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ORIGINAL ARTICLE

Histomorphological study on the tongue of the duck in the Caribbean with relation to feeding habit

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ABSTRACT

Objective: The objective of this study was to give detailed descriptions of the morphological and histological structures of the tongue of the Muscovy duck as it relates to their feeding habit.

Materials and Methods: Ten adult Muscovy ducks weighing 2–4 kg were used. The ducks were slaughtered and their oral cavities were opened to detect *in situ* position of the tongues. Each tongue was dissected and examined grossly. Samples of various parts of the tongue were taken for routine histological examination.

Results: The tongue of the Muscovy ducks was distinguished grossly as the apex, body, and root. A dorsal median sulcus, conical papillae, and lingual prominence were observed grossly. Microscopic observations showed the tongue of the Muscovy duck was covered by stratified squamous epithelium; keratinized and non-keratinized. The lamina propria of the tongue contained lingual glands, entoglossum cartilage, lymphoid nodules, as well as blood vessels and nerves.

Conclusion: The morphological and histological variations of the tongue of the Muscovy duck may infer that its unique structures are related to their feeding habits.

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KEYWORDS

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Introduction

Muscovy duck (*Cairina moschata*) belongs to the genus Cairina, descended from wild ducks of central and South America [1]. According to the most economic importance to the least, the birds are classified as fowl, duck, goose, turkey, pigeon, and guinea, respectively [2]. Duck meat is important as a supplement of protein in rural communities in the Caribbean island of Trinidad and other developing countries. Ducks are raised either in a semi-enclosed system or in a free-range system alongside domestic fowls. They are highly adapted to scavenging environmental conditions as a source of food. They forage for a diet of seeds, invertebrates, water fleas, and grasses. Birds have various feeding habits in relation to the versatility of the tongue structures. According to Harrison [3], there are three main groups of tongues which depends upon the structural adaptations of the tongues which enhance their performance; tongues that are used to catch and intake food, tongues with plenty firm papillae on their dorsal surface used to hold and manipulate the food, and tongues that retain the food in the oral cavity before swallowing. Schwenk [4] stated that feeding is a complex process in vertebrates and includes ingestion, intraoral transport, and swallowing. The tongue is a muscular organ which is situated on the floor of the oral cavity and acts as the primary organ of taste as it is covered with papillae and taste buds [5]. Many studies on the lingual structure were done in domestic duck [6], Muscovy duck [7], white-headed duck [8], pati duck [8], turkey [9], quail [10], ostrich [11], Japanese Quails [12], White-tailed eagle [13], woodpecker [14], little tern [15], cormorant [16], and falcon and kestrel [17]. As duck production is becoming increasingly popular in Trinidad and is in high demand by the local populace and is utilized almost exclusively in the restaurant trade,

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the understanding of ducks' food habit can help in the rearing of these ducks for business purposes. Therefore, the current study was aimed to investigate the detailed anatomical and histological structures of the tongue of the adult Muscovy duck, including the lingual papillae and lingual glands.

Materials and Methods

This study has been conducted with the ducks, according to the international ethical standard, by giving minimum pain to the bird. A total of 10 adult apparently healthy Muscovy ducks (*Cairina moschata*) irrespective of sex, weighing 2–4 kg were used in the study. They were collected from local farms in Trinidad. The ducks were slaughtered by cutting the blood vessels of the neck and the heads were washed thoroughly with water to remove any trace of blood. The heads were then left in a 10% neutral buffered formalin solution for 48 h for fixation. After fixation, the heads were rinsed in running tap water and then the oral cavity was carefully opened by making incisions at the right and left commissures of the beak followed by the reflection of the mandible ventrally by disarticulating the quadratomandibular joints. The topographic position of the tongue *in situ* was observed and photographed. The tongue was carefully removed from the oropharyngeal floor by cutting the peripheral tissue, including the frenulum linguae and by cutting through the ceratobranchials. The anatomical structure of the tongue was examined and gross photographs were taken using a digital camera (Sony 12 MP). After removal of the tongues, they were washed with water to remove any blood or food particles. Samples from the tongues including its apex, body with lingual prominence, and root were taken and left in a 10% neutral buffered formalin for 24 h for fixation, then the samples were dehydrated using ethanol, followed by clearing in xylene and then impregnated with soft paraffin and left to harden to obtain paraffin blocks. The blocks were then cut serially into thin sections of about 5–7 µm. thick using a microtome and then mounted on dry, clean glass slides. The slides were stained with Harris hematoxylin and eosin (H&E) stain as outlined by Drury and Wallington [18] and then examined under a light microscope. Nomina Anatomica Avium that was proposed by Baumel et al. [19] was used for the nomenclature of the structure of the tongue.

Results

Gross observations

The tongue of the Muscovy duck was narrow and elongated and it consisted of the root, the body with a lingual prominence, and the apex with the free tip. The tongue occupied the rostral part of the oropharyngeal floor without extending to the free tip of the bottom of the bill, rostrally (Fig. 1). The tongue apex was smooth and non papillated on its dorsal surface and was shovel-shaped. The body of the tongue was attached to the lower bill by the wide frenulum linguae. It had a prominent median groove on its dorsal surface. The lateral margins of the body had mechanical papillae with different sizes and shapes. The rostral half of the lateral margins of the tongue body had numerous small, long, brush-like horny conical papillae. While the conical papillae in the caudal half of the side edges of the tongue body were few, broader, with a flattened plate shape and serrated edges with small thread-like papillae inbetween. The base of the tongue had a triangular, bell-shaped lingual prominence dorsally, which was an elevated area, with rostral serrated edges and it is divided by the median groove into two symmetrical parts. The conical papillae situated caudal to the lingual prominence were arranged into two rows. They were directed obliquely and caudally marking the caudal border of the tongue. The smallest part of the tongue was its root which was situated just caudally and below the base of the tongue with its laryngeal prominence. There were two lateral mucosal swellings which were rounded papillae with spinal processes resembling filiform papillae. The two swellings were separated by a median ridge, which extended from the tongue base towards the laryngeal mound (Figs. 2 and 3). The ventral aspect of the tongue apex had the lingual nail which appeared as a flat wide triangular plate, whose its edges were the mucosa eminences projecting out to the sides and front. The mucosal eminences started at the tongue tip and extended caudally to terminate just rostral to the frenulum linguae. The skeleton of the tongue of the Muscovy ducks was formed by the paraglossal bone and paraglossal cartilage (Fig. 4).

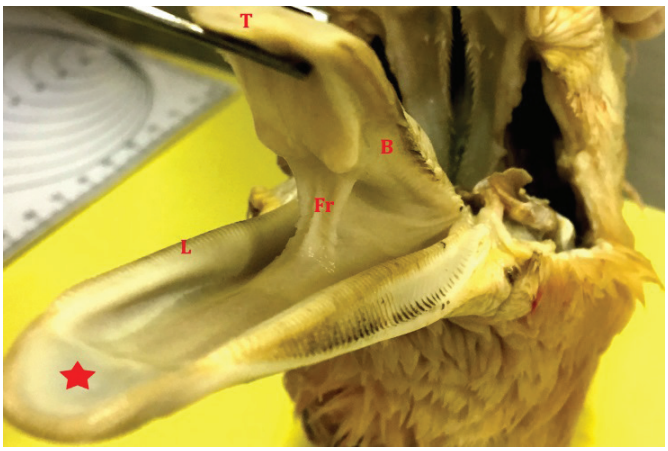

Figure 1. Photograph showing the ventral surface of the tongue and the lower beak in the Muscovy duck. Note the free tip of the lower beak (Star), tip of the tongue (T), body of the tongue (B), frenulum linguae (Fr), and lamellae of the bill (L)

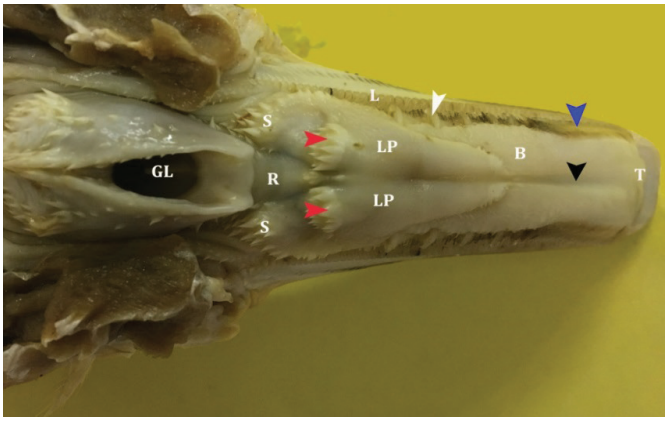

Figure 2. Photograph showing the floor of the oropharynx in the Muscovy duck. Note the tip of the tongue (T), body of the tongue (B), lamellae of the bill (L), lingual prominence (LP), mucosal swellings (S), median ridge (R), glottis (GL), median lingual sulcus (Black arrowhead), conical papillae on the caudal border of the lingual prominence (Red arrowheads), small conical papillae (Blue arrowhead), and large conical papillae (White arrowhead).

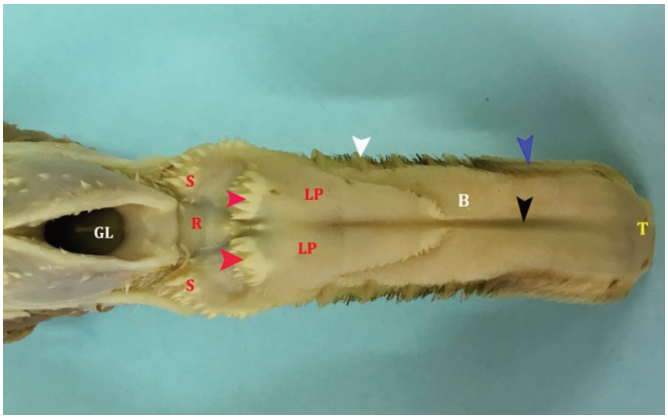

Figure 3. Photograph showing the tongue of the Muscovy duck. Note the tip of the tongue (T), body of the tongue (B), lingual prominence (LP), mucosal swellings (S), median ridge (R), GL, median lingual sulcus (Black arrowhead), conical papillae on the caudal border of the lingual prominence (Red arrowheads), small conical papillae (Blue arrowhead), and large conical papillae (White arrowhead).

Microscopic observations

The microscopic study of the tongue of the Muscovy ducks under investigation indicated that there was epithelial lining that covering the lamina propria (LP) containing lingual mucous glands, lymphoid nodules, blood vessels, and nerves, as well as a core of paraglossum and associated striated muscles. On the ventral surface of the rostral part of the tongue, the epithelium lining appeared orthokeratinized and

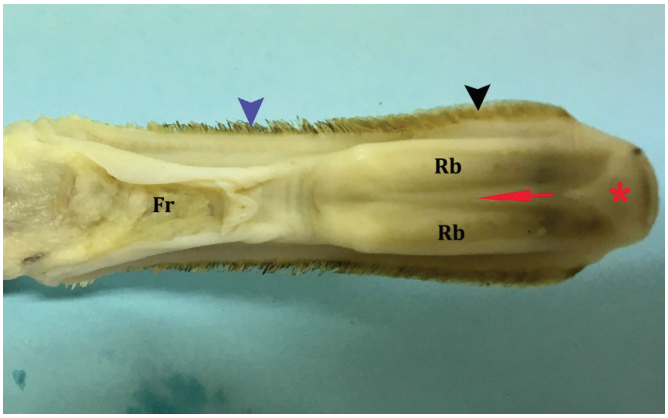

Figure 4. Photograph of the ventral aspect of the tongue of the Muscovy duck. Note the Asterisk and red horizontal arrow show the apex of the tongue and its extension, rectangular body halves (Rb), attachment site of the frenulum linguae (FR), small conical papillae (Black arrowhead), and large conical papillae (Blue arrowhead).

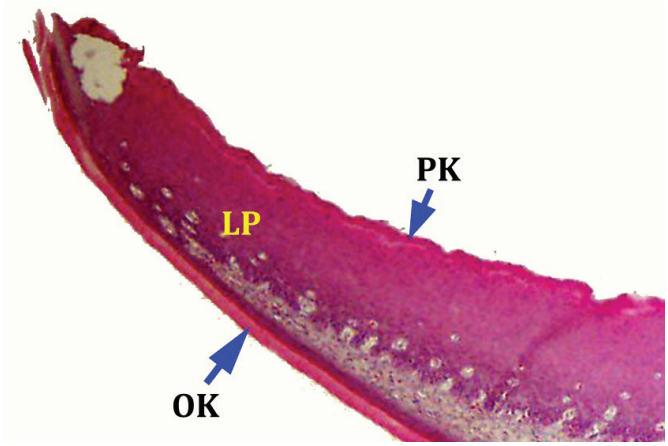

Figure 5. Photomicrograph of a longitudinal section of the lingual apex of the Muscovy duck. Note the parakeratinized epithelium in the dorsal surface (PK), in the ventral surface (lingual nail-OK) and lamina propria (LP). H&E stain.

was covered by three layers of cornified squamous cells; the basal, intermediate, and keratinized layers forming a lingual nail (Fig. 5). Also, parakeratinized epithelium with the same three layers was seen on the dorsum of the tongue. The dorsal and ventral surfaces of the root of the tongue and some areas on the lingual prominence were lined by non-keratinized stratified squamous epithelium. The dorsal marginal epithelium appears thicker than the ventral one. A dense irregular richly vascularized fibrous connective tissue (CT) was found underneath the epithelium of the dorsal and ventral surfaces of the tongue body which penetrated the layers of the epithelium in the form of connective tissue papillae

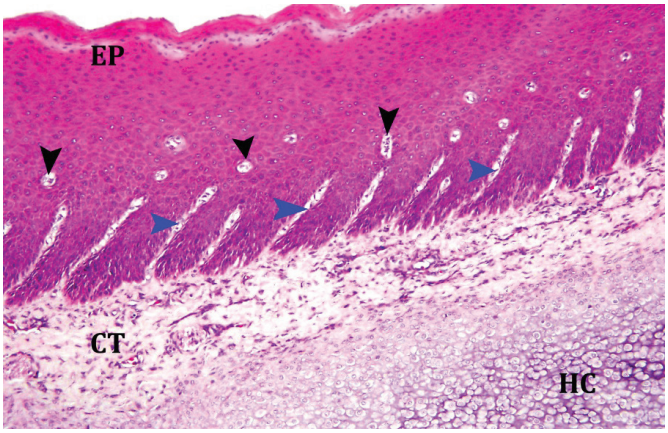

Figure 6. Photomicrograph showing the parakeratinized epithelium (EP) on the dorsal surface of the apex of the tongue of the Muscovy duck. Note the intraepithelial taste buds (Black arrowheads), CT papillae (Blue arrowheads), subepithelial CT, and hyaline cartilage (HC). H&E stain.

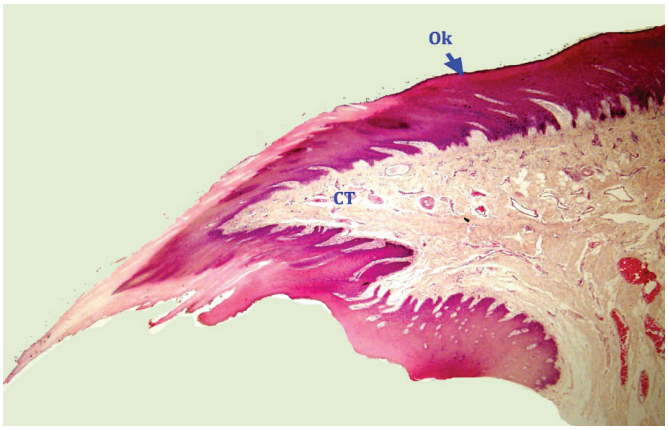

Figure 7. Photomicrograph of the conical papillae of the tongue of the Muscovy duck. Note the OK and CT core. H&E stain.

(Figs. 6 and 7). On the dorsal surface of the rostral part of the tongue, intraepithelial taste buds were seen within its epithelium (Fig. 6). The lingual conical papillae were seen as epithelial evaginations with CT cores emanating from the lateral margins of the body of the tongue. The epithelial covering of these papillae was orthokeratinized epithelium (OK) with its three layers (Fig. 7). Lymphoid nodules were scattered in the CT LP of the tongue body which constituted of a component of the gut-associated lymphoid tissues (GALT) of avian oropharynx for immune response (Fig. 8). The lingual glands were seen as complex and numerous tubular mucous glands situated along the tongue, except at its apex. They were located within the LP right under the

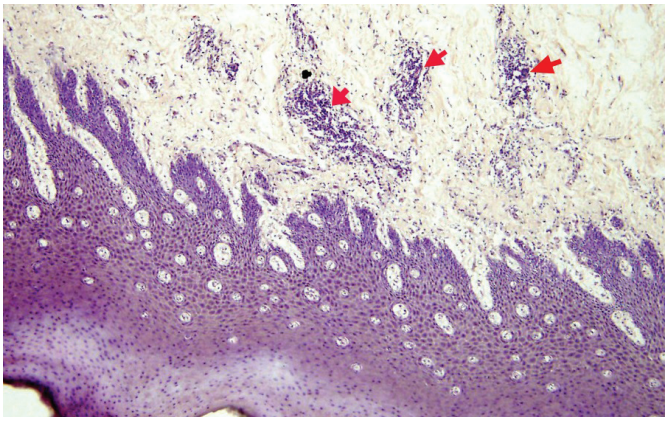

Figure 8. Photomicrograph of the ventral surface of the body of the tongue of the Muscovy duck showing the scattered lymphoid nodules (Red arrows) H&E stain.

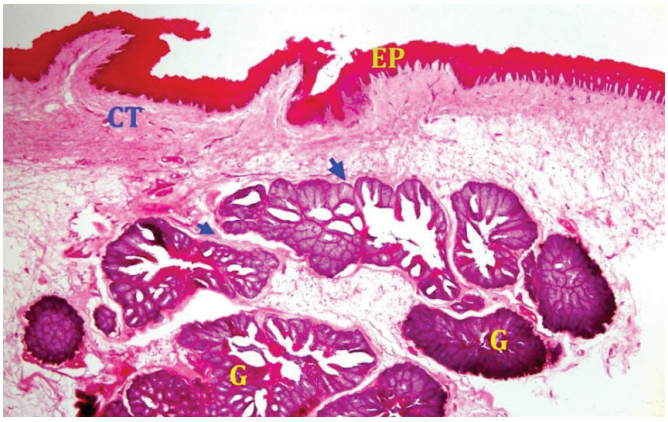

Figure 9. Photomicrograph of the body of the tongue of the Muscovy duck showing the stratified squamous epithelium (EP) and lingual glands (G). Note the sub-epithelial CT and CT sheaths (Blue arrows). H&E stain.

epithelial structures of the tongue. The secretory units, the glandular acinus, of the lingual glands were organized as lobules encapsulated by fine, fibrous and loose CT layers. Each secretory unit was made of mucous-secreting cells. The cytoplasm of the secreting cells appeared as lightly stained whereas the nuclei appeared dark and basally situated. The lingual glands were seen to have short excretory ducts and a wide storage chamber. The entoglossum cartilage was present within the core of the caudal part of the tongue (Figs. 9 and 10).

Discussion

The principal action of the tongue during feeding by birds is sieving in ducks, spearing in woodpeckers, brushing in

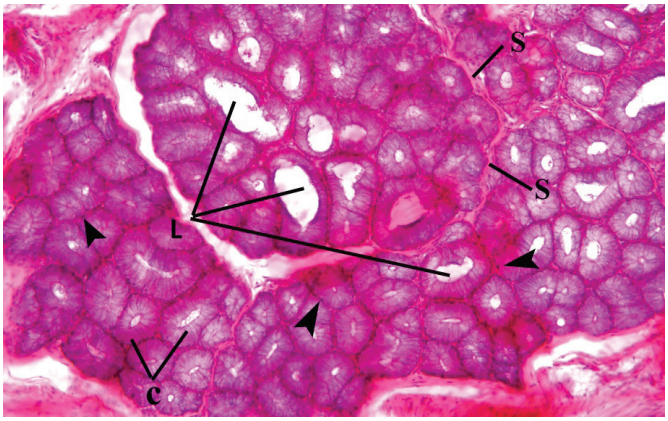

Figure 10. Photomicrograph showing the structures of the lingual glands of the tongue of the Muscovy duck. Note the lumen of acinus (L), cytoplasm (C), nucleus (Black arrowheads), and CT sheath (S). H&E stain.

Trichglossidae, capillary tubing in sunbirds, and rasping in vulture [20]. Therefore, the structure of a bird's tongue is related to their different feeding habits, habitats, and different lifestyles on the land, in the air, as well as around fresh and sea waters [17]. It is adapted for pecking, manipulating, filtering, and swallowing of the food [21,22]. Likewise, Van der Leeuw et al. [23] and Baussart and Bels [24] reported that the food collection behavior in members of Anseriformes is pecking, grazing, and filter-feeding.

The current work under discussion revealed that the tongue of the Muscovy ducks consisted of the root, body with lingual prominence, and apex. The lingual body was differentiated from the root by two rows of conical papillae; similar result was mentioned in other birds [25], in Anas crecca [26] and in mute swan [27]. The tongue in pati duck consists of root, body, tip, raised area, and a line like extension [8].

The tongue of the Muscovy ducks filled the oropharyngeal floor, except the free tip of the bottom of the bill, rostrally similar to that given by Igwebuike and Anagor [7] in Muscovy duck, Abdalla et al. [28] in the duck, Mohamed [10] in quails, Abd El-Fatah et al. [9] in turkey, and Koch [29] in fish eaters birds. However, Nickel et al. [2] mentioned that the tongue fills the oral cavity completely in lamellirosters (duck and goose).

The current investigation revealed that the tongue of the Muscovy duck was long, broad with shovel-shaped tip situated on the rostral part of the floor of the oropharyngeal cavity which indicated that the tongue was adapted for prehension and transportation of food; similar to that reported by Igwebuike and Anagor [7] in Muscovy duck and Akbari et al. [30] in white-headed duck. However, the tongue of the fowl is broad and shorter than the length of the lower beak. On the other hand, the tongue of laughing dove is thin and triangular in shape with a pointed tip [31]. The magpie has an elongated tongue with the oval-shaped fissured apex [32]. The tongue of the Egretta ibis is long with a sharp apex at its end and in Gallus gallus is short and triangular shaped with a flat base [33]. Igwebuike and Eze [34] stated that the rostral part of the tongue is free and can protrude out of the oropharyngeal cavity in the African pied crow.

The observations in this study were similar to that of Igwebuike and Anagor [7] in Muscovy duck, Akbari et al. [30] in white-headed duck, El Bakary et al. [26] in Anas crecca, and Sridevi et al. [27] in mute swan that the base of the tongue of the Muscovy duck was formed by the unique dorsal elevation; the lingual prominence. Moreover, it was recorded in our study that the movement of the lingual prominence against the palate may assist in the process of swallowing by pushing the food caudally; the same findings were also in fowl and duck [28,35,36] and in pati duck [8].

The obtained results were parallel to those described in Muscovy duck [7], in duck [28], in pati duck [8], in domestic duck [6], in white-headed duck [30], in quails [10], in domestic pigeon [37], in mute swan [27], in Anas crecca [26], and in laughing dove [31,38] that the median lingual sulcus was detected on the dorsal aspect of the tongue in the Muscovy duck. However, Jackowiak et al. [16] stated that the tongue of cormorant has a medial sacral crest in its dorsal surface. On the other hand, Abd-Elmohdy [39] mentioned that the median groove in the tongue of Hawk is shallow. Iwasaki and Kobayashi [12] and Jackowiak et al. [40] in pheasants, chickens, white-tailed eagles and penguins, as well as Igwebuike and Eze [34] in African pied crow mentioned that the lingual sulcus is absent.

The obtained results reported that the lateral and dorsal margins of the tongue of the Muscovy ducks had many lingual papillae and their functions depended on their location. The papillae which were situated on the side edges of the tongue were numerous, long, brush-like horny conical papillae which may work along with the horny lamellae on the lateral margins of the upper and lower beaks to act as a sieve to filter the food particles immersed in the water and the remaining water is discarded via the slit between the two beaks; a result which was in a line with that obtained by Igwebuike and Anagor [7] in Muscovy duck, Skieresz-Szewczyk and Jackowiak [41] in domestic duck, Akbari et al. [30] in white-headed duck, and El Bakary et al. [26] in Anas crecca. Moreover, The Muscovy duck can feed by grazing which entails grabbing and dragging of the grass between the beaks then tearing the leaves using the bottom beak lamellae and large caudal conical papillae on the side edges of the tongue; similar result was mentioned by Skieresz-Szewczyk and Jackowiak [41] in domestic duck, Van der Leeuw et al. [23] in Anseriformes, and Akbari et al. [30] in white-headed duck. Taki-El-Deen [42] stated that the tongue of whimbrel has no lingual papillae.

The conical papillae situated caudal to the lingual prominence were arranged into two rows, a result which was in a line with that obtained by Abdalla [43] in duck, Sarma and Deka [8] in pati duck, Abd-Elmohdy [39] and Mohamed [10] in quail and hawk, and Sridevi et al. [27] in mute swan. However, they are arranged in one transverse row in Muscovy duck [7], in chicken, turkey and pigeon [9,29,43,44], and in goose [45]. While they are arranged in a V-shaped in white-tailed eagle [13] and in a U-shaped arrangement in the domestic pigeon [37]. On the other hand, the caudal papillae are absent in ostrich [11,46] and in Japanese Pygmy Woodpecker [14]. Erdogan and Alan [32] in magpie and raven stated that there was a backward pointed conical papillary crest between the body and root of the tongue. Moreover, these papillae may serve the functions of transportation and swallowing of the food and prevent food regurgitation, similar to that reported by Igwebuike and Anagor [7] in Muscovy duck, Abdalla et al. [28] in duck, Sarma and Deka [8] in pati duck, and Parchami and Dehkordi [37] in domestic pigeon.

The tip of the tongue and its lingual nail in the Muscovy duck can act as a spoon which will help in grains collection; similar result was recorded in white-headed duck [30], in domestic duck [41], in domestic goose [47], and in Anas crecca [26].

The current study observed that the ventral aspect of the tongue of the Muscovy duck was characterized by the presence of two ventral mucosal eminences which started at the tongue tip and extended caudal to terminate just rostral to the frenulum linguae, similar to that reported by Abdalla et al. [28] in duck, Sarma and Deka [8] in pati duck, and Sridevi et al. [27] in mute swan. However, the two mucosal fold in the tongue of fowl and duck form the ventral papillae in its mid-region ventrally [35].

These results were also similar to that of Iwasaki [15,48] in vertebrae, Al-Zahaby and ElSheikh [49] in common kingfisher and in Anas crecca [26] in that there was a relationship between feeding habit and keratinization degree of the lingual epithelium which is higher in herbivorous birds than in aquatic birds. Since the lingual nail was covered by OK in its ventral surface, the Muscovy duck can use it as a spoon for lifting the grains and also was flexible enough to collect the food as its dorsal surface was covered by parakeratinized epithelium; similar result was mentioned in white-headed duck [30], in domestic duck [41], in the African pied crow [34], and in domestic goose [47]. However, all lingual mucosa covers non-keratinized stratified epithelium in Muscovy duck [7], in ostrich [11], and in Emu [50]. On the other hand, the tongue has keratinized epithelium in the ventral surface and non-keratinized epithelium in the dorsal surface in white-tailed eagle [13], in domestic pigeon [37], in common pigeon [51], in laughing dove [31], and in African pied crow [34]. The lingual mucosa is covered by three layers of keratinized epithelium and the thickest horny layer is present in the median crest and posterior tip in cormorant [16]. Moreover, the current study showed that the presence of OK in the mechanical papillae is important as it is involved in the feeding process which required mechanical pressure, especially during filtration and transportation of the food, however, the root and lingual prominence were covered by non-keratinized epithelium as they had less contact with food particles surrounded by the mucous of the lingual glands; similar result was mentioned in domestic duck [41].

The lingual glands were complex glands within the LP of the tongue of the Muscovy duck; similar result was mentioned by Skieresz-Szewczyk and Jackowiak [41] and Taki-El-Deen [42] in domestic duck, Liman et al. [52] in Japanese quail, Rossi et al. [53] in partiqe, El Bakary et al. [26] in Anas crecca, Crole and Soley [50] in Emu, Parchami and Dehkordi [37] in common pigeon, Igwebuike et al. [51] in domestic pigeon, Al-Nefeiy [31] in laughing dove, and Jackowiak and Godynicki [13] in white-tailed eagle. Furthermore, the Muscovy duck can also feed on dry and semi-dry food since the complex lingual glands secrete mucous which can moisten these foods and lubricate the caudal part of the oropharynx and the initial part of the esophagus for easy swallowing. Moreover, the mucous secretion can act as a glue to stick the small food particles either with each other or with the lateral conical papillae to prevent food loss during ingestion; similar results were recorded in Muscovy duck [7], domestic duck [41], in white-headed duck [30], and in Anas crecca [26] and in ostrich [11]. Also, the lingual glands protect the tongue from dryness in Muscovy duck [7] and from coarse food and microorganisms in domestic duck [42]. On the other hand, the lingual glands are not observed in cormorant [16] and in whimbrel [42].

The tongue of the Muscovy duck had intraepithelial taste buds which indicated their ability to select food; similar result was mentioned in African pied crow [34], in common pigeon [51], and in Emu [50]. Moreover, the salt and bitter tasting are rejected by birds [54] and this should be taken into consideration during oral administration of drugs. On the other hand, the tongue of the ostrich has no taste buds [11].

The current results are in line with that observed by Crole and Soley [50] in emu and Igwebuike et al. [51] in common pigeon that the subepithelial CT contains lymphoid nodules which constitute a component of the GALT of avian oropharynx for immune response.

The tongue was supported by hyaline cartilage, the paraglossum, which firms the tongue and is the site of attachment of lingual skeletal muscles which enables voluntary control of tongue movements during collection,

transportation, and swallowing of the food, as mentioned by many previous authors.

Conclusion

The study showed that the tongue of the Muscovy duck had specific features such as a lingual nail and mechanical papillae which were covered by the orthokeratinized and parakeratinized epithelium specialized for pecking, filtration, and transportation of the food to the esophagus, as well as prohibit waste of the food from the oral cavity. Also, the lingual glands are used to secrete mucous, which helps in moistening, and gathering the food contents, and in swallowing.

Acknowledgments

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Conflict of Interest

The author declared no potential conflicts of interest with respect to the research and publication of this article.

Authors' contribution

The author collected the samples, carried out the research, wrote, and revised the manuscript.

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