ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Functional morphology of the epidermal structures of the feeding apparatus of Guinea fowl (*Numidia meleagris*)

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Manuscript Info

Manuscript History:

Received: 17 August 2015
Final Accepted: 26 September 2015
Published Online: October 2015

Key words:

Feeding Apparatus: Guinea Fowl: Epidermal Structures; Head, Beak, Tongue

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Abstract

The aim of the present study is to understand the functional role of the various epidermal structures of the feeding apparatus of the guinea fowl. The study is carried out by utilizing six adult birds of both sexes. The morphometric measurements of the different epidermal structures of the head, beak and tongue were measured and tabulated and analyzed its functional significance. All the measurements taken are slightly higher in males than the female birds. The helmet, wattles, cere and the bare skin of the head help to tackle considerable range of environmental temperatures which facilitates the guinea fowl to forage in hot conditions. A stout and thick and pointed bill, sharp tomium, smooth culmen, well developed cere, gable shaped roof and concave surface of the lingua are the adaptations for the insect and seed- eating habit in hot climatic conditions .The V shaped mucosal swelling, well-developed palatine ridges provides a grip for the closure of the beak and also it does not allow the stored seed grains to escape out. The dorsally concave, ventrally convex, cranially pointed and slimy tongue helps in picking up the food, transportation and major support in drinking. The caudally backwardly directed papillae of the tongue, the choanal cleft and pharyngeal and palatal folds help in channelizing the food, cracking the nuts and seeds and to prevent regurgitation. The results of the present study on epidermal structures of the feeding apparatus of the head, beak and tongue reflects that these structures support several behavioral activities such as food seeking, drinking, preening, picking, probing, nesting, territory fighting, etc in semi-open habitats such as savanna or semi deserts and also in forests.

INTRODUCTION

The Guinea fowl (*Numidia meleagris*) are, ground-nesting birds which are resident and locally nomadic depending upon food supply. There has been an increasing demand for guinea fowl recently due to the advantages like greater disease resistance, greater ability to scavenge for food and high meat to bone ratio (Kozaczynski, 1998) over the chicken among the small scale farmers as an alternate source of income. The increased commercial demand due to the above reasons evoked interest to understand basic role of biology of birds. A detailed investigation of the structural and behavioural adaptations of the feeding apparatus would be useful in relation to the nutritional and medical management of these birds under semi-intensive production. But most of the scientific research conducted in recent times are in the chicken and the results have extrapolated the other birds including guinea fowl.

The anatomical structures of feeding apparatus include the epidermal structures of the beak and tongue, the bones of the skull and various muscles and ligaments operating the jaws, tongue and neck. Although many recent studies have attempted to describe the morphology of the avian oropharynx and tongue (Jackowiak and Godynicki, 2005), Crole and Soley, 2008, Tivane et.al.2011 and Erodegan and Allan, 2012) specific information about the functional morphology of the epidermal structures of the feeding apparatus in the guinea fowl is yet very scanty. The objective of the present work is to understand the functional role of the various epidermal structures of the feeding apparatus in the guinea fowl.

1. MATERIAL AND METHODS

The head of six adult birds of each sex of the guinea fowl above 36 weeks of age were procured from University Poultry Research Station, Madhavaram and the slaughter houses in and around Chennai, India. The head from all these birds were collected and the epidermal structures were studied carefully with the help of stereo-zoom dissecting microscope and through photograph. Morphometrical data of various epidermal elements of the head, beak and tongue were measured in both sexes by using calipers, divider and thread. The data were statistically analyzed and presented (Table-1).

2. RESULTS AND DISCUSSION

The wide variation in the morphology of the beak and structures of the avian feeding apparatus is related to the adaptation of strategies for obtaining food, feeding methods, and different kinds of food and climate conditions (Iwasaki, 2002). The epidermal structures of the head, beak, and tongue form the main complexes of the feeding apparatus and together play a major biological role in the capture and ingestion of food. The epidermal structures of the feeding apparatus of the guinea fowl include the epidermal structures of the head, beak, and tongue.

3.1 Epidermal structure of head

The head is covered by loose, thick, highly keratinised, folded skin with greyish –white tinged in colour. The avian skin is less sensitive, poorly vascularised as in other avian species (Dyce et al., 2010). The above all features helps to protect the skin while foraging in different habitats especially the dense bushes unlike in the predator birds where the skin is soft and covered with feathers (Gill ,1995). The major division of the head includes- forehead, crown, base of head, orbital, auricular, nasal, oral, rictal, malar and submalar, interramal. The forehead is robust and triangular which extends from nasal region to crown. The robust forehead reinforces the beak at the nasal bone which may help to withstand pressures of perching on the hard grounds. The very well developed frontal ridge on the lateral margin of the forehead in the present study protects the laterally placed eyeball while foraging which is unique in the guinea fowl among the galliformes. (Nickel et al 1977).The crown region is very wide, filled with grey-blue bare skin and is topped by a prominent horn colored bony casque (helmet) in red brown colour (2.57±0.45 cm in length and 2.22±0.35 cm width in males and 2.22±0.35cm in length and 2.2± 0.24 cm width in females) which is unique in the guinea fowl. The wattles are white tinged bright red colored, rounded, fleshy at gap sides. They measure 2.4± 0.12 cm in length and 12.8± 0.35cm in width in males and 2.1± 0.13 cm in length and 11.9± 0.45cm width in females. They are cupped and convex and carried at an acute to 90-degrees angle to the side of the head and tucked (carried flat, laterally and directed vertically close to the side of the throat). The nasal region is narrow and present epidermal thickening, cere at the junction of nasal and oral region margined with feather-like bristles. The cere is well developed in males (2.27±0.01cm in length) than the females (0.96 ± 0.78 cm in length) in adults which is contrary to the reports of Prinsloo et al (2005) where the females have well developed cere than males. The helmet, wattles and the cere help to tackle considerable range of environmental temperatures through the arteriovenous networks which help the guinea fowl to forage in hot conditions (Crowe and Crowe 1979; Umosen et al., 2008).

The nasal opening is wide with fine bristles at the caudal opening opens into the choanae internally. The nasal cartilaginous operculum (0.49±0.03cm in males and 0.33±0.03 cm in females) is poorly developed. Fine bristles on the caudal border of the nasal opening may help to keep the dust out while foraging in dusty habitats unlike in diving birds, where the operculum is well developed and keeps water out of the nasal cavity (Gill, 1995).

The craniofacial angle is short and establishes the bending zone across the region of junction of the nasal and premaxillary bones by skeletal mechanism. A craniofacial hinge angle is less (average 22°) than 90 degrees that provide prokinetic condition to the upper jaw in the guinea fowl like pigeons (Bock, 1964; Zusi, 1967).

The rictal (oral commissure) region is a simple dark red colored, thick epidermal fold extending along the edge of the jaws and has a mouth opening slit and devoid of bristles. The rictal bristles are characteristic of the insectivorous birds (Conover and Don 1980) which is suggested to function as a "net", helping in the capture of flying prey and may prevent particles from striking the eyes. This feature is not observed in the present study which could be possible due to the location of the eyes far away from the rictal commissure. The submalar region is relatively wide (2.40±0.36 cm diameter in males and 2.03±0.05cm diameter in females) and long (2.52±0.27cm length in males and 2.09±0.44cm length in females, which indicates that they can accommodate large volume of food while foraging.

3.2 Epidermal structure of beak (rostrum)

The beak is hard, rigid, horny covered non feathered integument and is made up of upper (maxillary rostrum) and lower beak (mandibular rostrum). The upper one is longer (3.95±0.03 cm in males and 3.66±0.02 in females) than the lower beak (3.73±0.08 in males and 3.43±0.09cm in females). There is no gap existing between the two arms of the beak when kept closed. The upper beak is short within a total of length of crown to beak tip (9.15±0.13cm in males and 9.13±0.13in females); Since the guinea fowl is primarily feeding on insects, grains and seeds pecked from the ground they do not require any massive or elongated beak for pecking and grasping their food grain. However, quite often these birds invade other food niches for which their beak and tongue epidermal structures have been suitably modified. The beak also helps in drinking, preening, picking, probing, nesting, territory fighting (Ushakumary et al, 2011). The outer surface of the beak consists of a thin horny sheath of keratin called the rhamphotheca, which is subdivided into the rhinotheca of the upper mandible and the gnathotheca of the lower mandible.

The upper beak is stout, thick and pointed. The rhinotheca extends in a hook beyond that of the lower beak. The upper beak can be differentiated in to the *base*, more or less curved *point* or dertrum, the *dorsum*, the *lateral surfaces*, the sharp edge or *upper tomium.* The base extends dorsally up to the caudal margin of nasal opening and laterally till quadratojugal bone. The *point* of the upper beak is of different texture and forms a sharp horny plate like finger nail. The culmen, the dorsal ridge of the upper beak is long (1.74±0.02 cm in males and 1.35±0.01cm in females) extends cranially up to the symphysis and bifurcate caudally towards the cere. The upper tomium is very sharp. The stout and thick upper beak is useful in scratching the soil and handling the hard coats of the seeds. The stout and pointed tip helps the birds in picking and holding the food grains and prevents the food from slipping. Thick and moderate toughness of the beak is an adaptation to tolerate the force while scratching the soil and probing. The smooth and keratinized culmen of upper beak also ensure the effectiveness of scratching and probing. The sharp upper tomium manipulate the seed and helpful in scraping the viscous food from the ground (Soni, 1982).

The lower beak is hard and thick extends up to whole length of mandible. The lower beak is made up of *point*, the *angle*, the *rami*, and the edge or *lower tomium.* It forms the oropharyngeal floor. The gony, the ventral ridge of the lower mandible, created by the junction of the bone's two rami is small (0.98±0.01cm in males and 0.76±0.024in females) and gable shape. The mentum is smooth, wide and continuous caudally with the submalar region which may be suggested that the guinea fowl can store the food transiently in the mentum.The lower tomium is round and slightly sharp cranially and blunt caudally.

3.3 Epidermal structures of the oropharyngeal cavity

The oropharyngeal cavity is dorso-ventrally flattened and the hard palate forms the roof whereas the floor is formed by the mandible, tongue and the laryngeal mound. The palate presents a broad V-shaped mucosal swelling at the anterior tip in the present study which has not reported in other birds (Jackowiak and Godynicki, 2005, Crole and Soley, 2011, Tivane et.al.2011 and Erodegan and Allan, 2012). The two arms of the V- shaped mucosal swelling extended caudally to mark the lateral boundaries of the rostral 1/3 of the palate. A groove is formed between the mucosal swelling and the ridges of the upper beak to house the lower tomium in the closed beak. A median palatine ridge is situated in the median plane, and separated the left and right arms of the V shaped mucosal swelling. Caudally the median palatine ridge runs into the choanal region bifurcated the right and left lateral palatine ridges. In the rhea (Gussekloo, 2006), emu (Crole and Soley, 2011) and ostrich (Tivane et al, 2011) only a prominent median palatine ridge is present and the lateral palatine ridges are absent. The median palatine and lateral palatine ridges occur in grainivorous passerines, and in most seed-eating passerines (Soni, 1982). Since the guinea fowl are mainly grainy and seed eater, the well-developed epidermal structures support in their fooding habits. The provision of the V shaped mucus swelling on the roof of buccal cavity can house the lower tomium; such an arrangement provides a grip for the closure of the beak and also it does not allow the stored seed grains to escape out. A groove occurs between the lateral palatine ridges and tomium of the beak also helps to grip the closure in the Guinea fowl as stated by Ziswiller (1965) in birds.

The palate presents a long median cleft /choanal slit (0.85±0.34 cm in males and 0.70±0.37cm in females) that connects the nasal cavity. It extended from the middle to the caudal aspects of the palate. The choanal slit is long and is divided into two parts viz. a narrow tubular rostral part (0.65±0.34 cm in males and 0.55±0.37cm in females) and a broad caudal portion (0.20±0.14 cm in males and 0.15±0.65 cm in females) which is comparable to the choana of ostrich (Tivane et al., 2011), bustards (Bailey et al., 1997) but differs from that of chicken (King and McLelland, 1989) where both parts are separated. The lumen of the choanal slit was partially demarcated into left and right compartments by a median ridge cranially. The ridges of the slit possess well developed sharp mechanical papillae. The para-median rows of caudally directed mechanical papillae occur on the palatine mucosal surface between the choanal slit and the lateral palatine edges. There are five to six rows of papillae on the left and right sides. The most caudal row of papillae contained densely arranged papillae that were large and prominent. Several barely visible openings seen in between the rows of the papillae. These papillae are typical in most avian species (McLelland, 1979; Igwebuike and Eze, 2010), but are absent in the rhea (Gussekloo and Bout, 2005) and ostrich (Tivane et al., 2011).The conical papillae present on the margins of the choanal cleft may serve to protect the choanal entrance (Malhotra, 1968). The caudally pointed conical papillae on the mucosal surface of the hard palate are thought to aid in unidirectional movement of food bolus towards the pharynx. The palatal folds and the spiny outgrowths of the epidermis help in holding the food as well as transporting it towards the gullets (Dubale and Thomas, 1978).

The floor of the mouth is a ditch-like depression between the rami of the lower beak, which accommodates the tongue. There are two lateral notches caudally present where the epidermal lining thrown into a number of enfolding called frenulum linguae to hold the tongue. The gable shaped oropharyngeal floor and concave surface of the tongue provide storage space for the transport of food towards the esophagus.

3.4 Epidermal structure of Lingua:

The shape of the tongue in birds is characteristically related to the form of the lower beak and feeding habits of the particular species. The tongue of the guinea fowl is relatively small (1.54±0.13cm length in males and 1.43±0.13cm length in females) and 0.73±0.03 cm width in males 0.75±0.02 cm width in females), triangular. The tongue is hard, concave and non protrusible and does not extend to the full limit of the lower beak which is similar to the chicken (Iwasaki and Kobayashi, 1986), quail (Parchami et al., 2010) and white-tailed eagle (Jackowiak and Godynicki, 2005). The dorsally concave, ventrally convex, cranially pointed and slimy tongue helps the beak in picking up the food and also playing a major role in drinking water. The tongue of the Guinea fowl lacks a median sulcus on its dorsal surface which is reported to be prominent in the white-tailed eagle (Jackowiak and Godynicki, 2005), black kite (Emura, 2008), nutcracker (Jackowiak et al., 2010) and goose (Hassan et al., 2010).

A "V" shaped transverse row of caudally pointed conical papillae demarcated the body and base of the tongue. The body appeared arrow-shaped and lacked lingual papillae whereas the lateral margins of the base exhibited prominent conical lingual papillae of various sizes. Likewise, V shaped arrangement of the papillary crest is observed in the partridge (Erdogan et al., 2012b), whitetailed eagle (Jackowiak and Godynicki, 2005), quail (Parchami et al., 2010a) and goose (Hassan et al., 2010), but not in the African pied crow (Igwebuike and Eze, 2010) and raven (Erdogan and Alan, 2012). The papillae help in transportation of food towards the esophagus during linear movements of the tongue and prevents regurgitation which is an adaptation of tongue for swallowing (Gardener, 1926).

Table.1. Morphometric data of epidermal structures of the rostral head, beak and tongue of the Guinea fowl

Name of epidermal elements	**Male (cm)**	**Female (cm)**
Mean Body weight (gm)	1400 ± 030	1280 ± 040
Length of the helmet(HL)	2.6 ± 0.04	2.22±0.35
Width of the helmet (HW)	2.8± 0.36	2.2± 0.24
Length of the wattle (WL)	2.4± 0.12	2.1± 0.13
Width of the wattle (WW)	12.8± 0.35	11.9± 0.45
Length of cere (CL)	2.27±0.01	0.96 ± 0.78
Length of nasal operculum (OL)	0.49±0.03	0.33±0.03
Length of the rictus commissure to crown (RCCL)	3.90±0.07	3.65±0.05
Length of rictus commissure (RCL)	3.53±0.04	3.31± 0.04
Length of submalar region(SML)	2.52±0.27	2.09±0.44
Diameter of submalar region(SMD)	2.40±0.36	2.03±0.05

Length of crown to bill tip (CBL)	9.15±0.13	9.13±0.13
Length of upper beak (UBL)	3.95±0.03	3.66±0.02
Width of the upper beak(UBW)	1.53±0.02	1.39±0.01
Height of the upper beak(UBH)	1.11±0.03	0.90±0.03
Length of the lower beak (LBL)	3.73±0.08	3.43±0.09
Length of the culmen (CL)	1.74±0.02	1.35±0.01
Length of the gony (GL)	0.98±0.01	0.76±0.02
Length of the choanal slit (CSL)	0.65±0.34	0.55±0.37
Length of tongue (TL)	1.54±0.13	1.43±0.13
Width of Tongue (TW)	0.73±0.03	0.75±0.02

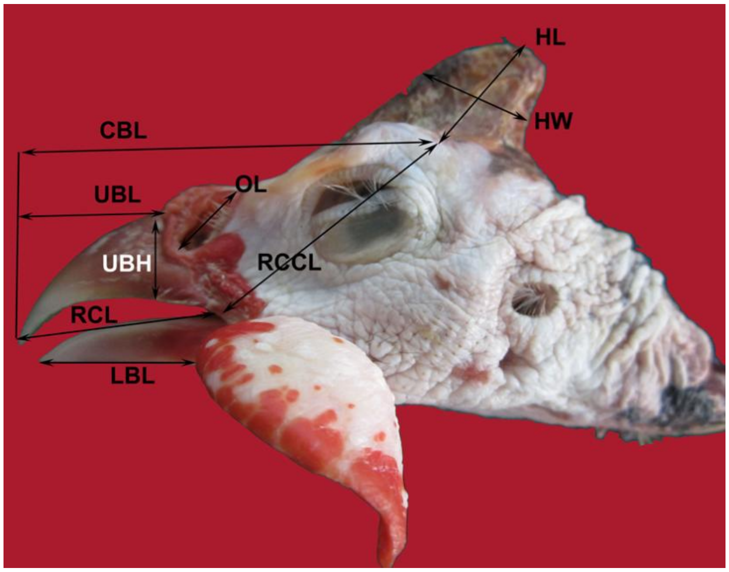

Fig.1 The lateral view of the Guinea fowl head. HL-Helmet Length; HW-Helmet width; OL-Operculum length, CBL-Crown to beak length, UBH- Upper beak Height, UBL-Upper bill length; LBL- Lower bill length; RCCL – Rictal commissure to crown length; RCL- rictal commissure length.

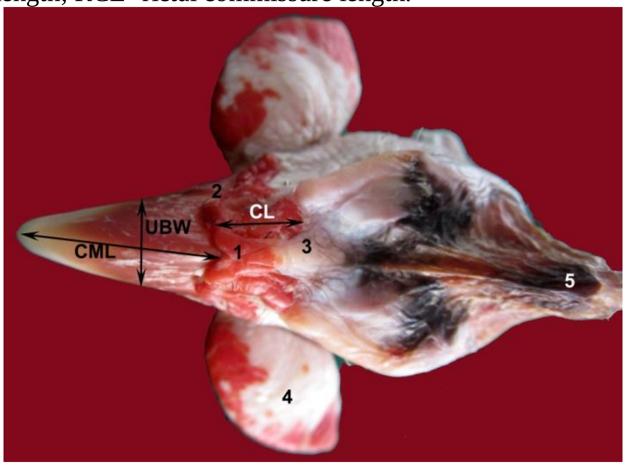

Fig.2 The dorsal view of the Guinea fowl head. CL-Cere length; CML- Culmen length, UBW- Upper beak length, 1-Cere, 2- Operculum,3-Forehead,4-Wattle,5,Helmet

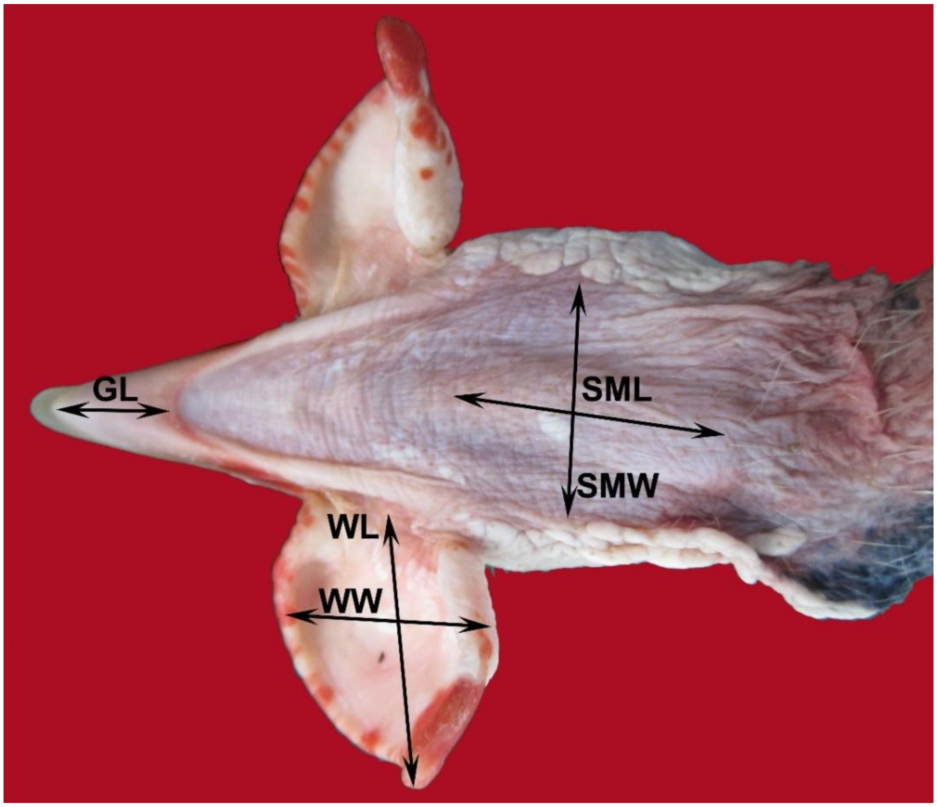

Fig.3. Ventral aspect of the Guinea fowl head.GL-Gony length; SML-submalar region length, SMW- Submalar region width; WL-Wattle length; WW- Wattle width

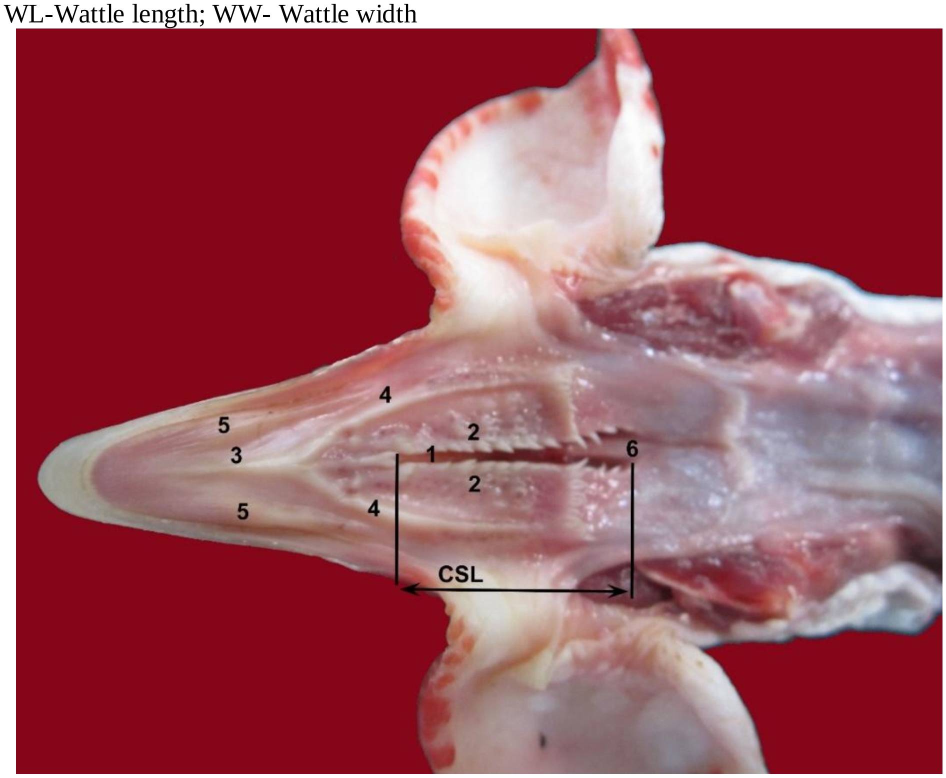

Fig .4. The oropharyngeal roof of the Guinea Fowl. CSL- Choanal slit length.1-Choanal slit, 2-Mariginal papillae of the Choanae 3.Median palatine ridge. 4- Lateral palatine ridge 5 -Palatine mucosal swelling 6. Median septum

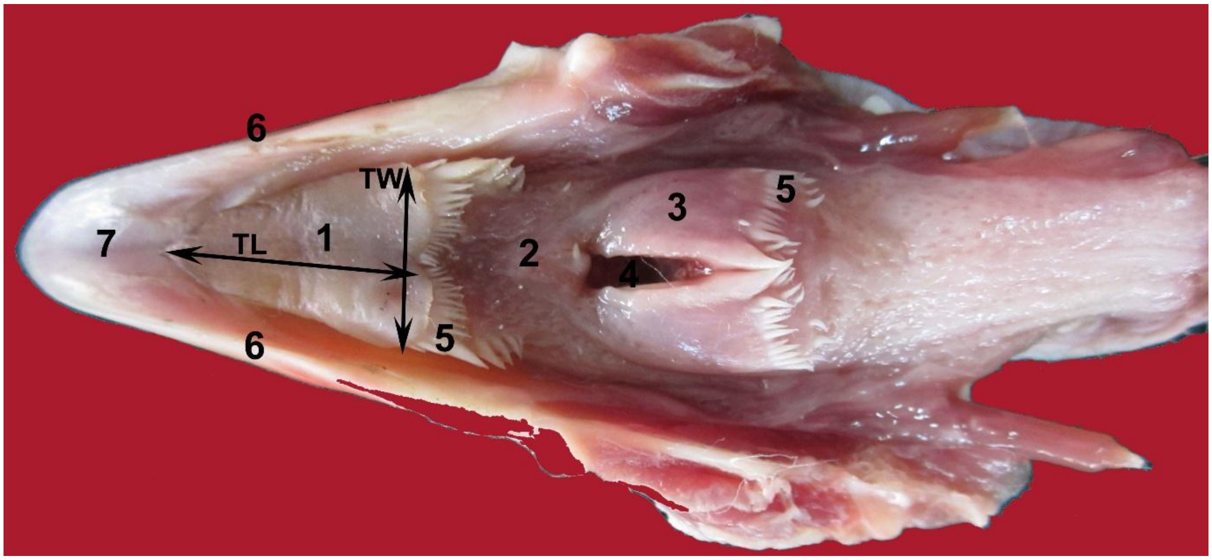

Fig.5.The oropharyngeal floor of the Guinea fowl.TW-Tongue width; TL-Tongue length, 1. Tongue, 2-Glosso-epiglottic space.3-Laryngeal mound, 4- Glottic cleft, 5-Papillae; 6.lower tomium 7-Gony.

3. CONCLUSIONS

All the Morphometric measurements taken in the present study are slightly higher in males than the female birds. The helmet, wattles, cere and the bare skin of the head help to tackle considerable range of environmental temperatures which facilitates the guinea fowl to forage in hot conditions. A stout and thick and pointed bill, sharp tomium, smooth culmen, well developed cere, gable shaped roof and concave surface of the lingua are the adaptations for the insect and seed- eating habit in hot climatic conditions .The V shaped mucosal swelling, well-developed palatine ridges provide provides a grip for the closure of the beak and also it does not allow the stored seed grains to escape out. The dorsally concave, ventrally convex, cranially pointed and slimy tongue helps in picking up the food, transportation and major support in drinking. The caudally backwardly directed papillae of the tongue, the choanal cleft and pharyngeal and palatal folds helps in channelizing the food, cracking the nuts and seeds and to prevent regurgitation. The results of the present study on epidermal structures of the feeding apparatus of the head, beak and tongue reflects that these structures support several behavioral activities such as food seeking, drinking, preening, picking, probing, nesting, territory fighting, etc in semi-open habitats such as savanna or semi deserts and also in the forests.

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