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Gross Morphometrical Parameters of the Upper Respiratory Tract (Nostril and Nasal Cavity) in Native Uttara Fowl (*Gallus domesticus*) During Post-natal Development

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ABSTRACT

Background: The present study was conducted to establish the baseline gross morphometrical parameters of the upper respiratory tract in native Uttara fowl (*Gallus domesticus*) during post-natal development. The synchronized maturation of these clearance pathways and turbinate surfaces underscores the anatomical capacity of this native breed to accommodate progressive metabolic demands.

Methods: A total of twenty-four apparently healthy birds were evaluated across four distinct age groups: 0, 7, 28 and 112 days, with 6 birds per group. Gross anatomical evaluations and high-precision morphometric scaling were utilized to map structural configurations across all developmental cohorts as follows.

Result: Gross anatomical evaluations revealed that the external nasal cavity communicated *via* elliptical nostrils protected by a cartilaginous operculum, which developed distinct black pigmentation post-hatching. Symmetrical left and right nasal chambers were partitioned by a complete cartilaginous medial nasal septum, with each chamber housing a distinct three-conchae system: Rostral, middle and caudal. Morphometric scaling showed significant age-dependent increases in total nasal cavity length, from 6.68±0.11 mm at day 0 to 18.13±0.16 mm at day 112, along with regional heights. The middle nasal concha remained the largest structural component across all cohorts, exhibiting a characteristic one-and-one-half turn configuration in transverse profile.

Key words: Avian anatomy, Conchae, Morphometry, Nasal cavity, Uttara fowl.

INTRODUCTION

The avian respiratory system possesses highly specialized anatomical adaptations that facilitate efficient gas exchange, air conditioning and protection of the lower air passages (Baumel *et al.,* 1993). Unlike mammals, avian species possess a uniquely adapted respiratory architecture. Their upper respiratory tract features highly specialized cartilaginous nasal conchae (turbinates) characterized by a distinct helical geometry. This specific morphology maximizes surface area to facilitate highly efficient heat exchange and countercurrent moisture conservation during respiration (Harem, 2026). Birds have special air sacs in their breathing system. No other animals that breathe air have these structures (Sakemohammed *et al.,* 2024). In birds, the upper respiratory tract begins externally at the nares and extends into the nasal cavity (*cavitas nasalis*), which is divided into right and left chambers by a medial nasal septum (Dharani *et al.,* 2020). The mucosal lining of each chamber is expanded by three cartilaginous conchae or turbinates: the rostral, middle and caudal conchae (Clark *et al.,* 2015). These structures contribute to the formation of the functional nasal meatuses, namely the dorsal, ventral, common and intermediate meatuses, which optimize the warming, humidification and filtration of inspired air before it reaches the lower respiratory tract (Dharani *et al.,* 2020).

The morphology of the avian upper respiratory tract varies considerably among species and reflects differences in ecology, physiology and evolutionary adaptation (Arnaout *et al.,* 2025). Previous studies have documented marked variation in nostril shape, operculum development,

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turbinate configuration and nasal cavity proportions across several wild and domestic birds (Clark *et al.,* 2015; Tadjalli *et al.,* 2008). Although the gross morphology of the cranial respiratory tract has been described in a number of commercial and wild avian species, information on post-natal developmental changes in indigenous poultry breeds remains remarkably limited (Dharani *et al.,* 2020). Certain viruses and bacteria make avians sick and cause change in their respiratory system. Chickens infected with *Mycoplasma synoviae* (MS) get a thick, creamy-gray liquid in their nose that leaks out as runny discharge. The inside of their nasal cavity also becomes red, swollen and filled with fluid (Gumasta *et al.,* 2023). Infectious laryngotracheitis (ILT) is a global poultry respiratory infection-increasingly prevalent across the Indian subcontinent-attributable to *Gallid alphaherpesvirus 1 (*Mishra *et al.,* 2020).

The Uttara fowl is an important indigenous poultry breed maintained under local backyard management conditions, yet its anatomical development has not been thoroughly characterized. Baseline information on the post-natal growth of the nasal passages and turbinate structures is vital for understanding breed-specific developmental biology and for generating comparative anatomical data. However, detailed morphometric information describing how these structures change sequentially from hatching to maturity is still lacking.

Therefore, the present study was undertaken to characterize the post-natal gross morphometrical development of the upper respiratory tract in Uttara fowl obtained from the University Poultry Farm of G.B. Pant University of Agriculture and Technology, Pantnagar. The study was aimed to quantify changes in nostril length and width, total nasal cavity length, regional cavity heights and the height and width of the rostral, middle and caudal nasal turbinates across four post-natal age groups: 0, 7, 28 and 112 days. These findings were intended to provide a standardized anatomical baseline for future veterinary diagnostics, comparative avian biology and optimized local poultry management strategies.

MATERIALS AND METHODS

Experimental animals and study design

The present study was conducted on 24 apparently healthy irrespective of sex were chosen as the breed poultry for this study “Uttara fowl” (*Gallus domesticus*). The birds were obtained at hatching from the University Poultry Farm, G. B. Pant University of Agriculture and Technology (GBPUAT), Pantnagar and were reared under uniform management and standard nutritional conditions throughout the study period. The birds were divided into four post-natal age groups with six birds per group: 0 day, 7 days, 28 days and 112 days. Preliminary statistical analysis revealed no significant main effects or interaction effects involving sex; therefore, data for males and females were pooled within each age cohort.

Ethical approval and sample collection

Before sample collection, the live body weight of each bird was recorded using a calibrated digital weighing balance. On the designated experimental day, birds from each group were humanely sacrificed in accordance with the Committee for Control and Supervision of Experiments on Animals (CCSEA) guidelines and with prior approval from the Institutional Animal Ethics Committee (IAEC). As prescribed by acceptable veterinary guidelines for avian models, euthanasia was performed humanely by exsanguination through targeted severance of the jugular vein and common carotid artery (Underwood and Anthony, 2020). After sacrifice, the head and thoracic region were dissected carefully to expose the respiratory tract and to permit collection of the relevant anatomical structures without causing regional artifacts.

Gross anatomical examination

The upper respiratory tract was examined grossly for external and internal anatomical features using standardized avian dissection methods (Baumel *et al.,* 1993). The nares, operculum, nasal cavity, conchae and nasal meatuses were observed and described *in situ* and after careful excision. Mid-sagittal and transverse sections were prepared using ultra-sharp surgical blades to study the internal architecture of the nasal cavity and the detailed scrolling patterns of its conchae. Gross morphological observations were recorded systematically across all age groups using a high-resolution imaging setup.

Gross morphometrical measurements

Morphometric measurements were taken for the nostrils, nasal cavity and individual nasal conchae. The parameters recorded included the length and width of the nostrils, the total length of the nasal cavity, the vertical heights of the rostral, middle and caudal regions of the nasal cavity and the individual height and width of the rostral, middle and caudal turbinates. Larger linear dimensions were measured using a non-stretchable surgical thread, measuring tape and metric scale, while finer, high-precision measurements were taken using a digital Vernier-caliper accurate to 0.01 mm.

To ensure structural reproducibility across all specimens, regional vertical heights of the nasal cavity were defined using the following specific anatomical boundaries such as rostral region height which was measured vertically at the level of the external nostrils, spanning from the mucosal floor to the dorsal roof of the vestibule, terminating at the caudal border of the rostral concha followed by middle region weight, measured vertically at the mid-point of the elongated middle nasal concha, spanning from the ventral floor to the dorsal nasal wall. As will as caudal region height, measured vertically at the level of the caudo-dorsal territory occupied by the caudal (olfactory) concha, extending down to the margin of the internal choanae.

Statistical analysis

All quantitative data were expressed as mean±standard error (SE). The data were analyzed using one-way analysis

of variance (ANOVA) to assess the differences among the post-natal age groups. Variations between means were evaluated and significance levels were assessed at $p<0.05$. The statistical approach followed established biometric procedures optimized for livestock and poultry research data structures (Snedecor and Cochran, 1989).

RESULTS AND DISCUSSION

Gross morphological observations

Nostrils and operculum

Gross anatomical evaluation of the upper respiratory tract in the native Uttara fowl (*Gallus domesticus*) revealed that external communication with the nasal cavity occured *via* a pair of symmetrical, elliptical nostrils situated at the base of the upper beak. These external nares were covered and protected dorsally by a distinct cartilaginous operculum (Fig 1).

This specific structural configuration aligns with observations documented in the turkey (*Meleagris gallopavo*), which also featured an operculum-covered nasal entry (Dharani and Kumaravel, 2024). However, this architectural arrangement varied significantly from the narrow longitudinal nostrils paired with a reduced operculum seen in the Japanese quail (Cevik-Demirkan *et al.,* 2007). It also differed from the circular nostrils covered by a dense tuft of feathers in the hooded crow and the elongated, slit-like nostrils bounded by a horny operculum typical of doves and common quails (Madkour, 2019). Furthermore, the presence of an operculum differentiates the Uttara fowl from ostriches and geese, which exhibit oval nostrils entirely devoid of an opercular covering, as well as the Common Moorhen, which presents simple open holes or slit-like nares without any protective cartilaginous flap (Jaifar, 2023; Tadjalli *et al.,* 2008).

A key physical marker identified during post-natal growth in the Uttara fowl was the development of a distinct black pigmentation on the surface of the operculum. This dark pigmentation was visible across all progressive age groups, except on day 0 (the day of hatching), where the opercular tissue remained completely unpigmented (Fig 2).

Biometrical mapping established that the absolute length of the nostrils expanded significantly from day 0 through day 112, whereas the nostril width increased at a gradual rate as age advanced. The specific post-natal morphometrical trajectories of the external nares were detailed in (Graph 1).

When compared to other adult avian models, the mature morphometric profile of the Uttara fowl represented a distinct breed index. The nostril length of the adult Uttara fowl (8.12±0.11 mm) was greater than that recorded for the domestic duck (6.93±0.03 mm) the dove (3.11±0.10 mm) and the quail (4.07±0.12 mm, while remaining highly comparable to the adult domestic goose (8.72±0.57 mm) (Madkour, 2019). Similarly, its mature nostril width (4.54±0.19 mm) surpassed that of the duck (2.75±0.06 mm), dove (0.88±0.08 mm) and quail (0.99±0.08 mm), though it scales below the Goose (3.79±0.57 mm) (Madkour, 2019). These values were smaller than those of the Broad-breasted white turkey, which exhibited a nostril length of 15.73±1.47 mm and a width of 5.73±1.27 mm, but were substantially larger than the dimensions noted in the Eurasian common moorhen, which measured 9.0 mm in length and 3.0 mm in width (Jaifar, 2023).

Nasal cavity geometry and medial nasal septum

The internal nasal cavity of the Uttara fowl exhibited a cone-shaped geometry that stretched continuously from the external nostrils to the internal choanae. Anatomically, the apex of this cone pointed rostrally, while its wider, expanded base was positioned caudally. This architectural arrangement was found to be identical to the nasal geometry described in the ostrich and the Nandanam chicken (Dharani *et al.,* 2020; Tadjalli *et al.,* 2008). Conversely, it was in contrast to the hooded crow, which displayed a short, narrow slit-like rostral segment paired with a wide, elongated triangular caudal chamber.

Mid-sagittal examinations demonstrated that the overall length and the three regional vertical heights (rostral,



Fig 1: Photograph showing elliptical-shaped nostrils, it located at either side of the base of upper beak and dorsally covered by a pigmented cartilaginous operculum (arrow) in 28 days old Uttara fowl.

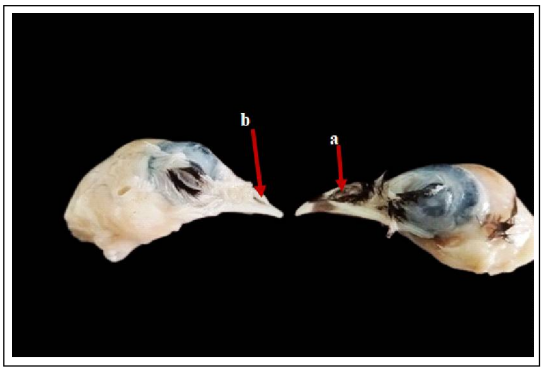


Fig 2: Photograph showing nostrils dorsally covered by pigmented cartilaginous operculum (a) in 7 days and nonpigmented cartilaginous operculum (b) in 0-day old Uttara fowl.

middle and caudal zones) of the nasal cavity underwent highly significant, continuous expansions as the birds matured. These age-dependent changes are systematically detailed in Table 1.

The scaling patterns observed in the Uttara fowl followed the general trends reported across various avian species. The total length of the mature nasal cavity (18.13±0.16 mm) was longer than that of the adult quail (11.53±0.22 mm) and dove (13.02±0.67 mm), but was shorter than that of larger birds such as the duck (35.22±0.63 mm) and the Goose (44.63±3.02 mm) (Madkour, 2019). Furthermore, the clear, progressive increase in vertical height from the rostral to the caudal zone observed in the Uttara fowl matched the widening patterns recorded in ducks and geese (Madkour, 2019).

A complete, fully cartilaginous medial nasal septum cleanly divided the internal nasal cavity into symmetrical left and right chambers across all post-natal age cohorts (Fig 3). This architectural arrangement matched findings documented in non-aquatic birds, the Common Moorhen, the Nandanam chicken and the turkey (Dharani *et al*., 2020; Dharani and Kumaravel, 2024). However, it differed fundamentally from the ostrich and the Eurasian common moorhen, where the nasal septum transitioned from a cartilaginous framework in its rostral zone into a solid bony framework within the caudal region (Jaifar, 2023; Tadjalli *et al.,* 2008).

Architectural features of nasal conchae (Turbinates)

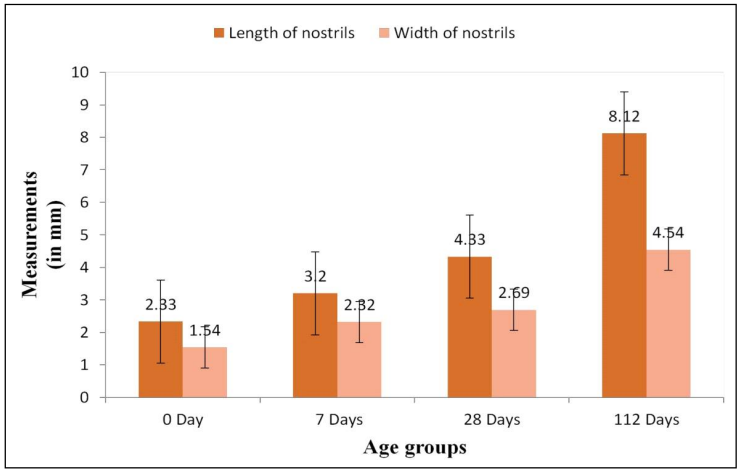
The mucosal landscape within each symmetrical chamber of the nasal cavity was expanded by three types of creamy-white cartilaginous conchae, arranged sequentially as the rostral, middle and caudal conchae. Among these structures, the middle nasal concha was consistently the largest structural component across all developmental stages. The rostral concha formed the second largest element, while the caudal concha remained the smallest.

This specific size distribution pattern matched anatomical descriptions of the goose, common quail, Nandanam chicken, Eurasian common moorhen and turkey (Dharani *et al.,* 2020; Dharani and Kumaravel, 2024; Madkour, 2019). However, it differed from the hooded crow and the dove, both of which possessed an ill-developed rostral concha paired with a well-developed, dominant caudal concha (Madkour, 2019).

The precise post-natal dimensions of these individual turbinates, measured *via* high-precision transverse cross-sections, are compiled in Table 2.

Rostral nasal concha

In mid-sagittal sections, the lateral border of the rostral nasal concha was fixed directly to the lateral wall of the vestibule, extending caudally into the middle third of the nasal passage. The rostral tip was positioned so it could be seen from the exterior while viewing through the nostril opening. Morphologically, it displayed a characteristic outline similar to that of the kite (Fig 4). This shape matched the turkey, but differed from the triangular profile with a caudoventrally directed apex found in the Japanese quail and hooded crow, as well as the slightly involuted conical shape of the Nandanam chicken (Cevik-Demirkan *et al.,* 2007;



Graph 1: Showing average length and width of nostrils in different age groups of Uttara fowl.

Table 1: Mean length and regional heights of the nasal cavity (Mean±S.E.) in sagittal section.

Cavity parameter	Day 0 (n=6)	Day 7 (n=6)	Day 28 (n=6)	Day 112 (n=6)
Length of nasal cavity (mm)	6.68±0.11^{a}	7.44±0.12^{b}	11.90±0.14^{c}	18.13±0.16^{d}
Height of rostral region (mm)	2.47±0.11^{a}	3.19±0.09^{b}	4.96±0.21^{c}	5.83±0.17^{d}
Height of middle region (mm)	3.63±0.12^{a}	4.71±0.17^{b}	6.39±0.13^{c}	8.20±0.11^{d}
Height of caudal region (mm)	4.32±0.15^{a}	5.44±0.22^{b}	8.30±0.12^{c}	11.43±0.26^{d}

Means within a row bearing different superscript letters (a,b,c,d) indicate statistically significant differences (P<0.05) across age groups.

Dharani *et al.,* 2020; Dharani and Kumaravel, 2024). Transverse cross-sections revealed a distinct C-shaped configuration that projected directly from the lateral wall of the nasal cavity (Fig 6). matching the structural patterns seen in the Japanese quail, hooded crow, Common Moorhen and turkey (Cevik-Demirkan *et al.,* 2007; Jaifar, 2023). Conversely, this shape differed from the shelf-like projection found in ducks, the T-shaped concha characteristic of geese and the single ventrolateral half-turn present in the Eurasian common moorhen (Jaifar, 2023; Madkour, 2019). The significant post-natal growth recorded from day 0 to day 112 closely tracks the expansion trends documented across indigenous Galliformes.

Middle nasal concha

Situated obliquely within the sagittal plane between the rostral and caudal conchae, its rostral extremity attached firmly to the dorsal nasal wall while its caudal end projected down toward the choanal slit (Fig 5). This specific structural placement matched findings in the Japanese quail and the ostrich (Cevik-Demirkan *et al.,* 2007; Tadjalli *et al.,* 2008). The concha exhibited an elongated shape that was widest at its rostral origin, constricted through its middle segment and tapered to its narrowest point caudally right above the level of the choanal slit. This morphological profile was consistent with the turkey, but differed from the spirally curved concha noted in the Nandanam chicken (Dharani *et al.,* 2020; Dharani and Kumaravel, 2024). Transverse sections revealed that the middle concha formed one and one-half full turns (Fig 6). This scroll-like curvature matches configurations described in ducks and turkeys (Dharani and Kumaravel, 2024; Madkour, 2019). However, it differed from the simpler, single ventrolateral

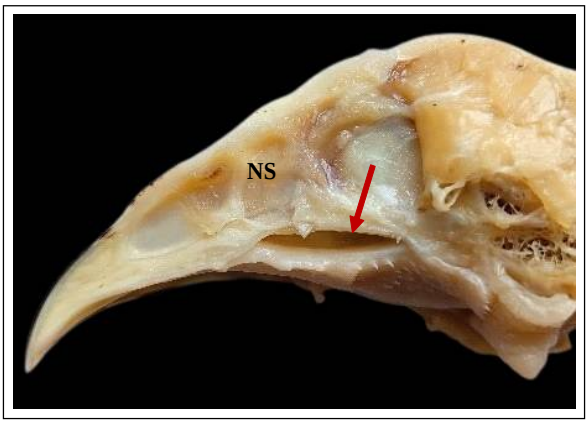


Fig 3: Photograph of nasal cavity (sagittal sections) showing nasal septum (NS) and choanal slit (Arrow) in 112 days old Uttara fowl.



Fig 4: Photograph of nasal cavity (sagittal sections) showing rostral nasal concha (R), middle nasal concha (M), caudal nasal Concha (C) in 7 days old Uttara fowl.

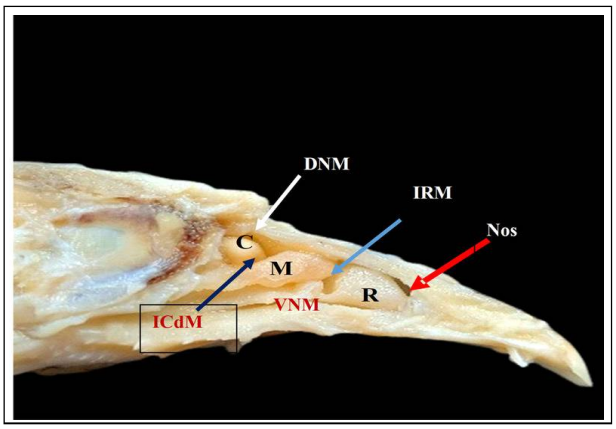


Fig 5: Photograph of nasal cavity (sagittal sections) showing rostral nasal concha (R), middle nasal concha (M), caudal nasal concha (C), nostril (Nos), dorsal nasal meatus (DNM), ventral nasal meatus (VNM), intermediate rostral meatus (IRM) and intermediate caudal meatus in 112 days old uttara fowl.

Table 2: Transverse cross-sectional dimensions of the nasal turbinates (Mean±S.E.) across post-natal development stages.

Turbinate parameter	Day 0 (n=6)	Day 7 (n=6)	Day 28 (n=6)	Day 112 (n=6)
Height of rostral turbinate (mm)	0.96±0.18^{a}	1.59±0.16^{b}	3.12±0.05^{c}	4.19±0.09^{d}
Width of rostral turbinate (mm)	0.66±0.01^{a}	0.89±0.02^{b}	1.64±0.08^{c}	2.13±0.04^{d}
Height of middle turbinate (mm)	1.65±0.09^{a}	2.33±0.71^{b}	3.66±0.52^{c}	6.16±0.06^{d}
Width of middle turbinate (mm)	0.89±0.02^{a}	1.38±0.07^{b}	2.14±0.02^{c}	3.88±0.05^{d}
Height of caudal turbinate (mm)	1.59±0.08^{a}	2.31±0.05^{b}	3.54±0.11^{c}	4.22±0.14^{d}
Width of caudal turbinate (mm)	0.93±0.01^{a}	1.43±0.04^{b}	2.18±0.06^{c}	3.16±0.04^{d}

Means within a row bearing different superscript letters (a,b,c,d) are significantly different (P<0.05).

half-turn seen in Japanese quails and the two full turns presented in geese (Cevik-Demirkan *et al.,* 2007; Madkour, 2019) and the two complete and one half-ring coiled towards lumen (Harem, 2026). The dataset obtained for the Uttara fowl in the present study provided a far more comprehensive and extended developmental timeline up to full structural maturity at 112 days (attaining in height) compared to the restricted 45-day growth window previously documented for other native poultry lines.

Caudal nasal concha (olfactory concha)

The caudal concha represented the smallest turbinate element and was located in the caudo-dorsal region of the nasal cavity, resting directly above the dorsal surface of the middle concha. Sagittal cross-sections showed a roughly triangular profile (Fig 5) similar to the structures observed in the ostrich and Nandanam chicken (Dharani *et al.,* 2020; Tadjalli *et al.,* 2008). This shape differed from the hemispherical concha typical of the Japanese quail, the oval structure found in the hooded crow and the inverted comma-shaped architecture seen in the turkey (Cevik-Demirkan *et al.,* 2007; Dharani and Kumaravel, 2024). In transverse profiles, the caudal concha exhibited a pear-shaped structure characterized by a shallow central depression (Fig 6). This conformation matches the hollow, pear-shaped concha described in doves, but stood in contrast to the single and a half turns seen in hooded crows and Eurasian common moorhens, as well as the hollow mould-shaped conformation typical of the turkey (Jaifar, 2023; Dharani and Kumaravel, 2024); Madkour, 2019), (Fig 7).

Spatial organization of nasal meatuses

The internal airflow pathways of the nasal cavity were organized into four functional anatomical passages: the dorsal meatus, ventral meatus, common meatus and intermediate meatus.

Due to the oblique orientation and large size of the middle concha, the intermediate meatus was divided into two distinct structural chambers. The rostral section of the intermediate meatus was positioned between the rostral and middle conchae, whereas its caudal section occupied the space between the middle and caudal conchae. This intermediate pathway served as a central hub, communicating directly with the vestibule, the dorsal nasal meatus, the common nasal meatus and the ventral nasal meatus. The boundaries of the remaining pathways were organized as follows:

Dorsal nasal meatus

Positioned between the dorsal wall of the nasal cavity and the upper boundary of the conchae.

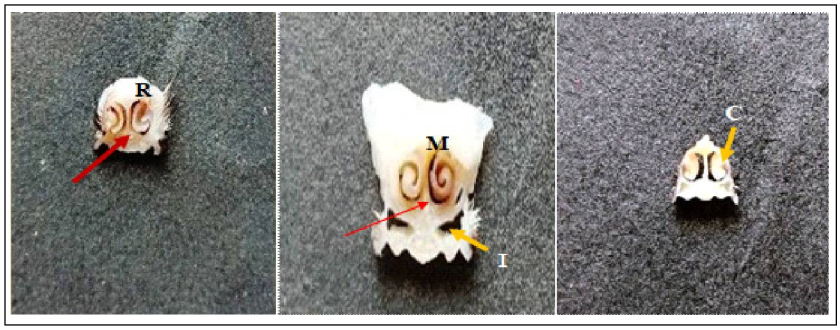


Fig 6: Transverse sections of nasal cavity showing rostral nasal concha (R), middle nasal concha (M), caudal nasal concha (C), nasal septum (arrow) and infraorbital sinus (I) in 28 days old Uttara fowl.

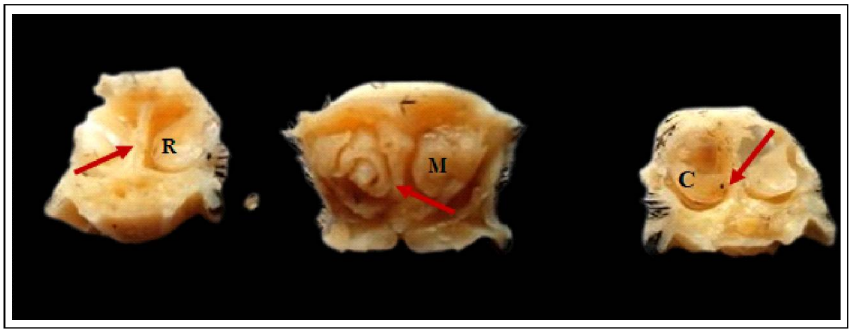


Fig 7: Transverse sections of nasal cavity showing rostral nasal concha (R), middle nasal concha (M), caudal nasal concha (C) and nasal septum (arrow) in 112 days old Uttara fowl.

Ventral nasal meatus

Bounded dorsally by the lower surfaces of the middle and rostral conchae and ventrally by the solid floor of the nasal cavity.

Common nasal meatus

Formed by the central vertical clearance space between the medial face of the conchae and the medial nasal septum, communicating directly with all other regional meatuses.

This structural distribution slightly similar to other avian models; for example, the turkey exhibited up to five specialized meatuses (Dharani and Kumaravel, 2024), whereas Japanese quails displayed a modified intermedio-dorsal and intermedio-caudal routing system (Cevik-Demirkan *et al.,* 2007), (Fig 5).

CONCLUSION

Respiratory system of fowl consisted of nares as operculum, nasal cavity (cavitas nasalis), larynx, trachea, syrinx and lungs. On gross observations the externally nasal cavity opened as ellipti-cal-shaped nostrils located at the base of the upper beak on either side. Nostrils were covered by a cartilaginous operculum. Nasal cavity was cone shape extended from the nostrils to the choanae. A cartilaginous medial nasal septum divided the nasal cavity into two equal halves (right and left) in all age group and each half of the nasal cavity exhibited three types of creamy white cartilaginous (hyaline) conchae in rostral, middle and caudal region as rostral, middle and caudal conchae out of these middle conchae was the largest in all age groups. The shape of rostral concha was kite-like in sagittal section but in transverse section of the rostral concha was C shaped and projected from lateral wall of the nasal cavity. In sagittal section, the shape of middle concha was elongated which was widest rostrally, constricted in the middle and narrowest at caudal end but in transverse section, there was one and one-half turn of middle concha. The conchal curve of middle concha started from dorsal wall, projected medioventrally, further turned laterodorsally and terminated medially. In sagittal section of nasal cavity, the caudal nasal concha (olfactory concha) was the smallest and located at the caudo-dorsal side of the nasal cavity above the dorsal surface of the middle concha. It was roughly triangular in shape in sagittal section, but in transverse section, the caudal concha was pear-shaped with shallow depression at centre. The nasal cavity had four meatuses *i.e.* dorsal meatus, ventral meatus, common meatus and intermediate meatus.

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Informed consent

The data used in this study were obtained from G.B. Pant University of Agriculture and Technology, Pantnagar, Ethical clearance of the research work was obtained vide File No. IAEC/C.V.A.Sc/VAN/424.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No specific funding is available for the publication of this manuscript or funding the APC.

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