three subtypes only (Ghassemi & Jahromi, 2013) in Egyptian fruit bat captured from Iran were noted that three subtypes of the filiform papillae. or this variation may reflect the different in subspecies as; certain P. *poliocephalus* adapted to a nectar diet and others to fruit diet (Eby, 1991). This was clear in case of, *P. scapulatus* having long pointed, and dense giant papillae on a large area of anterior part of tongue, suggest that *P. scapulatus* prefers a diet of nectar (Eby, 1995), with its migratory behaviour to area with little or no flowering, so *P. scapulatus* consume fruit (Eby, 1995), so some variation in giant papillae morphology. Also, this variation extended to include the presence or absence of some type of papillae (Jackowiak *et al*., 2009; Ghassemi & Jahromi) Egyptian fruit bat have bifid filiform papillae in addition to trifid ones, in constant our result agree with (Trzcielinska-Lorych *et al*.; Emura *et al*., 2012), that there is no presence of bifid papillae.

In rabbit, the differences in the filiform morphology among the same animals may be related to type of food eaten, which varied according to geographical distribution; in our study in New Zealand white rabbit (captured from Egypt), there were four subtypes, while there are three subtypes of filiform papillae in New Zealand white rabbit (captured from Japan) as noted by (Nonaka *et al*.).

There are some variation in the lingual adaptation between the New Zealand white rabbits (domestic mammals eating directly from the ground) and the Egyptian fruit bat (wild mammals eating during the flight), this adaptation is clear in the our study in the Egyptian fruit bat; firstly, the tongue tip not have giant filiform papillae and instead a blunt small filiform papillae, in which this distribution may have an important role in feeding habits, this confirmed by (Hall *et al*., 1995), while (Paton & Collins, 1989) in nectar-feeding bats, noted that the functions of giant filiform papillae on the tongue tip to increase the surface area to collect nectar. The another adaptation, the giant filiform papillae were rough to touch to help in power catching by piercing the skin of soft fruits to consume fruit and press it between the tongue the ridged hard palate to release the juices (Bonaccorso & Gush, 1987). Also, among the lingual papillae morphology the orientation; in Egyptian fruit bat, cornflower filiform papillae on two lateral regions of middle part; some orientated medioposteriorly and some orientated medially while, in lateral region of posterior part; having the medio-

anterior directed conical papillae in anterior part and medioposteriorly directed conical papillae in posterior part, while (Pastor *et al*., 1993) in common European bat, at junction of posterior and intermolar eminence, a tuft of filiform papillae was oriented anteriorly in opposition to all the others. While in the filiform papillae these were characterized by the purely mechanical functions of grasping food and grooming in yak and cattle and also serve to protect the fungiform papillae and fulfill a mechanical cleaning function in the interdental spaces of the lower jaw, similar to that which occurs in other mammals (Pastor *et al*., 2008; Hofer *et al*., 1993).

There are variation in the distribution of the filiform papillae between animals (species-specific) and there are different form of distribution in the same animal (region-specific) confirm the different feeding methods between the two animals to adapt to its life history; in the Egyptian fruit bat, there arethree subtypes of filiform papillae on the anterior part of tongue; small (Lingual apex), conical (two lateral regions) and giant (median region) filiform papillae, while there are two subtypes in middle region of the tongue at two the lateral regions; medioposteriorly directed papillae (cornflower filiform papillae), while the median region contain posteriorly directed leaf-like filiform papillae only. But only one type of the posterior part of tongue at the median region of contains posteriorly directed rosette-shape filiform papillae. While in New Zealand white rabbits, there is only one subtype of filiform papillae on the anterior part of tongue (spoonful conical filiform papillae), while there are two subtypes in lingual prominence; processed filiform papillae (at the anterior edge of lingual prominence) and leaf-like filiform papillae (on the posterior wide area of lingual prominence), but the lingual root contain only one subtype; Triangular filiform papillae.

Our study in Egyptian fruit bat agrees with that noted in the previous articles (Emura*et al*., 2001b; Mqokeli & Downs; Birt *et al*.; Kobayashi & Shimamura, 1982, EmuraHayakawa *et al*., 2002b), that the giant trifid filiform papilla are common in all bat species, but (Greenbaum and Phillips, 1974) in two species of bats (flower-eating), added that there are also two large, bifid, horny papillae located next to each other along the midline of the tongue, and also (Ghassemi & Jahromi; Jackowiak *et al*., 2009) noted that there are bifid Filiform Papillae and described as they are similar to giant type but had bifid ends and oriented to the lateroposterior of tongue, moreover (Park & Hall) made comparative studies of the tongue in a total of three families and eight species, nectar-eating, fruit-eating, and vampire bats, and reported that there are large bifid papillae were distributed on the posterior middle area of the tongues of fruit-eating bat (Macrotus and Artibeus), while out distributed near the tongue tip in all bats. Whouber, the trifid and bifid filiform papillae were abscent in; molossid bats (Gregorin), common European bat (Pastor *et al*., 1993), hematophagous bats (Masuko *et al*.).

The filiform papillae were observed throughout the whole tongue, in which their shape, size, number and orientation of the papillae itself and its processes varied according to their location within the tongue (region-specific) in relation to the feeding habits and types of food particles. The ones close to the middle part of tongue were posteriorly directed toward the pharynx and the base of tongue, while these present on the lateral edge of tongue are directed medioposteriorly to help in the collection and gathering of food particles in the middle part region of the posterior part of tongue then to pharynx. Furthermore in the lesser dog-faced fruit bat (Emura *et al*., 2001b) and the large flying fox (Emura *et al*., 2002b) the filiform papillae were not observed in the region of the circumvallate papillae, however, our study in the Egyptian fruit bat agree with (Emura *et al*., 2012), that the filiform papillae were observed in the region of the circumvallate papillae.

In general, the filiform papillae ended with a pointed apex and are oriented caudally in all species, as reported in our study. Filiform papillae of raccoon dog, fox, silver fox and giant panda have multiple processes (Jackowiak & Godynicki, 2004; Emura *et al*., 2009; Pastor *et al*., 2008) that are likely to have a mechanical effect by increasing the friction, but blind mole rats do not have these structures. In the raccoon dog and Japanese marten, each filiform papilla of the apical surface of the tongue has several pointed processes; and filiform papillae of the lingual body consist of a main papilla and some secondary papillae (Emura *et al*., 2007; Jackowiak & Godynicki, 2004), in the insectivores from the Sorex and Dymecodon species, the filiform papillae lack processes on the apex of the tongue, but on the surface of the body of the tongue they have two well-developed processes, tilted towards the back of the tongue (Kobayashi *et al*., 1989; Jackowiak *et al*., 2004). Filiform papillae on the lingual apex are reduced in size, structure and rounded shape as reported in our study in the Egyptian fruit bat, raccoon dog, fox, macaque, monkey and European mole rat (Jackowiak, 2006; Emura *et al*., 2006; Emura *et al*., 2002a; Emura *et al*., 2002b). Besides, the fact that filiform papillae are easily bent in the direction of the radix, but not in the opposite direction could be related to the need to secure in place and move the food taken into the mouth (Iwasaki; Ciuccio *et al*., 2008), but in our study in New Zealand white rabbits tongue, all the filiform papillae were directed posteriorly except the processed filiform papillae present on the anterior narrow part of the lingual prominence were anteriorly directed, in which this results in contrast with noted by (Nonaka *et al*.) in rabbit.

The filiform are considered to have a mechanical function (Nickel, 1979); but (Mistretta & Baum, 1984) suggested the gustatory function of it. On the contrary, it forms the primary pathway for the transport of food that comes in contact with the palate during mastication and swallowing, thus the observed more intensive keratinized layer, which serves as a protective mechanism (Trzcielinska-Lorych *et al*.). Filiform papilla provides the tongue with a rough surface suited for the movement and grinding of food (Karan *et al*., 2011).

The above mentioned types of filiform papillae form the primary pathway for the transport of food, being mainly fruit, as well as coming into contact with the palate during mastication and swallowing, thus the observed more intensive increment in the keratinized layer, which serves as a protective measure. For comparison, the keratinized layer on the lateral parts of the tongue, adjacent to teeth and surfaces of the tongue, postnatally increases in thickness only 2-fold.

ABUMANDOUR, M. A. M. Comparación morfológica de las papilas filiformes de conejos blancos Nueva Zelanda (*Oryctolagus cuniculus*) como los mamíferos domésticos y los murciélagos de la fruta egipcios (*Rousettus aegyptiacus*) como los mamíferos salvajes utilizando muestras de microscopía electrónica de barrido. ***Int. J. Morphol., 32(4)***:1407-1417, 2014.

RESUMEN: Se comparó la estructura morfológica de las papilas filiformes de un mamífero doméstico (conejo neozelandes) y de un mamífero silvestre (murciélagos de la fruta egipcio). El estudio fue realizado en animales de ambos sexos. Se observó cuatro tipos de papilas linguales, en ambas especies de animales. En los murciélagos de la fruta egipcio se observaron seis subtipos de papilas filiformes; tres en la parte anterior (pequeño, cónico y gigante), dos en la parte media (aciano y hojas como papilas) mientras que en la parte posterior se observaron papilas filiformes y papilas de transición cónica. En los conejos se observaron cuatro subtipos de papilas filiformes; cónica cucharada (en la parte anterior lingual), procesado (en el margen anterior de la prominencia lingual), tipo hoja (en la zona posterior de la prominencia lingual) y papilas filiformes triangulares (en la raíz lingual). La forma, tamaño, número y orientación de las papilas linguales y sus procesos varían de acuerdo a la función y a la ubicación en la lengua (específicos de la región) en relación con los hábitos de alimentación, las estrategias para la obtención de alimentos, las condiciones climáticas y tipos de partículas de alimentos.

PALABRAS CLAVE: Papilas filiformes; Murciélago de la fruta egipcio; Conejo blanco Nueva Zelanda; Microscopio electrónico de barrido.

REFERENCES

Abayomi, T. A.; Ofusori, D. A.; Ayoka, O. A.; Odukoya, S. A.; Omotoso, E. O.; Amegor, F. O.; Ajayi, S. A.; Ojo, G. B. & Oluwayinka, O. P. A Comparative Histological Study of the Tongue of Rat (*Rattus Norvegicus*), Bat (Eidolon Helvum) and Pangolin (Manis Tricuspis). *Int. J. Morphol., 27(4)*:1111-9, 2009.

Abumandour, M. M. & El-Bakary, R. M. Morphological and scanning electron microscopic studies of the tongue of the Egyptian fruit bat (*Rousettus aegyptiacus*) and their lingual adaptation for its feeding habits. *Vet. Res. Commun., 37(3)*:229-38, 2013.

Altringham, J. D.; McOwat, T. & Hammond, L. Bats: biology and behaviour. Oxford, Oxford University Press, 1996.

Azalli, G.; Gabbi, C.; Grandi, D. & Bonomini, L. Morphological and ultrastructural features of the non-sensory papillae in the tongue of hibernating bats. *Arch. Ital. Anat. Embryol., 96*:257-80, 1991.

Birt, P.; Hall, L. S. & SmithDep, G. C. Ecomorphology of the Tongues of Australian Megachiroptera (Chiroptera: Pteropodidae). *Aust. J. Zool., 45(4)*:369-84, 1997.

Bonaccorso, F. J. & Gush, T. J. Feeding behaviour and foraging strategies of captive phyllostomid fruit bats: an experimental study. *J. Anim. Ecol., 56(3)*:907-20, 1987.

Ciuccio, M.; Estecondo, S. & Casanave, E. B. Scanning electron microscopy study of the dorsal surface of the tongue in *Zaedyus pichiy* (Mammalia, Xenarthra, Dasypodidae). *Int. J. Morphol., 26(1)*:13-8, 2008.

Eby, P. *Finger-winged night workers: managing forests to conserve the role of grey-headed flying foxes as pollinators and seed dispersers. In*: Lunney, D. (Ed.). Conservation of Australias Forest Fauna. Mosman, Royal Zoological Society of New South Wales, 1991. pp.91-100.

Eby, P. *The biology and management of flying foxes in New South Wales*. Sidney, New South Wales National Parks and Wildlife Service Report No. 18, 1995.

Emura, S.; Hayakawa, D.; Chen, H.; Shoumura, S.; Atoji, Y. & Agungpriyono, S. SEM study on the dorsal lingual surface of the lesser dog-faced fruit bat, *Cynopterus brachyotis*. *Okajimas Folia Anat. Jpn., 78(4)*:123-8, 2001a.

Emura, S.; Hayakawa, D.; Chen, H. & Shoumura, S. Morphology of the dorsal lingual papillae in the newborn panther and Asian black bear. *Okajimas Folia Anat. Jpn., 78(5)*:173-7, 2001b.

Emura, S.; Hayakawa, D.; Chen, H. & Shoumura, S. Morphology of the dorsal lingual papillae in the *Japanese macaque* and *Savanna monkey*. *Anat. Histol. Embryol., 31(5)*:313-6, 2002a.

Emura, S.; Hayakawa, D.; Chen, H.; Shoumura, S.; Atoji, Y. & Wijayanto, H. SEM study on the dorsal lingual surface of the large flying fox, *Pteropus vampyrus. Okajimas Folia Anat. Jpn., 79(4)*:113-9, 2002b.

Emura, S.; Okumura, T. & Chen, H. Morphology of the lingual papillae in the Japanese marten. *Okajimas Folia Anat. Jpn., 84(2)*:77-81, 2007.

Emura, S.; Okumura, T. & Chen, H. Scanning electron microscopic study of the tongue in the Japanese pygmy woodpecker (*Dendrocopos kizuki*). *Okajimas Folia Anat. Jpn., 86(1)*:31-5, 2009.

Emura, S.; Okumura, T. & Chen, H. Morphology of the lingual papillae in the Egyptian rousette bat (*Rousettus aegyptiacus*). *Okajimas Folia Anat. Jpn., 89(3)*:61-6, 2012.

Emura, S.; Okumura, T.; Chen, H. & Shoumura, S. Morphology of the lingual papillae in the raccoon dog and fox. *Okajimas Folia Anat. Jpn., 83(3)*:73-6, 2006.

Emura, S.; Tamada, A.; Hayakawa, D.; Chen, H. & Shoumura, S. Morphology of the dorsal lingual papillae in the barbary sheep, *Ammotragus lervia. Okajimas Folia Anat. Jpn., 77(2-3)*:39-45, 2000.

Ghassemi, F. & Jahromi, H. K. Histological study of tongue in *Rousettus aegyptiacus* in the southwest of Iran (Jahrom). *Int. J. Res. Appl. Nat. Soc. Sci., 1(6)*:43-50, 2013.

Greenbaum, I. F. & Phillips, C. J. Comparative anatomy and general histology of tongues of long-nosed bats (*Leptonycteris sanborni* and *L. nivalis*) with reference to infestation of oral mites. *J. Mammal., 55(3)*:489-504, 1974.

Gregorin, R. Comparative morphology of the tongue in free-tailed bats (Chiroptera, Molossidae). *Iheringia Sér. Zool., 93(2)*:213-21, 2003.

Hall, L. S.; Richards, G. C.; & Spencer, H. J. *Eastern tube-nosed bat Nyctimene robinsoni Thomas, 1904. In*: Strahan, R. (Ed.). The Mammals of Australia: the National Photographic Index of Australian Wildlife. Chatswood, Reed Books, Australian Museum, 1995. pp.426-8.

Hofer, H. O.; Castenholz, A. & Zöltzer, H. The sublingua and tongue of Tupaia (Scandentia, Mammalia): a scanning electron microscope study. *Folia Primatol. (Basel), 60(4)*:185-94, 1993.

Iwasaki, S. Evolution of the structure and function of the vertebrate tongue. *J. Anat., 201(1)*:1-13, 2002.

Jackowiak, H. Scanning electron microscopy study of the lingual papillae in the European mole (*Talpa europea*, L., Talpidae). *Anat. Histol. Embryol., 35(3)*:190-5, 2006.

Jackowiak, H. & Godynicki, S. The scanning electron microscopic study of lingual papillae in the silver fox (*Vulpes vulpes fulva*, Desmarest, 1820). *Ann. Anat., 186(2)*:179-83, 2004.

Jackowiak, H. & Godynicki, S. The distribution and structure of the lingual papillae on the tongue of the bank vole *Clethrinomys glareolus*. *Folia Morphol. (Warsz.), 64(4)*:326-33, 2005.

Jackowiak, H.; Godynicki, S.; Jaroszewska, M. & Wilczyn´ska, B. Scanning electron microscopy of lingual papillae in the common shrew, *Sorex araneus*, L. *Anat. Histol. Embryol., 33(5)*:290-3, 2004.

Jackowiak, H.; Trzcielin´ska-Lorych, J. & Godynicki, S. The microstructure of lingual papillae in the Egyptian fruit bat (*Rousettus aegyptiacus*) as observed by light microscopy and scanning electron microscopy. *Arch. Histol. Cytol., 72(1)*:13-21, 2009.

Karan, M.; Yilmaz, S. & Aydin, A. Morphology of the filiform lingual papillae in porcupine (*Hystrix cristata*). *Anat. Histol. Embryol., 40(2)*:100-3, 2011.

Kilinc, M.; Erdogan, S.; Ketani, S. & Ketani, M. A. Morphological study by scanning electron microscopy of the lingual papillae in the Middle East blind mole rat (*Spalax ehrenbergi*, Nehring, 1898). *Anat. Histol. Embryol., 39(6)*:509-15, 2010.

Kobayashi, K.; Miyata, K.; Takahashi, K. & Iwasaki, S. Three-dimensional architecture of the connective tissue papillae of the mouse tongue as viewed by scanning electron microscopy. *Kaibogaku Zasshi, 64(6)*:523-38, 1989.

Kobayashi, S. & Shimamura, A. Comparative anatomical observations of the tongue of the Japanese long-fingered bats, Miniopterus schreibersi fuliginosus. *Okajimas Folia Anat. Jpn., 58(4-6)*:923-32, 1982.

Kumar, S. & Bate, L. A. Scanning electron microscopy of the tongue papillae in the pig (*Sus scrofa*). *Microsc. Res. Tech., 63(5)*:253-8, 2004.

Mançanares, C. A. F.; Santos, A. C.; Piemonte, M. V.; Vasconcelos, B. G.; Carvalho, A. F.; Miglino, M. A.; Ambrosio, C. E. & Assis Neto, A. C. Macroscopic and microscopic analysis of the tongue of the common opossum (*Didelphis marsupialis*). *Microsc. Res. Tech., 75(10)*:1329-33, 2012.

Masuko, T. S.; Boaro, N.; König-Júnior, B.; Cabral, R. H. & Costa-Neto, J. M. Comparative scanning electron microscopic study of the lingual papillae in three species of bats (*Carollia Perspicillata*, *Glossophaga Soricina* and *Desmodus Rotundus*). *Microsc. Microanal., 13(Suppl. 2)*:280-1, 2007.

Mistretta, C. M. & Baum, B. J. Quantitative study of taste buds in fungiform and circumvallate papillae of young and aged rats. *J. Anat., 138(Pt. 2)*:323-32, 1984.

Mqokeli, B. R. & Downs, C. T. Palatal and lingual adaptations for frugivory and nectarivory in the Wahlberg's epauletted fruit bat (*Epomophorus wahlbergi*). *Zoomorphology, 132(1)*:111-9, 2013.

Nasr, E. S.; Gamal, A. M. & Elsheikh, E. H. Light and scanning electron microscopic study of the dorsal lingual papillae of the rat *Arvicanthis niloticus* (Muridae, Rodentia). *J. Am. Sci., 8(4)*:619-27, 2012.

Nickel, R.; Schummer, A. & Seiferle, E. *The Viscera of the Domestic Mammals.* 2nd ed. Berlin, Springer Verlag, 1979.

Nonaka, K.; Zheng, J. H. & Kobayashi, K. Comparative morphological study on the lingual papillae and their connective tissue cores in rabbits. *Okajimas Folia Anat. Jpn., 85(2)*:57-66, 2008.

Ogunbiyi, O. A. & Okon, E. E. Studies on the digestive enzymes of the African fruit bat *Eidolon helvum* (Kerr). *Comp. Biochem. Physiol. A Comp. Physiol., 55(4A)*:359-61, 1976.

Ojima, K.; Hosaka, M. & Suzuki, Y. Functional and positional difference and classification of the fungiform papillae on the rabbit tongue seen in microvascular cast specimens by means of scanning electron microscope. *Ann. Anat., 182(6)*:521-4, 2000.

Ojima, K.; Saeki, C.; Matsumoto, S. & Takeda, M. The distributive pattern, form and function seen in microvascular cast specimens of filiform papillae on the anterodorsal surface of the adult rat tongue. *Ann. Anat., 178(6)*:531-6, 1996.

Ojima, K.; Takeda, M.; Matsumoto, S.; Saiki, C. & Takahashi, T. Functional role of V form distribution seen in microvascular cast specimens of the filiform and fungiform papillae on the posterior central dorsal surface of the cat tongue. *Ann, Anat., 179(4)*:321-7, 1997.

Park, H. & Hall, R. The gross anatomy of the tongues and stomachs of eight New World bats. *Trans. Kans. Acad. Sci. Topeka, 54(1)*:64-72, 1951.

Park, J. & Lee, J. H. Comparative Morphology of the Tongue of Miniopterus schreibersi fuliginosus and *Pipistrellus savii*. *Korean J. Microsc., 39(3)*:267-76, 2009.

Pastor, J. F.; Moro, J. A.; Verona, J. A:; Gato, A.; Represa, J. J. & Barbosa, E. Morphological study by scanning electron microscopy of the lingual papillae in the common European bat (*Pipistrellus pipistrellus*). *Arch. Oral Biol., 38(7)*:597-9, 1993.

Pastor, J. F.; Barbosa, M. & de Paz, F. J. Morphological study of the lingual papillae of the giant panda (*Ailuropoda melanoleuca*) by scanning electron microscopy. *J. Anat., 212(2)*:99-105, 2008.

Pastor, J. F.; Barbosa, M.; De Paz, F. J.; García, M. & Ferrero, E. Functional and comparative study of lingual papillae in four species of bear (Ursidae) by scanning electron microscopy. *Microsc. Res. Tech., 74(10)*:910-9, 2011.

Paton, D. C. & Collins, B. G. Bills and tongues of nectar-feeding birds: A review of morphology, function and performance, with intercontinental comparisons. *Aust. J. Ecol., 14(4)*:473-506, 1989.

Qayyum, M. A.; Fatani, J. A. & Mohajir, A. M. Scanning electron microscopic study of the lingual papillae of the one humped camel, *Camelus dromedarius. J. Anat., 160*:21-6, 1988.

Romer, A. S. *Vertebrate paleontology*. Chicago, University of Chicago Press, 1960.

Selim, A.; Nahla, N. E. & Shelfeh, M. Comparative Anatomical and Histological Studies of the Tongue between the Egyptian Bat *Pipistrillus Kuhli* and the Syrian Bat *Pipstrillus Kuhli*. *Tishreen Univ. J. Biol. Sci. Ser., 30(1)*:247-55, 2008.

Takemura, A.; Uemura, M.; Toda, I.; Fang, G.; Hikida, M. & Suwa, F. Morphological study of the lingual papillae in the ferret (*Mustela putorius furo*). *Okajimas Folia Anat. Jpn., 86(1)*:17-24, 2009.

Toprak, B. Light and scanning microscopic structure of filiform papillae in mice. *Veterinarski Arhiv., 76(6)*:555-62, 2006.

Trzcielinska-Lorych, J.; Jackowiak, H.; Skieresz-Szewczyk, K. & Godynicki, S. Morphology and morphometry of lingual papillae in adult and newborn Egyptian fruit bats (*Rousettus aegyptiacus*). *Anat. Histol. Embryol., 38(5)*:370-6, 2009.

Wilson, D. E. & Reeder, D. M. *Mammal Species of the World. A Taxanomic and Geographic Reference*. 2nd ed. Washington, Smithsonium Institution Press, 1993.

Yoshimura, K.; Shindo, J. & Kageyama, I. Light and scanning electron microscopic study on the tongue and lingual papillae of the Japanese badgers, *Meles meles anakuma*. *Okajimas Folia Anat. Jpn., 85(4)*:119-27, 2009.

Zheng, J. & Kobayashi, K. Comparative morphological study on the lingual papillae and their connective tissue cores (CTC) in reeves' muntjac deer (*Muntiacus reevesi*). *Ann. Anat., 188(6)*:555-64, 2006.

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Received: 04-09-2014
Accepted: 23-09-2014