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Comparative Morphological Features of the Tongue in Camels (Camelus dromedarius) and Sheep (Ovis aries): Relationship to Feeding Adaptations

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Abstract

Background: The tongue, as a distinct muscular organ, is critical for prehending food, chewing it, swallowing it, as well as perceiving its taste. The purpose of this study was to perform a comparative anatomic study of the tongue in camels (Camelus dromedarius) and sheep (Ovis aries) with an emphasis on structural differences that are associated with their diets and their habitats. **Materials and Methods:** A total of twenty apparently healthy adult animals (10 camels and 10 sheep) that were between the ages of 1 and 3 years old comprised the sample size for this study. All tongues were collected from animals raised in Basra, Iraq. The anatomy of the tongue was assessed by measuring the weight, length, and width. Detailed observations of lingual papillae were made regarding their distribution and morphogenesis. **Results:** The specimens revealed significant differences in tongue structure between the two species. Camels have a distinct anatomy of their tongues that includes a visible differentiation into the apex, body, and base. The distribution of the filiform papillae was homogeneous; however, there were conical and lenticular papillae located at the tip and base of the camel's tongue. The study of the tongue of sheep shows how it differs structurally from that of camels and provides information that relates directly to their different feeding behaviours. With respect to each shoulder, there are two dorsolateral rows of vallate (circumvallate) papillae and these are significantly larger in size than those seen in camels. In addition to having a greater number of vallate papillae (circumvallate), the tongue of sheep (but not camels) infect are very densely clustered with abundant filiform (thread-like) papillae which give the tongue a plush velvety-like appearance and also indicate that they were avascular. Lenticular papillae are also abundantly distributed throughout the sheep tongue, especially in the body regions. **Conclusion:** The significant structural differences between both species' tongues are related to their diet; camels possess anatomical adaptations for consuming desert vegetation that is coarse, salty, and/or potentially poisonous; while sheep possess anatomical adaptations for consuming lush, soft grasses. Thus, the findings of this research are a strong indicator of the morphological similarities and differences of the tongues of herbivorous mammals and their influence on the behavioural feeding differences of these herbivorous mammals.

Keywords: Comparative anatomy, tongue, camel, sheep, lingual papillae, dietary

adaptation, gross anatomy

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I. Introduction

A specialized muscular organ called the tongue is an important part of the anatomical structure of the oral cavity responsible for many functions, including food prehension, mastication, swallowing, and taste perception. The tongue detects tastes when the molecules in food interact with taste receptors located on lingual papillae, helping researchers better understand how mammals feed and their dietary adaptations (Madkour et al., 2023). The oral cavity includes the space bounded by the anterior lips and posterior oropharyngeal isthmus and laterally by the cheeks; going inferiorly through the mobile muscular tongue; and going superiorly through the hard and soft palate. The oral vestibule represents the space between the lips/cheeks and teeth; the oral cavity itself (i.e., the oral cavity proper) lies internally to the dental arches (Alexander et al., 2019). The tongue has three anatomical components: 1) the root (attached to the hyoid bone), 2) the body, and 3) the free apex. Physiologically, the tongue has a vital role in food mixing with saliva, moving the bolus, grooming, and licking (Gray). The dorsal surface of the tongue contains differing types of lingual papillae that have 2 primary mechanical (filiform, conical, and lenticular) and gustatory (fungiform, vallate, and foliate) functions (Dyce). The morphology and structure of lingual papillae are affected by environmental factors. The tongue is equipped with taste, pain, and temperature receptors (Meier et al. 2016). The morphological traits of the lingual region are modified as a result of food intake and mastication, affecting the selection of forage and thus the palatability of food available to ruminants (Ginane & Favreau-Peigné 2011). Thus, lingual characteristics can be used to evaluate the choice of diet (Meier et al. 2016). There are many anatomical/histological differences in the tongues of different animal species worldwide. The primary factors affecting these variations are dietary habits and environmental conditions, which allow for the grouping of animals into three major categories: herbivores, carnivores, and omnivores (Hassan et al. 2018). The tongue and oral cavity of the animal display morphological and histological adaptations, which are associated with the specialized dietary habits of the animal. Camels (Old World camels) are the only herbivores that can tolerate a high-salt diet including members of the Asteraceae and Chenopodiaceae families, with daily salt intakes of up to eight times higher than that of cattle or sheep; they can even consume plants that are toxic to other mammals, such as Cynanchum and Stellera (Fitak et al. 2025). Inactivation of TAS2R16 (a gene encoding the well-characterized bitter taste receptor) has been confirmed through experimentation to enable Old World camels to consume certain species of toxic plant matter that are otherwise considered to have a bitter taste when eaten by other species of mammals (Fitak et al., 2025). Conversely, sheep are grazing herbivores that possess distinct adaptations in their tongues. On either side of the torus linguae are two rows of circumvallate papillae, shaped as circular, ellipsoidal, pyramidal, and ovoid; in the centre of each are papillary grooves and flat; wide, undulating annular rods (Madkour et al., 2023). Fungiform papillae in sheep have been classified into two subtypes: Round papillae exist on the top (dorsal) surface; and, ovoid papillae exist on the bottom (ventral side) surface of the tip (Abumandour & Kandyel, 2023). Previous studies have shown that ruminants and camels differ in the structure, dimension and configuration of their lingual papillae (El Bakary, 2014; Erdogan et al., 2016). Many of these differences between the lingual papillae of Bactrian camels and the lingual papillae of other domestic ruminants will likely provide Bactrian camels with adaptations to their ability to consume the inorganic, hardy greens in their environment (Eerdunchaolu et al., 2014).

Aims of the Study

1. To conduct a comparative anatomical study of the tongue in camels and sheep.

2. To identify and describe the gross anatomical distribution of lingual papillae

on the tongue in both species.

3. To compare the morphological characteristics of different papilla types

between the two species.

4. To correlate structural differences with dietary and environmental adaptations.

Materials and Methods

Twenty adult animals were selected at random with equal representation from 2 different species (Ovis aries and Camelus dromedarius), with ages ranging from 1-3 years, and no consideration of sex (or gender). On the day of slaughter, animals were selected randomly from Basra, Iraq, and tongue samples were taken immediately following euthanasia. Prior to euthanization, each animal was evaluated in terms of general health, and each tongue sample was cleaned thoroughly under running water to remove any dirt and other debris. Tongue samples were weighed by using a sensitive scale (WANT Scale Company). After tongues were weighed, they were placed in 10% formalin solution for 24-48 hours, after which length and width measurements were made using a chart measuring device. The following types of tongue papillae were analyzed: filiform, fungiform, vallate (circumvallate), conical and lenticular. The number of vallate papillae was counted in each species.

Morphometric Analysis

The tongue measurements that were taken from each sample consisted of the following:

(1) total tongue length from apex to base of tongue

(2) tongue width at apex, body, and base of tongue

(3) total tongue weight

Biostatistical Analysis

Statistical analyses for the present study were performed utilizing one-way ANOVA and the significance level was defined at $P < 0.05$ (Field, 2009; Abd-Elkareem et al., 2022) to determine the significance of all variables measured. The mean and ± standard deviation (SD) of every value are presented as + and - SD.

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Results

General Tongue Morphology :

The anatomy of the tongue from camels differs significantly from that of sheep, although the basic structure of the tongue is similar in division into an apex or tip, body, and base, both of which are similar to one another. The camel's division of the three tongues was much clearer; all three regions (apex, body, and base) were readily identifiable (see figures 1 and 2). In sheep, the body of the tongue was physically separated from the base of the tongue by an obvious protrusion at the posterior end of the body (see figure 8). The camel's tongue was very large and very strong, making it well suited for chewing through coarse desert plants. The sheep's tongue, by comparison, is smaller and weaker, suited for eating soft grasses.

Table 1: Morphometric measurements of the tongue in camels and sheep (Mean ± SD)

Parameter	Camel (n=10)	Sheep (n=10)	P-value
Tongue length (cm)	28.4 ± 2.1	12.6 ± 1.3	<0.05
Tongue width at apex (cm)	5.8 ± 0.6	2.9 ± 0.3	<0.05
Tongue width at body (cm)	7.2 ± 0.8	3.4 ± 0.4	<0.05
Tongue width at base (cm)	6.5 ± 0.7	3.1 ± 0.3	<0.05
Tongue weight (g)	425.6 ± 32.5	78.4 ± 8.9	<0.05

Filiform Papillae

Both species had significant amounts of similar filiform papillae, but they had very different shapes and systems of papillae. Camel: The camel had a uniform arrangement and growth of filiform papillae over its entire dorsal tongue surface (Figures 3, 5, 7). They were all conical in shape and—the direction they pointed (posteriorly)—was consistent with the function of being mechanical papillae that move food toward the pharynx. In both species, filiform papillae were found from the apex to the base. Sheep: The sheep had an extremely high density of filiform papillae, and due to their elongated shape, the tongue was velvety in appearance (Figures 4, 6, 8).

Fungiform Papillae

Both species had fungiform papillae, and their location and abundance were inconsistent.
Camel: Fungiform papillae were interspersed with filiform papillae on the dorsal tongue surface, located mainly at the lateral edges of the tongue (Figures 5 and 7). Fungiform papillae of the camel were mushroom shaped and located in between (less frequent) filiform papillae. Sheep: Fungiform papillae of the sheep were less numerous than those of the camel and thus less conspicuous compared to those of the camel.

Vallate (Circumvallate) Papillae

Vallate papillae showed striking differences across species in size, number, and arrangement. Camel: Vallate papillae were arranged in two rows on each side of the tongue.

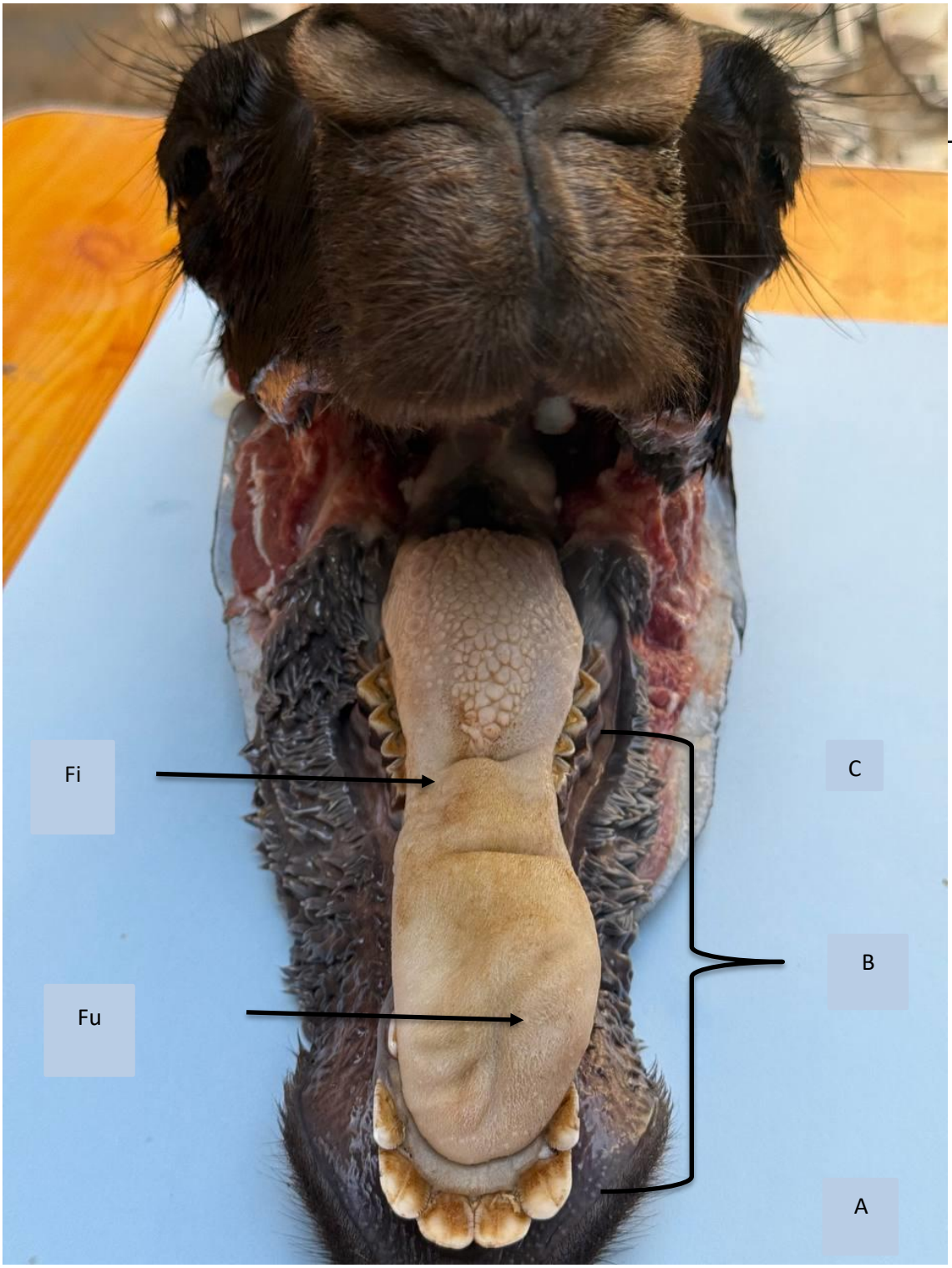

Figure (1): Dorsal surface of the camels tongue (whole organ) shows its division into A. apex, B. body, and C. base, with filiform (Fi) and fungiform(Fu) papillae (black arrow) observed on its surface.

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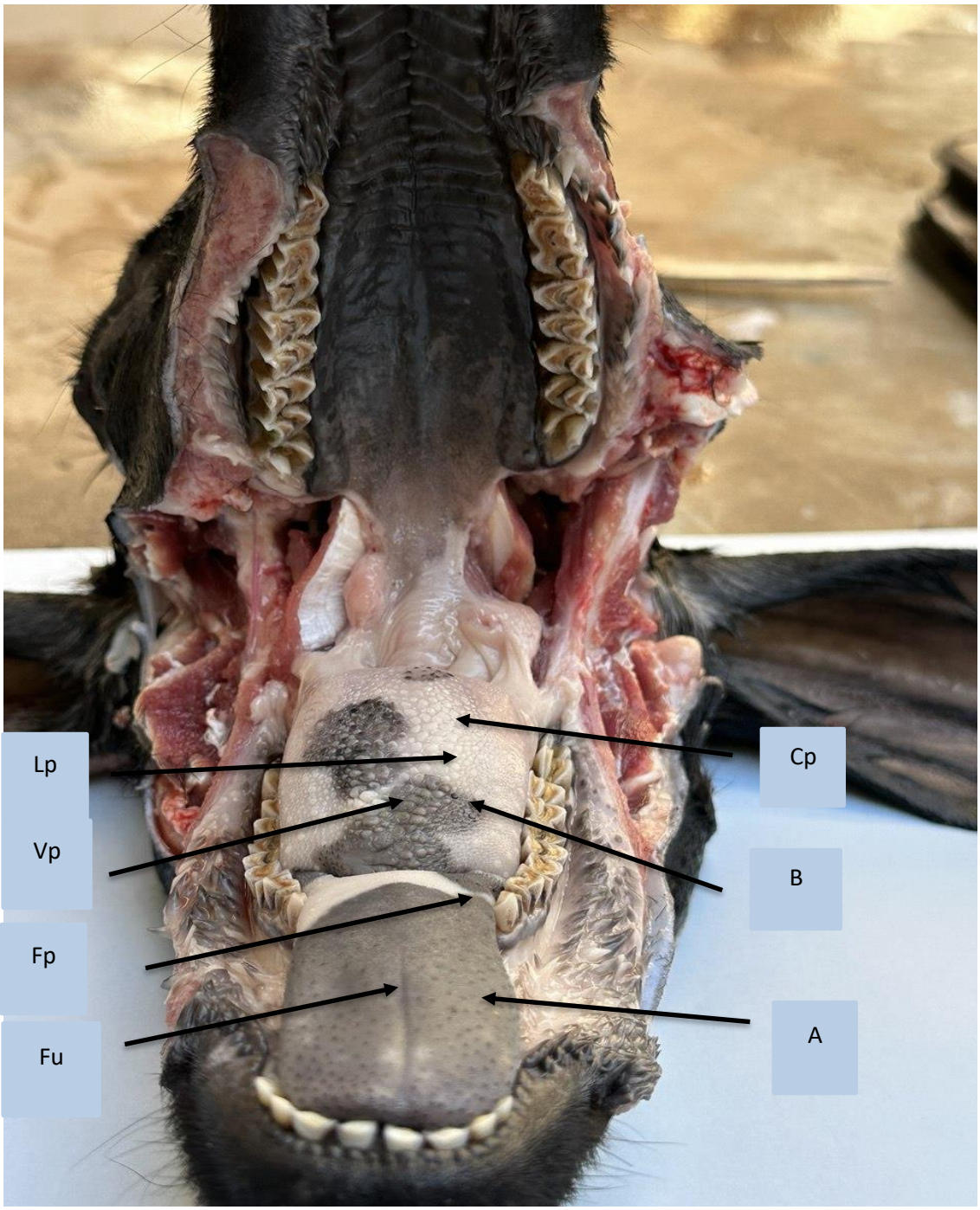

Figure (2): Dorsal view of the sheeps tongue inside the oral cavity (in-situ), showing A. apex, B. body, filiform papillae (Fi), vallate papillae (Vp), conical papillae (Cp), fungiform papillae (Fu), and lenticular papillae (Lp).

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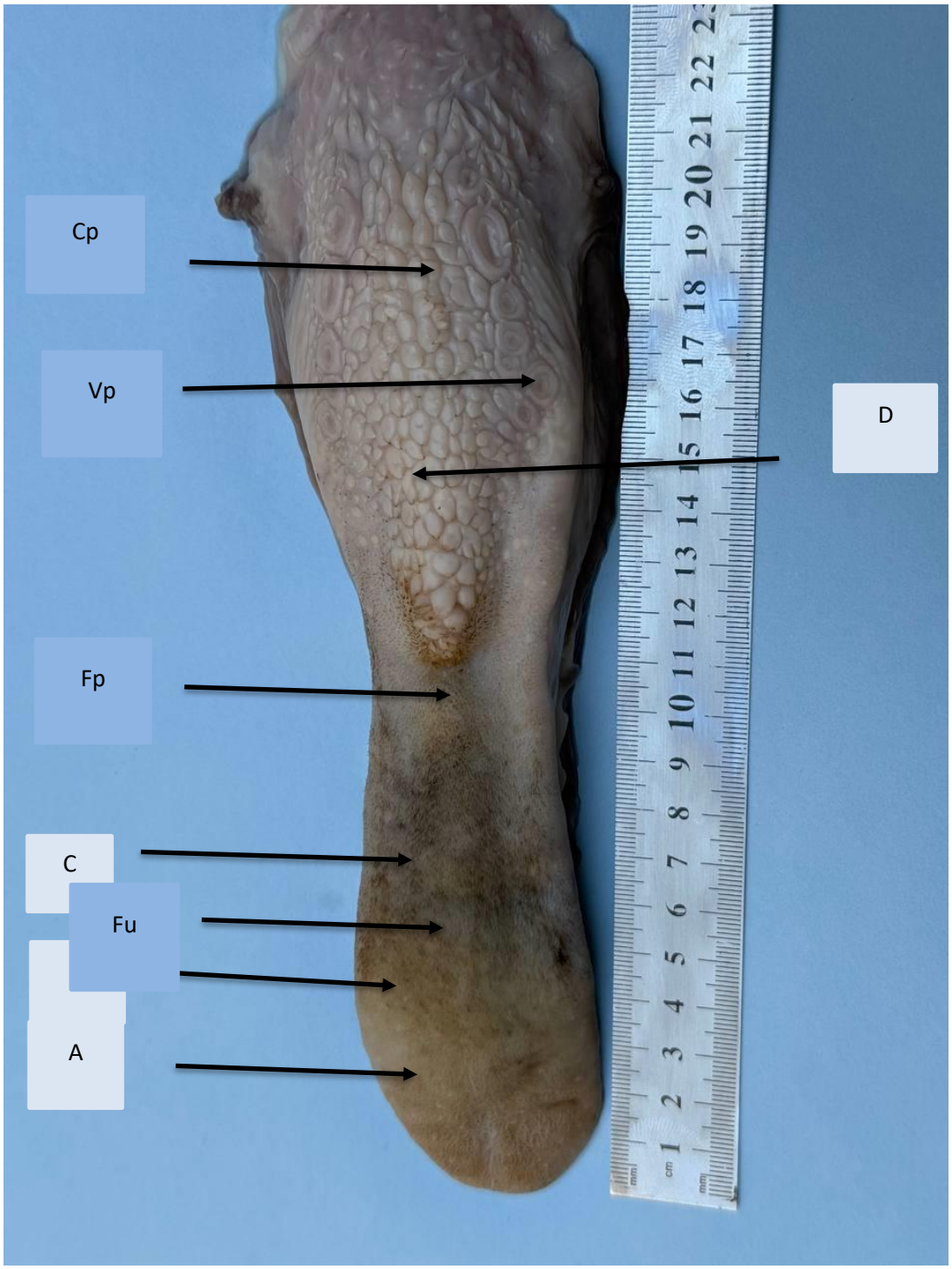

Figure (3): Dorsal surface of the camels tongue (whole organ) shows its division into apex, body, and base, with filiform (F p), fungiform (Fu), conical (Cp), and vallate (Vp) papillae observed on its surface.

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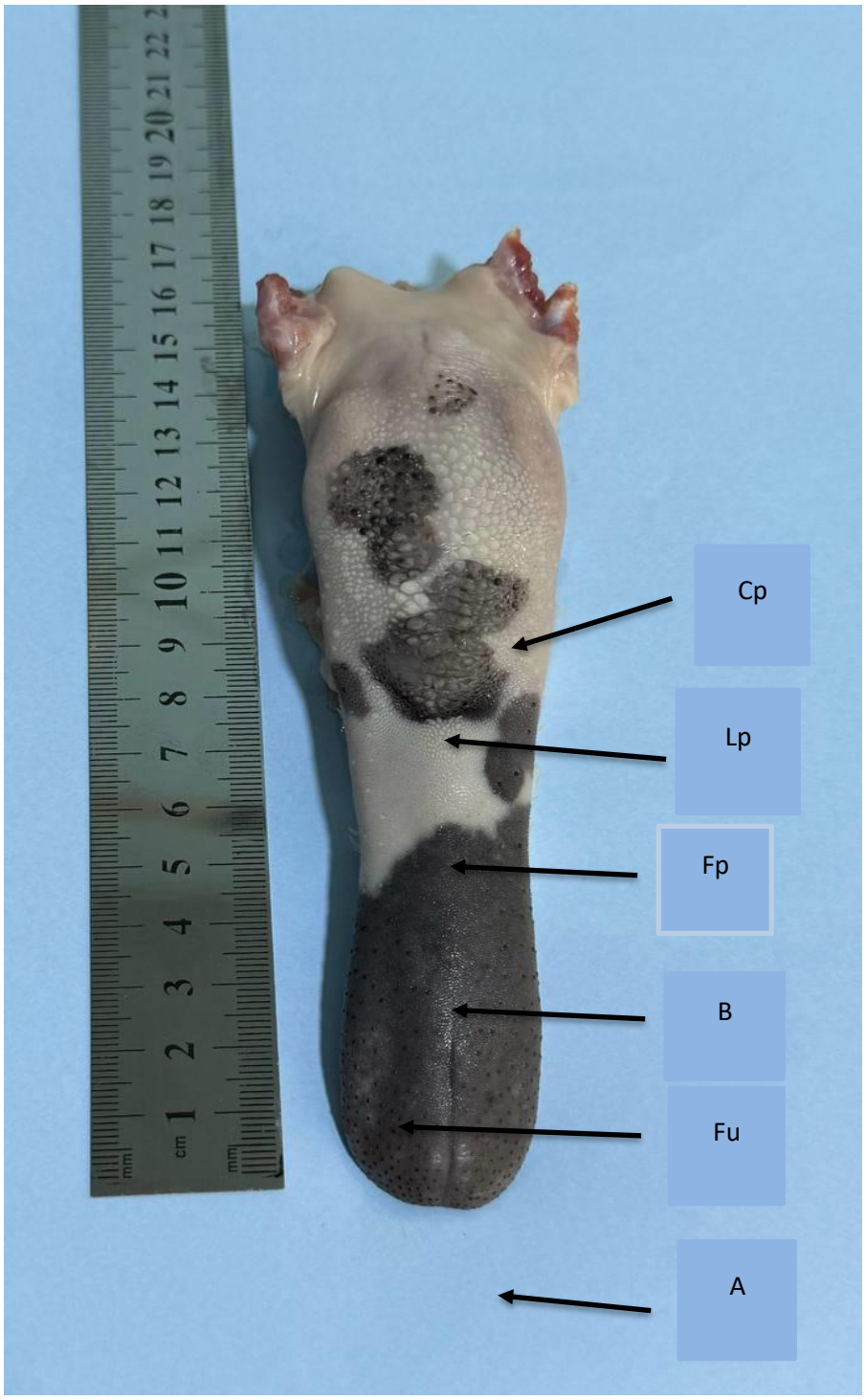

Figure (4):Dorsal surface of the sheeps tongue (whole organ) shows the clear anatomical separation between the body and the base (posterior protrusion), apex (A), filiform (F p), fungiform (Fu), vallate (Vp), conical (Cp), and lenticular (Lp) papillae on its surface

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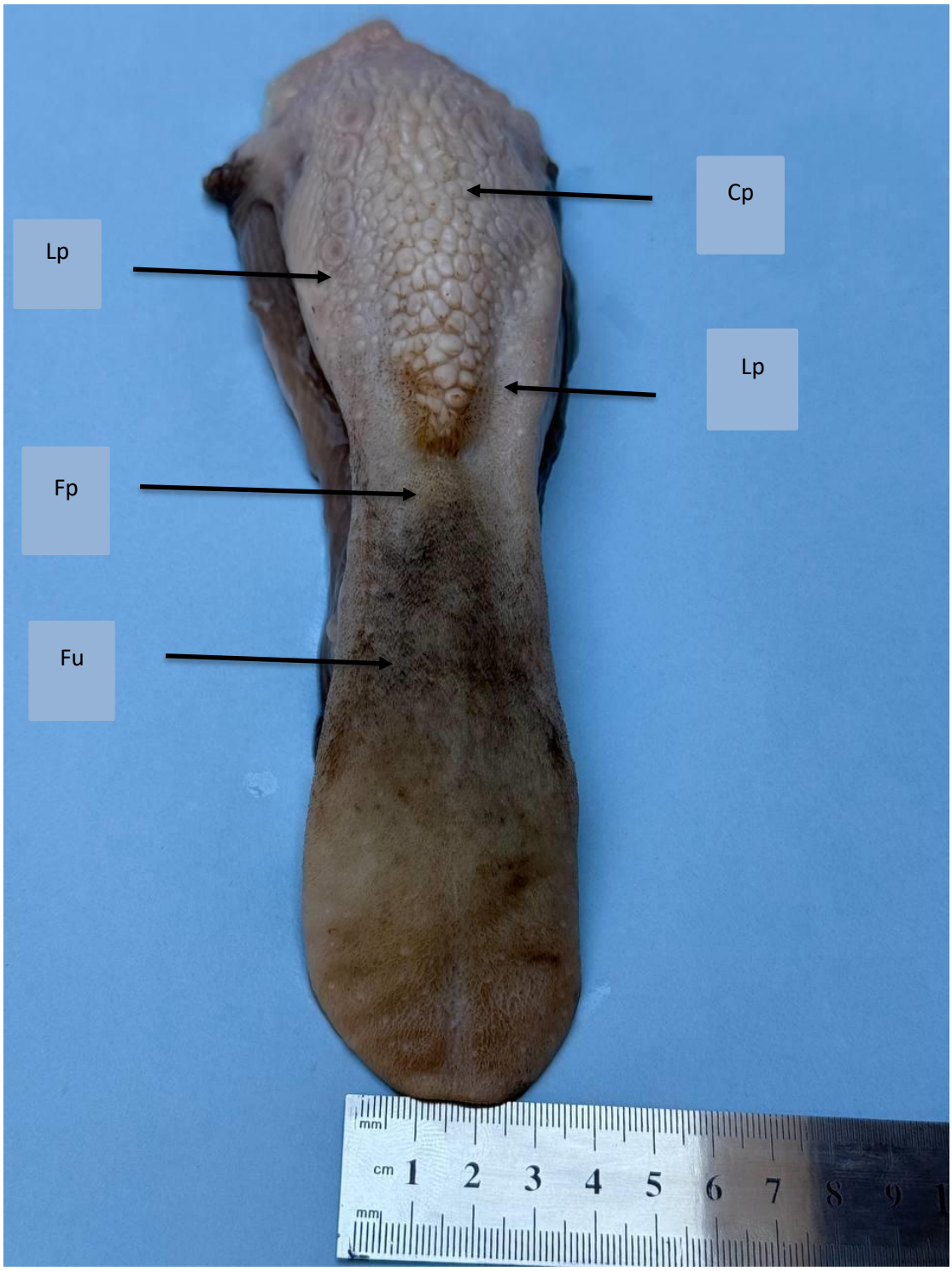

Figure (5): Dorsal surface of the camel's tongue tip, showing the scattering of fungiform (Fu), filiform (Fp), conical (Cp), lenticular (Lp) papillae, and two rows of vallate papillae (Vp) on each side.

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Figure (6): Dorsal surface of the tip of the sheep's tongue, showing the rounded shape of the tip and the presence of dense thread-like filiform papillae (Fp) that giv

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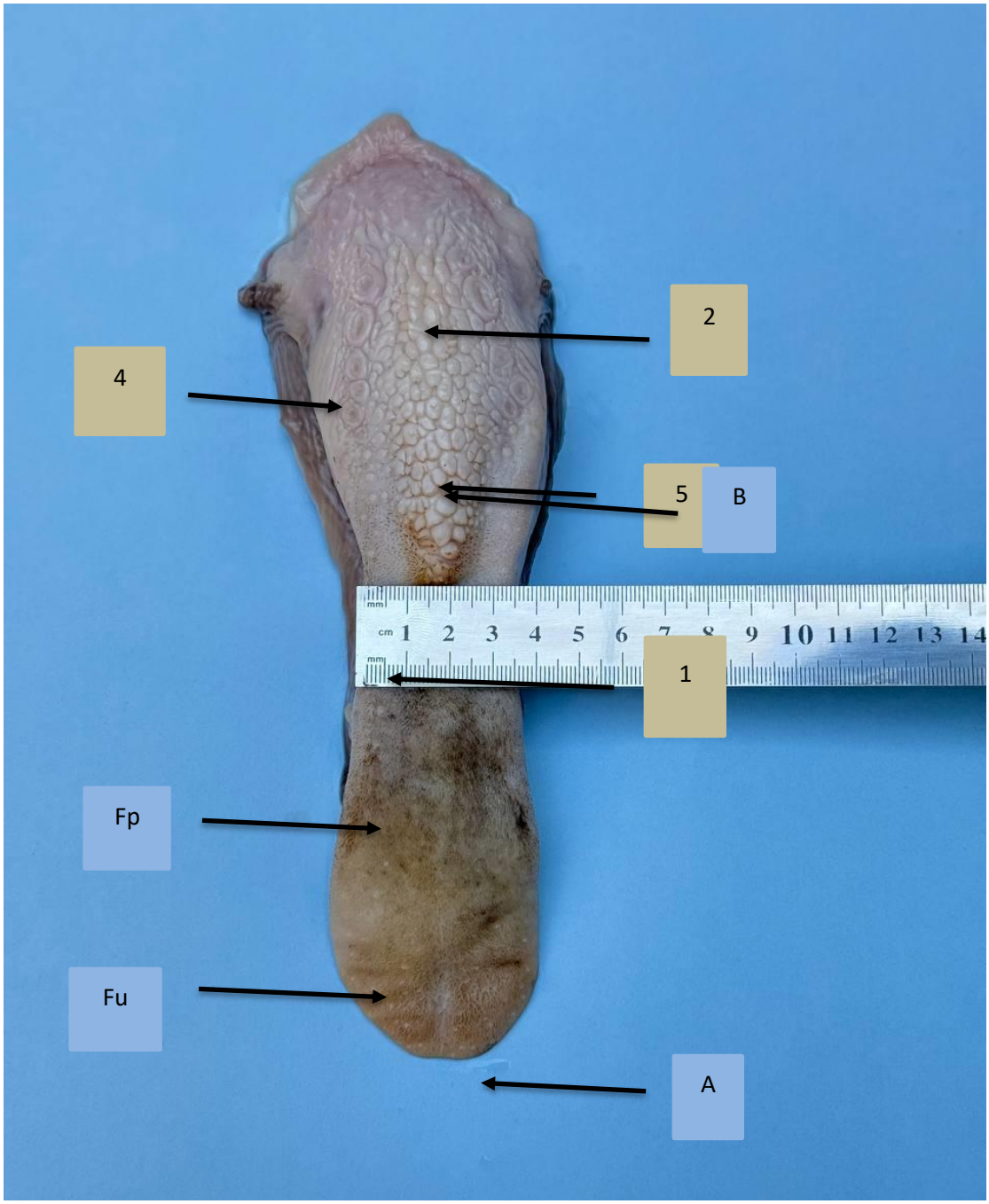

Figure (7): Dorsal surface of the camel's tongue body, showing the apex (A), body (B), base (C), and distribution of filiform (Fp), conical (Cp), fungiform (Fu), and goblet (vallate) papillae if present within

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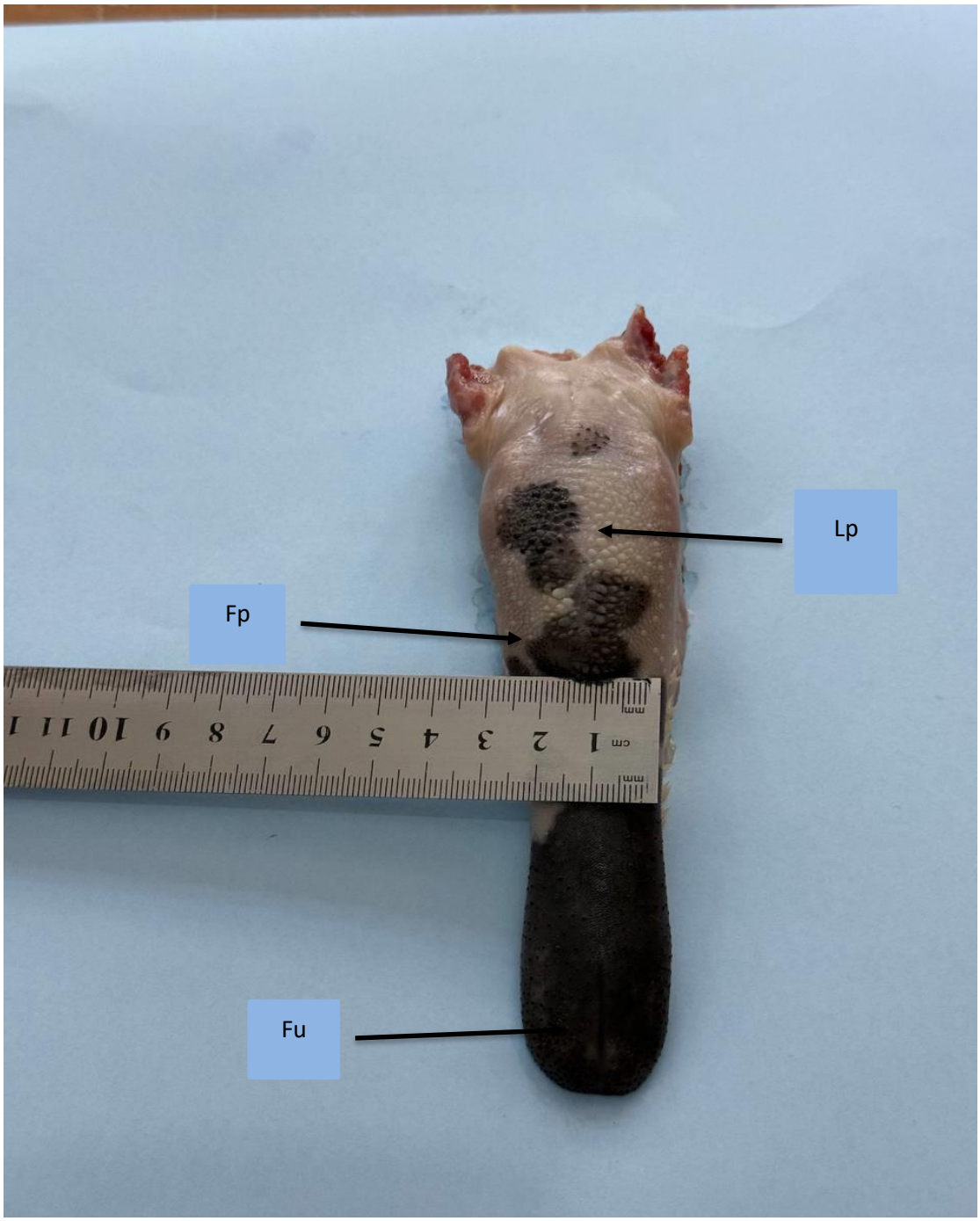

Figure (8): Dorsal surface of the sheep's tongue shows the distribution of lenticular papillae (Lp), which are characteristically widespread in this region of the sheep.

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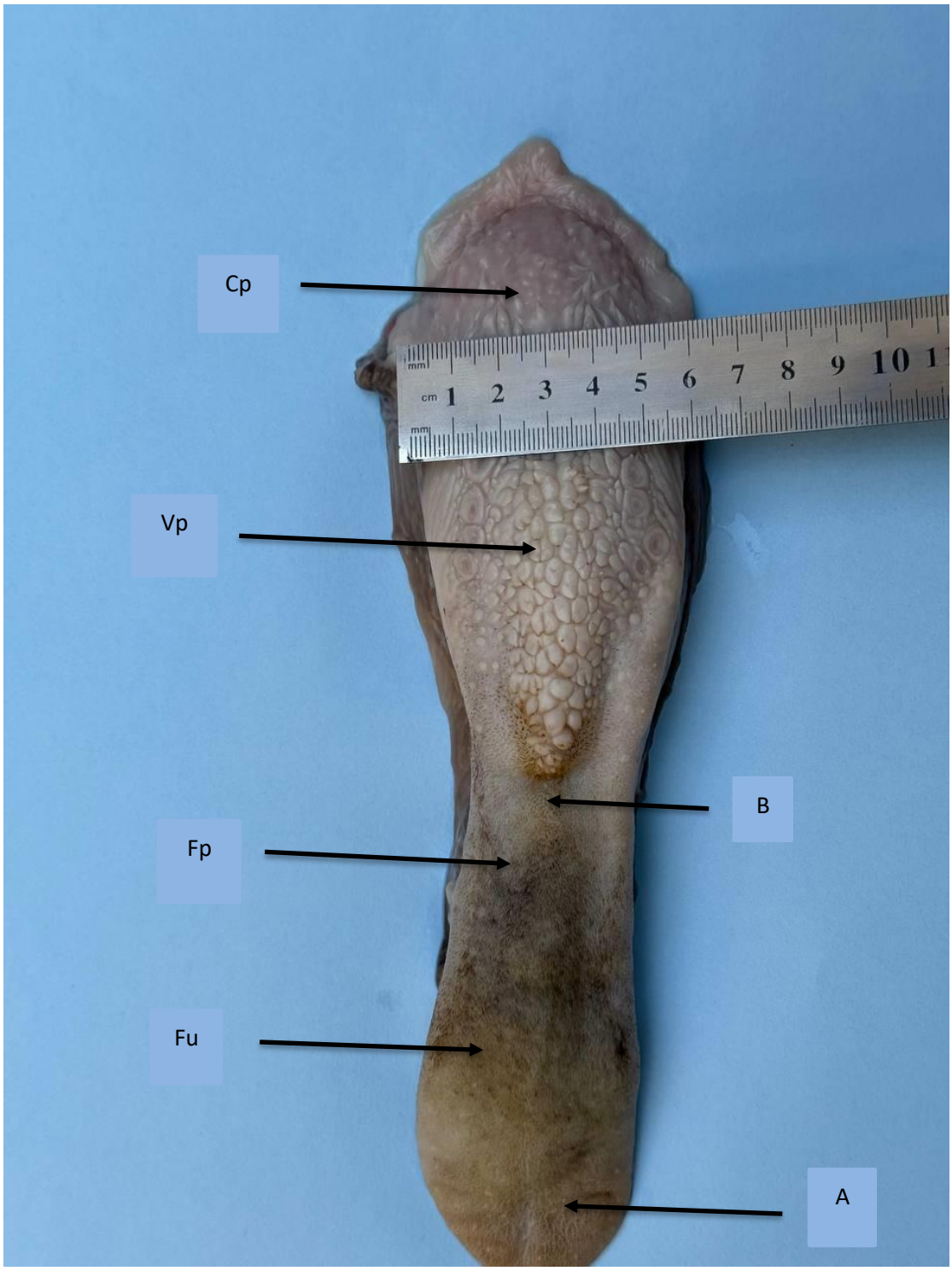

Figure (9): Dorsal surface of the base of the camel's tongue, showing the presence of the lingual tonsil (Tonsilla lingualis) and several conical (Cp) or lenticular (Lp) papillae, along with filiform (Fp), vallate (Vp), and fungiform (Fu) papillae.

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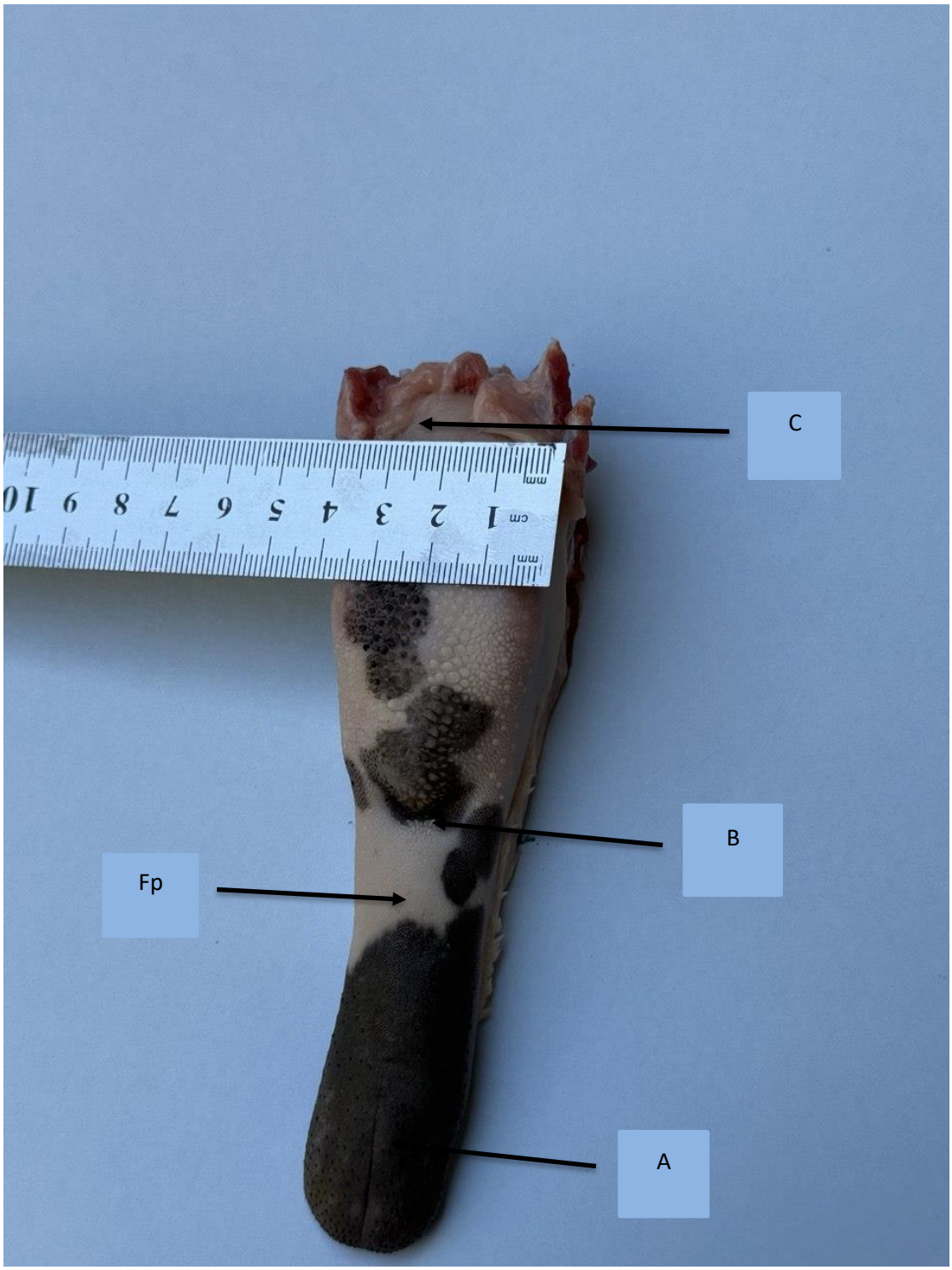

Figure (10): Dorsal surface of the base of the sheep's tongue, showing the large vallate papillae, usually found in two rows, in addition to the filiform papillae (Fp) in the body (B).

Discussion

The anatomical features of camels' tongues differ from those of sheep in a way that reflects their respective feeding behaviour and where they eat. Some past studies support the finding that mammalian tongues adapt to food types consumed (Meier et al., 2016; AbuBakr et al., 2020). Camels are adapted to survive in the harsh conditions of the desert, where they eat coarse, sharp, salty and toxic foods. Thus, the conical and lenticular papillae that develop on the front and the back of the camels tongue help breakdown the tough plant material (Eerdunchaolu et al., 2014). The papillae not only function as barriers for the mechanical breakdown of foods but they also aid in handling rough or fibrous foods. The even distribution of the filiform papillae on the dorsal surface of the camel's tongue enables it to mechanically break down food throughout its length. Finally, the pointed tips of the papillae at the back of the tongue assist in moving food boluses to the pharynx when the animal swallows. TAS2R16 is a gene for a bitter tasting receptor protein. A loss of function of this gene has allowed camels to eat toxic plants that would be avoided by other mammals (Fitak et al., 2025). This explains how camels are able to consume species of Cynanchum and Stellera that are toxic to both sheep and cattle. In addition to this ability, camels can also tolerate salt consumption at levels that are up to 8 times higher than those of Sheep, making them able to eat halophytic plants belonging to the Asteraceae and Chenopodiaceae Families (Fitak et al., 2025). The layout of the vallate papillae along two lines at the base of the camel tongue, each separated by deep circular grooves, increases the total area available for gustatory use while still maintaining an efficient mechanical form. The intermediate size of the camel's papillae compared to those of sheep may reflect a decreased degree of dependence on gustatory discrimination overall which corresponds with the camel's generalised nutritional resource allocation strategy in the wild. Sheep are typically grazing herbivores that primarily eat soft grasses and forbs. As a result, the intense, thread-like structure of the filiform papillae comprising the sheep tongue apex function to adequately assist in gathering and manipulating soft forage (Madkour et al., 2023) This special type of papilla has been developed to help an animal efficiently grab and eat grass and is an adjustment to a grazing lifestyle. The many different forms of filiform and conical papilla found in sheep suggest there is a large amount of specialization for various functions. There are five forms of filiform papilla and three forms of conical papilla found on the tongue of a sheep (Abumandour & Kandyel, 2023) that allow the precise movement of food items when a sheep is grazing and chewing cud. The size of the vallate papilla in sheep is larger than that of a camel which may suggest there is a greater need to rely on taste when evaluating food items in sheep. Because the bitter taste receptor is genetically disrupted in camels, sheep have to be better at choosing food that will not contain toxins found in pastures. The annular ridge and two cushions found around the Vallate papillae (Abumandour & Kandyel, 2023) may provide a unique passage for food items to be deposited on the taste receptors by allowing food to move into the grooves created by the cushion-ridge-cushion combination.

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