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Macroscopic and microscopic study of the tongue of the aardvark (*Orycteropus afer,* Orycteropodidae)

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ABSTRACT

The aim of this study was to describe the morphology of the tongue in the aardvark (*Orycteropus afer*). The tongues from one adult and one three-week old aardvark females and one neonate aardvark were studied. The tongue was elongated in the adult and young aardvarks and had a triangular apex in the rostral part of the tongue. Its dorsal surface was covered by numerous papillae divided into mechanical papillae, present in the form of abundant conical or drop-like filiform papillae, and taste papillae in the form of numerous fungiform papillae and three vallate papillae arranged in a V-shape in the caudal part of the tongue (one papilla was located centrally and caudally with respect to the remaining two papillae). The vallate papillae were round with conical pseudopapillae on their surface. They were surrounded by an annular pad, which was formed by filiform papillae with conical tip. Numerous openings of barrel-shaped taste buds were present in the epithelium covering the surface of fungiform papillae, and in the epithelium of inner walls of the vallate papillae. The serous von Ebner`s glands were located beneath the vallate papillae. The mucoserous Weber`s glands were PAS, AB pH2.5, pH1.0 and AB/PAS positive and HDI-weakly positive.

1. Introduction

The aardvark (*Orycteropus afer* Pallas, 1766) is a large myrmecophagous mammal native to Africa (Shoshani et al., 1988; Kingdon, 1997; Taylor et al., 2002; Stetter, 2003; Taylor and Skinner, 2003, 2004; Tabruce et al. 2008, Patoka et al., 2018). Aardvarks are the only living members of the Tubulidentata order (Lehmann et al., 2004; Lehmann, 2007, 2008, 2009). According to the IUNC Red List of Threatened Species, the aardvark belongs to the "least concern species" (Version 2017-3 < www.iucnredlist.org >). Based on its lifestyle, it is sometimes called an "earth pig" (Knöthig, 2005; Feldhamer et al., 2015). Aardvarks are active at night and usually live alone (Melton, 1976; Feldhamer et al., 2015). It is difficult to observe their natural habitat as they dig underground burrows where they spend most of their time (Endo et al., 2002; Rey et al., 2017). The burrow digging of the aardvark, used inter alia to find food, is quite efficient due to its morphological traits (Endo et al., 2002; Endo et al., 2003; Endo et al., 2013; Kingdon et al., 2013; Wible, 2012; McKusick, 2014). The aardvark diet may vary depending on the season and consists mainly of ants and termites as well as pupae of scarabaeid beetles (Melton, 1976; Taylor et al., 2002; Skinner and Chimimba, 2006). Due to its type of diet, the aardvark was thought to be closely related to members of the Vermilingua suborder, such as the giant anteater (*Myrmecophaga tridactyla*). However, this has been disproven based on filogenetic studies (Melton, 1976; Dene et al., 1983; Hallström et al., 2007; Davit-Béal et al., 2009). The "living fossil" aardvark was found to belong to a completely different order than the giant anteater (Romer, 1938; Reiss, 2001; Pickford, 2003, 2005; Whittington-Jones et al., 2011; Pohlová et al., 2014; Patoka et al. 2018). The aardvark is most closely related to elephants, manatees, elephant shrews, hyraxes, dugongs, tenrecs and golden moles from Afrotheria clad of mammals (Dene et al., 1983; Springer et al., 1997; Hallström et al., 2007; Davit-Béal et al., 2009; Taylor, 2013). Aardvarks have a very well developed sense of smell (Skinner and Chimimba, 2006), and they have a specialized long tongue coated with strongly adhesive saliva in order to facilitate food intake (small insects) (Bender 1909; Sonntag, 1923; Sonntag, 1925, Beidler, 1971; Kingdon, 1971). An individual animal may eat up to 50 000 insects in one night (Kingdon, 1971; Davit-Béal et al., 2009). Another feature of the dietary adaptation of the aardvark is its well-developed single-chamber gizzard-like stomach which enables grinding up the food ingested with sand and soil (Kingdon, 1971, Buss and Meyer, 2014, Langer, 2017). Interestingly, the aardvark diet also contains the aardvark cucumber *Cucumis humifructus* (Skinner and Chimimba, 2006). In most mammals, the masticatory muscles play a key role in

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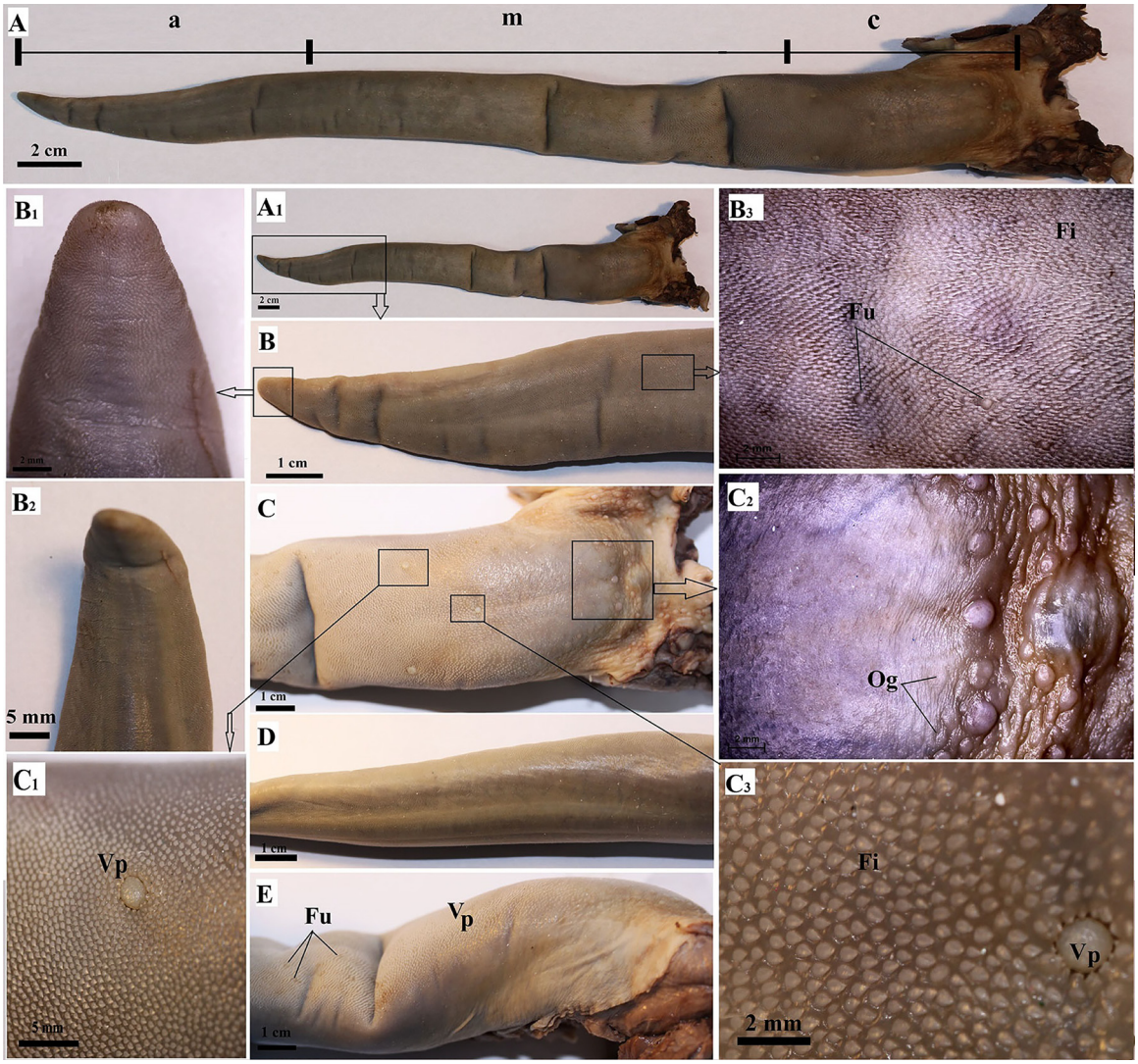

Fig. 1. Macroscopic view of the adult aardvark (*Orycteropus afer*) tongue. **A.** division into three parts: the apex, the body and the root. Bar = 2 cm. **A_1.** Bar = 2 cm. **B.** apex of the tongue. Bar = 1 cm. **B_1.** dorsal surface of the apex of the tongue. Bar = 2 mm. **B_2.** ventral surface of the apex of the tongue. Bar = 5 mm. **B_3.** magnification of the dorsal surface of the body of the tongue. Bar = 2 mm. **C.** magnification of the surface of the root of the tongue. Bar = 1 cm. **C_1.** magnification of the lateral vallate papilla. Bar = 5 mm. **C_2.** magnification of the dorsal surface of the root of the tongue with openings of the lingual glands. Bar = 2 mm. **C_3.** magnification of the central vallate papilla. Bar = 2 mm. **D.** lateral view of the body of the tongue. Bar = 1 cm. **E.** lateral view of the root of the tongue. Bar = 1 cm. *Abbreviations*: a- apex of the tongue, c- root of the tongue, Fi- filiform papilla, Fu- fungiform papilla, m- body of the tongue, Og- opening of the lingual glands, Vp- vallate papilla.

food processing alongside the tongue by facilitating the elevation and anteromedial movements of the mandible and teeth, enabling preliminary food grinding (Naples, 1999). The well developed tongue muscles that include intrinsic muscles and extrinsic muscles, are responsible for tongue protrusion and retraction and its shape changes. They also facilitate the intake of food and sound emission (Sonntag, 1925; Saito and Itoh, 2003; Sanders and Liencai, 2013). Aardvarks "chew" their food although their dentition is atypical as the teeth do not have roots or enamel (Skinner and Chimimba, 2006; Feldhamer et al., 2015). Animals that eat ants and termites include the pangolin, which also has an elongated tongue (Kubota et al., 1962; Doran and Allbrook, 1973; Abayomi et al., 2009; Adeniyi, 2010) or the armadillo (de Morais et al., 1994, Ciuccio et al., 2010). To date, detailed histologic and ultrastructural studies carried out on the tongues of members of the Vermilingua suborder include the giant anteater (*Myrmecophaga tridactyla*), the southern tamandua (*Tamandua tetradactyla*) and the pygmy anteater (*Cyclopes didactylus*) (Casali et al., 2017). Those studies also compared the tongue structure of mammals from the Vermilingua order and chosen members of the Cingulata order, including the nine-banded armadillo (*Dasypus novemcinctus*), the southern naked-tailed armadillo (*Cabassous unicinctus*), the Brazilian lesser long-nosed armadillo (*Dasypus septemcinctus*) and the yellow armadillo (*Euphractus sexcinctus*) (Casali et al., 2017). According to the current anatomical nomenclature, the tongue consists of an apex (*apex linguae*), body (*corpus linguae*) and root (*radix linguae*) (Nomina Anatomica Veterinaria, 2017). Due to lack of histologic and histochemical studies of the aardvark tongue, the aim of the present study was to characterise this organ in young and adult aardvarks using these methods. In addition, there was a comparison between the structure of the tongue between young and adult aardvarks, the tongue microstructure of the aardvark and other members of the Afrotheria clad of mammals, and the tongue structure of animals with a myrmecophagous diet and those with other diets.

2. Materials and methods

2.1. Animals

The study material was collected from three aardvarks from the