MORPHOLOGICAL STUDIES OF DIGESTIVE TRACT OF THE EDDIBLE – NEST SWIFTLETS (*Collocalia fuciphaga*)

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ABSTRACT

The research focuses in studying the micro and macro morphology, and also mucus substantial on the digestive tract of the swift. The observation was held to the macromorphology after the fixation in Bouin solution and followed with microanatomy on the mucus composition on the digestive tract using Haematoxylin-Eosin and Alcian Blue-Periodic Acid Schifft (AB-PAS) staining method. The aim of this study is to make a better understanding about the relation between feeding behavior and morphology of digestive tract.

The average sizes of *C. fuciphaga* are 2800 gram body weight and 9.2 cm body length. The swift's digestive tract consists of mouth, pharynx, oesophagus, stomach, small intestine, large intestine and cloacae. Caecum was failed and therefore the border between small intestine and large intestine is difficult to be recognized. The average length of intestine is 11.7 cm

The average length of oesophagus is 4.00 cm or 45% length of the body. The crop as temporary food storage was not found, but there are many active ooesophagus glands found on the transition between oesophagus and stomach.

The stomach consists of proventriculus and ventriculus. The surface of proventriculus is lined by a thick keratin shield. The mucosa of proventriculus is lined by simple columnar epithelium and the proventriculus gland formed lobulus called adenomere. The ventriculus is divided into cardia, fundus, and pylorus zones. Ventriculus is arranged by the simple columnar epithelium. The surface of ventriculus is lined with a thick keratin shield.

Vili of small intestine are long and crowded, getting shorter toward to the caudal and disapear at the rectum. The Lieberkuhn gland was found and has no caecum. along the intestine.

C. fuciphaga needs fuel to go around their daily activities, and this is where the digestive system plays its role. It converts food into raw materials that build and fuel the body cells, so the digestive system must be efficient.

Key words : digestive tract, feeding behaviour

INTRODUCTION

Background

Indonesia is a tropical country with the inheritance of prosperous natural resources, in a wide range of flora and fauna variety. This prosperity must be taken care appropriately as an object for science research either as an effort of conservation.

One of Indonesia's popular fauna prosperity is the swift. Swift is well-known for its nest that affects restorative power to human health. Other way, swift's nest is a potential commodity for Indonesia and have an economically meanings.

Swift belongs to Ordo Apodiformes, Famili Apodidae, Genus Collocalia. There are six species that found in Indonesia's environment: *Collocalia fuciphaga*, *Collocalia gigas*, *Collocalia maxima*, *Collocalia brevistrosis*, *Collocalia vanikoresis*, and *Collocalia esculenta*. The swift species is commonly classified by body size, color of feather, and the material used to build the nest. The white swifts (*Collocalia fuciphaga*) produce a nest that is made entirely from their saliva, which makes them as the most popular and most hunted species, since their nest becomes the most expensive among others. The demand of swift nests increases time after time, and this pursues humankind to develop the swift preservation. As a potential commodity, an effort to manage the breeding of the swift's and to enhance its nest production must be lead. Therefore basic researches to collect biological data are needed to answer the problem above.

Most registered research journals only focused to the effort of conservation and the processing of the nests. Until present time, there is still no scientific report about morphological studies of digestive tract of the edible-nest swiflets on cellular level.
The morphology of digestive tract is strictly correlated with feeding behavior and sort of food intake. Nearly all swift's activities are done while its flying, including food hunting. Mostly swift prefers insects as its food. Data about feeding behavior and sort of food intake are important information for the breeding management of the swift's, besides understand the physiological function of the digestive tract is also important.

The aimed of the study is to show the general morphological structure of the digestive tract of *C. fuciphaga* to make a better understanding about the relation between feeding behaviour and morphology of the digestive tract.

MATERIAL AND METHODS

Five swiftlet's (*C. fuciphaga*) were used for this study. They were catched from a cave in Pasuruan, East Java and directly anaesthetized with eter, followed with dissection the thorax cavity and then fixed in Bouin solution.

a. Macroanatomy

Macroanatomy observation consist the position of the situs viscerum and measuring the part of digestive tract using sliding caliper measurement tool concerning the length of oesophagus, stomach and intestine, also the diameter of the stomach. The observation was also held to the sex and *glandulae mandibulares.*

b. Microanatomy

Microanatomy observation consist the general structure of the digestive tract concerning the surface structure, wall, mucosa, villi and various kind of glands. All part of the digestive tract were prepared with paraffin embedded and stained with Hematoxyline-Eosin and Mason trichrome, and observed under light microscope.

The slides were also stained with Alcian Blue-Periodic Acid Schiff's (AB-PAS) reaction to observed the carbohydrate composition of the mucosa substance.
All microanatomy founding were documented with microphotograph technique.

RESULT AND DISCUSSION

RESULTS

A. MACROANATOMY OBSERVATION

The average body length of *C. fuciphaga* is 9.20 cm and the body weight is 2800 gram (Table 1). The colour of the feather is black, and the difference between male and female are difficult to be recognized from external morphology. After the surgery, we discovered that the samples are 3 males and 2 females. Generally from the body size and length of the digestive tract showed that female has its shorter than male.

From all samples, the *glandulae mandibulares* are not well developed. The chest muscles are strong and grew well.

The digestive tract of *C. fuciphaga* consists of mouth, faring, oesophagus, stomach, and intestines but failed on crop and caecum. Oesophagus has its average length is 4.00 cm or equal to 45 % of the body length. Oesophagus lays between orofaring and stomach. Right after the mouth, oesophagus goes through the right side of trachea. To the caudal before entering the stomach, the size of oesophagus is smaller than the cranial area, and the syrinx area is lower and goes through *hiatus oesophageus* into the stomach.

The simple form stomach, in a form similar to reversed letter "C", lays on the left of cranial part of the abdomen area. The size is quite small and thick, and consists of proventriculus dan ventriculus, which have no significant border. The *curvatura major* is very wide while the *curvatura minor* is narrow. The dorsal part of ventral proventriculus is covered by heart and lungs. There is heart lobules lays both on the left and right sides.

Table 1. Morphometry of the digestive tracts of *C. fuciphaga*

No.	Code	Sex	Body Length (cm)	Oesophagus Length (cm)	Stomach Diameter (cm)		Intestines Length (cm)
					A	B	
1.	W2	Female	9.00	4.00	0.50	0.80	11.50
2.	W5	Female	8.00	3.50	0.50	0.80	11.00
Average			8.50 ± 0.70	3.75 ± 0.35	0.50	0.80	11.25 ± 0.35
1.	W1	Male	9.50	4.00	0.50	0.9	12.50
2.	W3	Male	10.00	5.00	0.40	1.00	12.00
3.	W4	Male	9.50	4.00	0.40	1.00	11.50
Average			9.67 ± 0.29	4.33 ± 0.58	0.43 ± 0.06	0.97 ± 0.06	12.00 ± 0.50
Average Total			**9.20 ± 0.76**	**4.00 ± 0.61**	**0.46 ± 0.05**	**0.84 ± 0.21**	**11.7 ± 0.57**

Half part of the caudal ventriculus surface is covered with fats. The duodenum prolongs to be the jejunum and the thin rectum ends at the cloacae. The caecum is hardly recognized, which caused difficulty to differentiate the partition of the small and the large intestines.

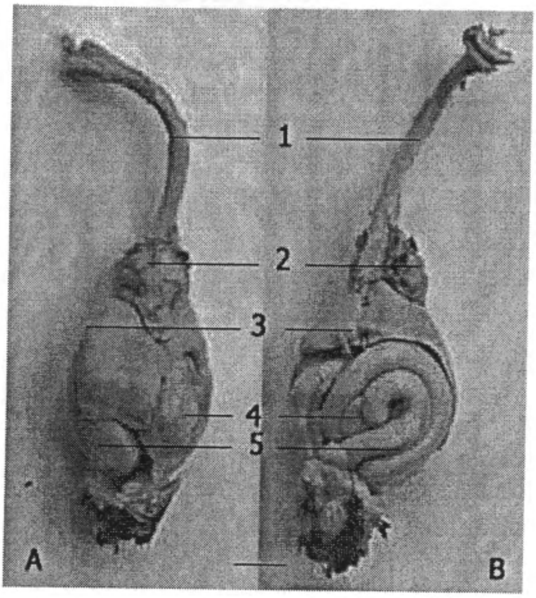


Figure 1.

Digestive tract of the *C. fuciphaga*,
A. Dorsal view,
B. Ventral view.
1.oesophagus,
2. heart,
3. liver,
4. pancreas,
5. intestine

bar = 1 cm

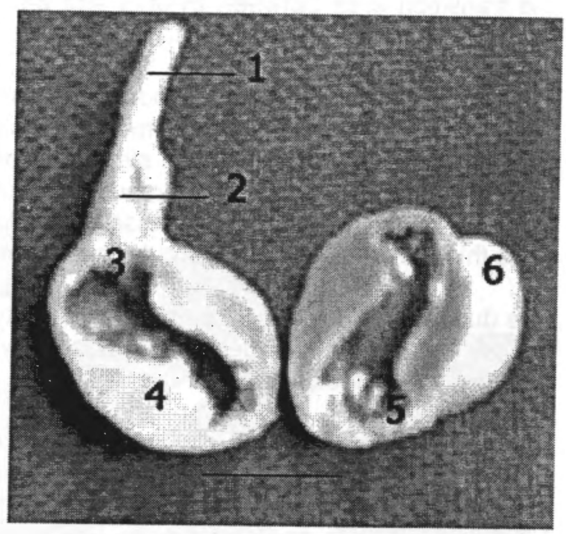


Figure 2.

Stomach of the *C. fuciphaga*

1. oesophagus,
2. proventriculus,
3. cardia,
4. fundus,
5. pylorus,
6. duodenum

bar = 1 cm

B. Microanatomy

Observation

The transition area between oesophagus dan proventriculus is identified with an active and a dense amount of oesophageal glands, and also the changing of mucosa epithelia cells from the thin-layered epithelia into the simple columnar epithelia. The shape of oesophageal glands is tubuloalveolar. Moreover, the surface of proventriculus mucosa is layered with a thick keratin layer.

The proventriculus mucosa consists of simple columnar epithelia that forms the longitudinal folds to the lumen. The proventricular glands is a bifurcate tubular glands and forms gland lobules called adenomere. The shape of the formation cells of proventricular glands (chief cells) is hexagonal with the core at the perifer. The muscularis mucosa is moderately thick and the inner part is formed by circular muscles layers while the external part is formed by the longitudinal muscles layers.

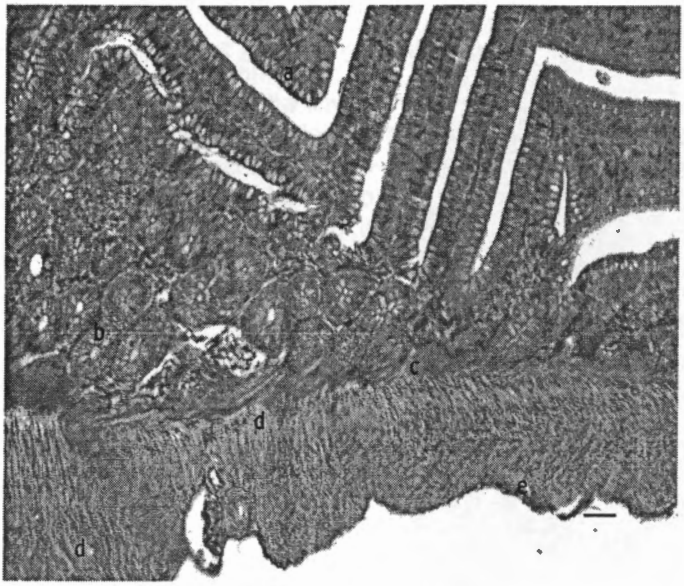
The ventriculus is divided into the cardia, fundus, and pylorus area. The ventriculus mucosa consists of simple columnar epithelia, and the surface is covered with a thick keratin layer. Together with the mucosa, the submucosa is also forming folds without the extension of the muscularis externa. The submucosa is thin, covered with blood vessel, lymph vessel, nerve dan plexus Meissner. The muscularis externa is thick and consists of two muscle layers; the thick circular layer on the inner side and the thin longitudinal layer on the outer side. The cardia glands is a simple tubular that consists of cubic cells with a round core. The cardia area is the smallest part of the ventriculus.

The next area is the fundus. Fundus takes the largest part in stomach. There are 4 kinds of cells in the fundus area: the chief cells, the parietal cells, the neck cells, and the mucus cells. The shape of fundus glands is bifurcating tubular. The chief cells are found in fundus glands in a quite large amount. Meanwhile the parietal cells are spread between the chief cells and the neck cells.
The type of pylorus glands is flowing tubular, formed by cuboid cells that produce mucus. The muscularis externa of the pylorus is thinner compared to the one in cardia and fundus area. In the transition area between pylorus and duodenum, there is a significant keratin layer that borders the pylorus and duodenum.

The histological overview of duodenum, jejunum and ileum provides a general structure of digestive organs that consists of mucosa layer, submucosa, muscularis externa, and serosa. The mucosa epithelial cells are simple columnar cells with some Goblet cells, Lieberkuhn glands and lymphocyte cells spreading in the lamina propria area. On the thin submucosa there are blood vessel, lymph vessel, and plexus Meissner. The muscularis externa layer is quite thick, which consists of circular and longitudinal layer.

The duodenum has long size and high density of vili. As it prolonged to the caudal, the vili is shorter and the density decreases. Caudally the amount of Goblet cells increase. Peyer's patches can be found in ileum.

The histological overview of the large intestines is different with the former three area overview. This area showed shorter vili with flat shape and doesn't form folding. The amount of Goblet cells is rising and the size is getting bigger. In the lamina propria we can found the Lieberkuhn glands and lymphocyte tissue which are solitaire or in group. The muscularis mucosa in this area is adjoining the mucosa and the submucosa.



HE staining

a. villi with Goblet cells
b. Lieberkuhn glands
c. submucosa
d. muscularis mucosa
e. tunica serosa

bar = 55 μ

Figure 3. Duodenum of the *C. fuciphaga*

HE staining

a. villi with Goblet cells
b. Lieberkuhn glands
c. submucosa
d. muscularis mucosa
e. tunica serosa

bar = 44 μ

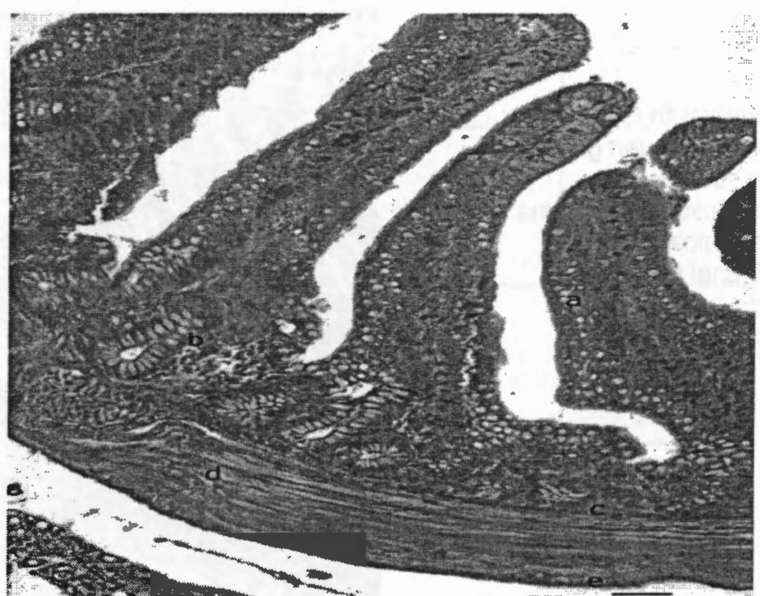
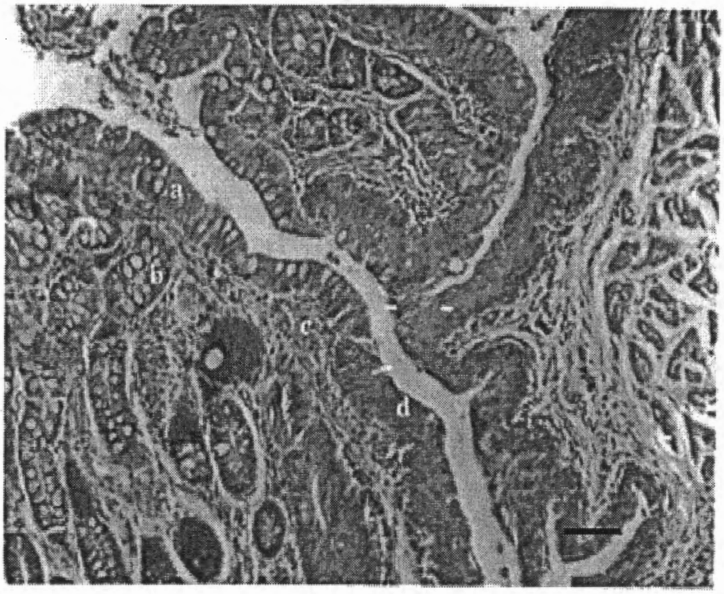


Figure 4. Jejunum of the *C. fuciphaga*



HE staining
a. villi with Goblet cells
b. Lieberkuhn glands
c. submucosa
d. Peyer's patches
e. muscularis mucosa
f. tunica serosa

bar = 59 μ

Figure 5. Ileum of the *C. fuciphaga*

HE staining

a. villi with Goblet cells
b. Lieberkuhn glands
c. submucosa
d. muscularis externa
e. tunica serosavili
f. anal mucosa

bar = 47 μ

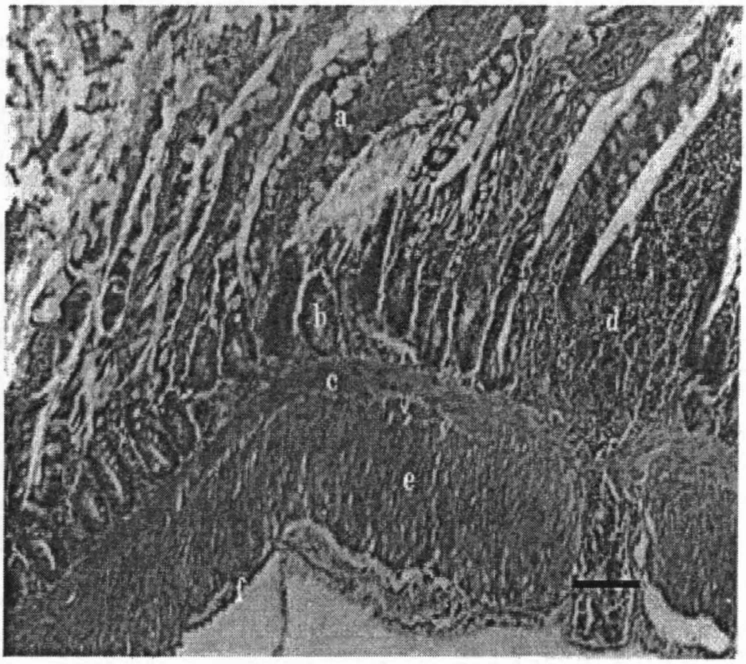


Figure 6. Rectum of the *C. fuciphaga*

The result of AB- PAS staining of the digestive tracts of *C. fuciphaga* is shown in Table 2.

Table 2. AB- PAS staining of the digestive tracts of *C. fuciphaga*

No.	Organ	Staining	
		AB	PAS
1.	Stomach		
	a. Proventriculus		
	- mucosa epithel	++	++
	- gland lumen	-	-
	b. Cardiac		
	- mucosa epithel	++	++
	- gland lumen	-	-
	c. Fundus		
	- mucosa epithel	++	++
	- gland lumen	-	-
	d. Pylorus		
	- mucosa epithel	+	++
	- gland lumen	-	-
2.	Intestines		
	a. Duodenum		
	- mucosa surface	+	+
	- Goblet cells	+	++
	- Lieberkuhn gland	+	+
	- gland lumen	-	-
	b. Jejunum		
	- mucosa surface	+	+
	- Goblet cells	++	+++
	- Lieberkuhn gland	++	++
	- gland lumen	-	-
	c. Ileum		
	- mucosa surface	+	+
	- Goblet cells	++	+++
	- Lieberkuhn gland	++	++
	- gland lumen	-	-
	d. Rektum		
	- mucosa surface	+	+
	- Goblet cells	++	+++
	- Lieberkuhn gland	++	++
	- gland lumen	-	-

Notes :- = negatif; +/- = very weak; + = weak; ++ = moderate; +++ = strong

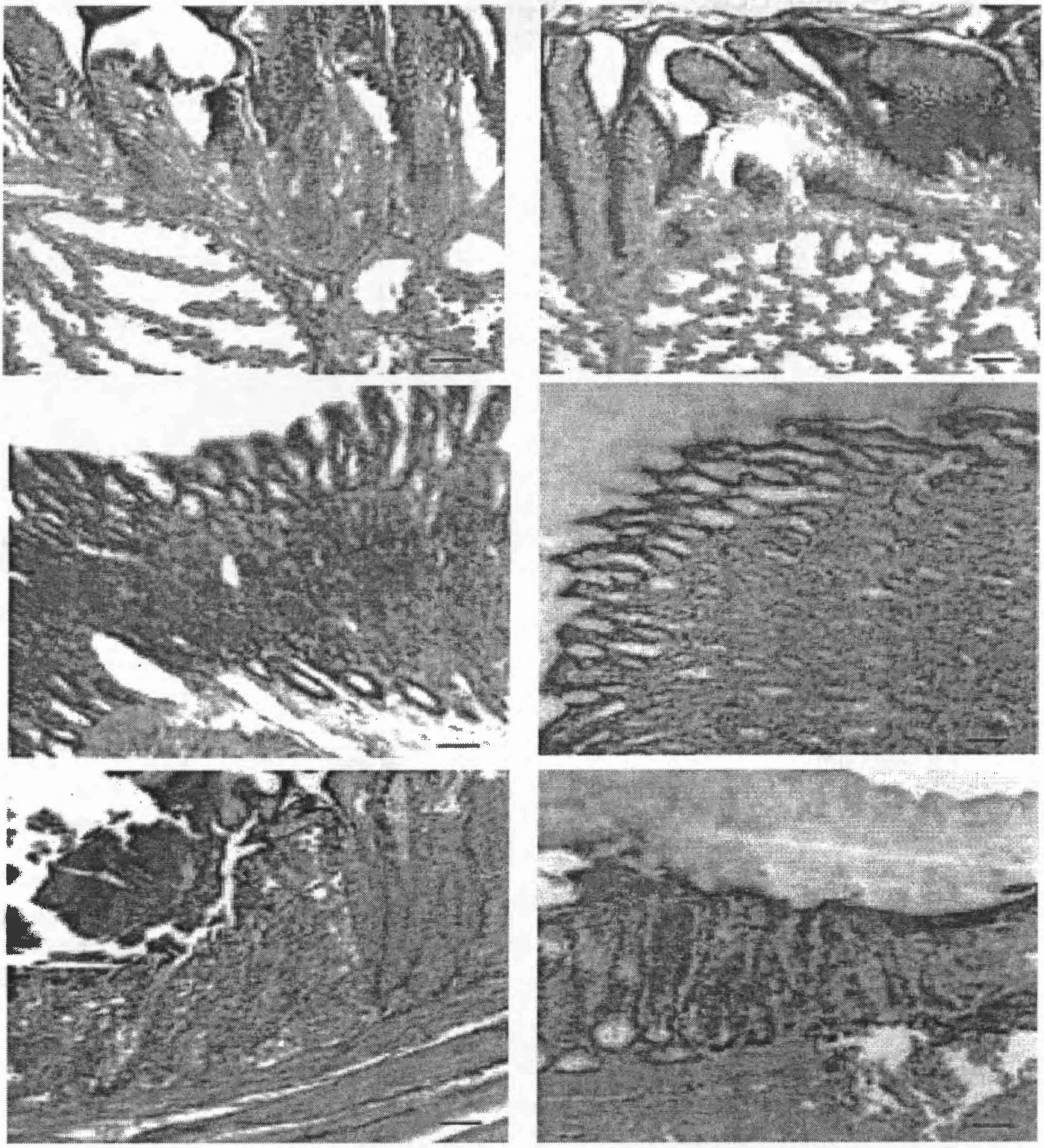


Figure 7. AB-PAS staining on the proventriculus mucus substances of the *C. fuciphaga*

A. cardia, B. fundus, C. pylorus
(a). light blue, very weak to weak positive reaction in AB staining
(b). red, moderate positive reaction in PAS staining

bar = 56 μ

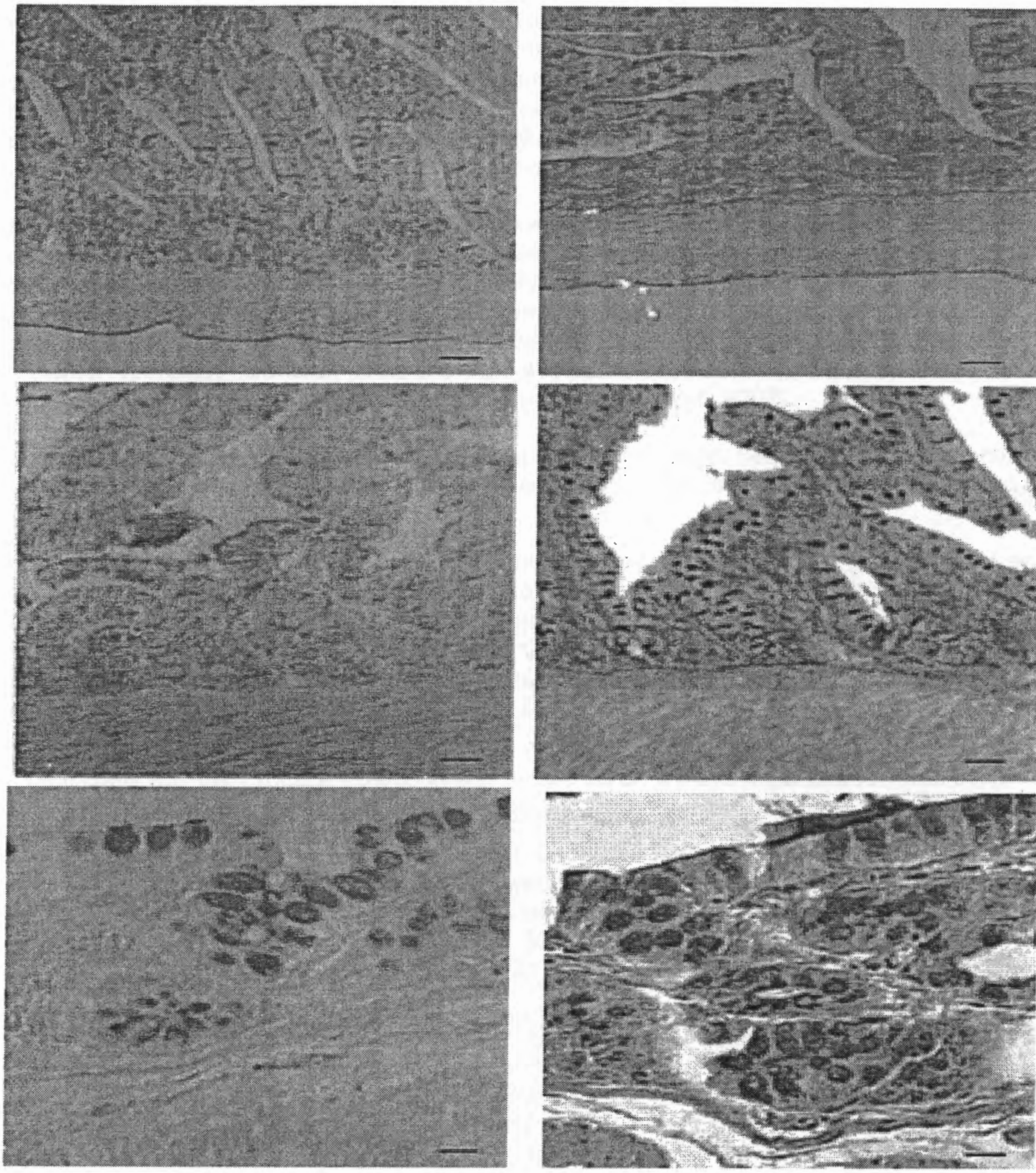


Figure 8. AB-PAS staining in Intestine Goblet Cells of the *C. fuciphaga.* A. duodenum, B. jejunum, C. rectum.

(a). light blue, weak to strong positive reaction in AB staining
(b) red, strong positive reaction in PAS staining

bar = 56 µ

The result of AB staining offers negative outcome for the stomach gland. In the mucus, along in the surface of stomach mucosa, the AB staining brings positive outcome. Meanwhile the PAS staining on mucus along the stomach surface and the neck cell offers a strong positive outcome. This positive reaction shows that the mucus produced by stomach gland contains neutral mucopolisacharida that is constructive to neutralize the excessive gastric juice and to protect stomach mucosa from gastric juice.

The AB-PAS staining to the intestines (duodenum, jejunum, and ileum) and rectum offers a positive result, especially to the mucus and Goblet cells that are spread between intestine's mucosa epithelia. The color intensity is mutual with the amount of Goblet cell that rises to the caudal. Further to the caudal, the color intensity is stronger. This is mutual to the larger amount of Goblet cells in the rectum, so the color intensity is stronger in rectum. This condition shows that the mucus substantion in intestine is either neutral or base.

DISCUSSION

The common way to determine the sexes of the birds is by observing the body size and the color of the feather, which mostly male birds have bigger body size than the females (Pettingill, 1985). But according to Chantler and Drissens (1995) this condition can not be applied to *C. fuciphaga,* it is difficult to determine the sex using exterior morphology. None of the samples showed developed *glandulae mandibulares* which probably the swifts are still immature or they were not active in the process of making their nest. Adult birds or those who are actively making their nest have *glandulae mandibulares* 5-6 mm in length. (Biro Pusat Rehabilitasi Sarang Burung, 1975).

The morphological study of digestive tracts is closely related with feeding behavior and the sort of food intake. The edible-nest swiflet (*C. fuciphaga*) is a very unique species. Its body size is considered as small to medium (Adiwibawa, 2000). The feeding behaviour of this swift is food hunting while its flying in a wide range area (Chantler and Drissens, 1995), so it is clearly described that even though it's a small bird, it has a high level of daily activity who needs large amount of energy to keep it flying all day long (Marzuki *et al.*, 2000).

To fulfill the high demand of energy, the digestive system plays an important role to convert the food into the nutrients which is needed for the growth and the formation of body cells (Cunningham, 1997). Moreover, the efficiency of digestive tracts deals a primary part to the digestive process of *C. fuciphaga.* The digestive efficiency includes the ingestion and digestion of the food, as fast and as efficient as can be (Cunningham, 1997).

C. fuciphaga has a high level of metabolic rate. This condition forces the swifts to consume high amount of food, which is not proportional compared to its body size, and they have to assimilate the food as fast and as efficient as it can (Carpenter, 1999).

Furthermore, to perform the high metabolic rate, the swift must also have light body weight, as light as possible to keep up an efficient fly. Therefore, the swift only have limited mouth muscles (Pettingill, 1985; Welty, 1982). Besides, it also has a very simple digestive tract (Carpenter, 1999; Stevens, 1988).

The efficiency of the digestive tract of *C. fuciphaga* can be assumed by the failed of crop dan caecum. Some avian species, such as chicken, has crop in the oesophagus area. The function of crop is as temporary food storage which the food will be processed into a softer form (Pesek, 1999; Welty, 1982). The failed of crop can be related with *C. fuciphaga*'s feeding behavior, where they are hunting the food while flying in a wide range area, so it needs high supply of energy and rapid metabolism process to absorb the food (Van and Berger, 1976).

The oesophagus glands of *C. fuciphaga* grows well, even some is still actively secreting the mucus (Dellman, 1993). *C. fuciphaga* is an insectivore, and insects is considered as dry feed mill (Mardiastuti *et al.*, 1999), therefore *C. fuciphaga* needs a huge amount of mucus as the lubricant when the food is transferred to the proventriculus (Perrins and Birkhead, 1983). Another species of swiflet's (*Hirundo rustica*) also failed of crop, and have similar feeding behavior and sort of food intake with *C. fuciphaga* (Nurhidayati, 2002).

Proventriculus is the place where the process of digestion firstly begins. Not like in mammals, in birds the chief cell of the proventriculus secretes the HCl and pepsinogen together at the same time (Caceci, 2000).

The surface of proventriculus mucosa is covered by a thick keratinoid layer, which produced by the combination of upper mucosa gland and the keratinisation process of desquamated surface epithelia (McLelland, 1990). The mucus is produced by the mucus cells that are enable to protect the proventriculus surface from gastric juice (Dellman, 1993). The gastric juice has pH range from 0.7 – 2.5. For some carnivore bird species, this low pH helps them to break big bones and meat (Welty, 1982). The motility function of proventriculus is to force the ingesta and digestive secretion move to the ventriculus, the muscle stomach (Pesek, 1999). Ventriculus has thick muscles partition and keratin layer. It plays important role in mechanical process of digestion by blending and grinding the food, mixed with gastric juice, into smaller and milder form so it will be easily absorbed by the small intestine (Carpenter, 1999).

The small intestine of *C. fuciphaga* has long and impenetrable vili, so its surface becomes wider and its absorption level is higher. This condition is closely related with the efficiency of bird digestion system (Pettingill, 1985). The small intestine is the main primary organ in chemical process of digestion and nutrition absorption, and also in the growth and formation of energy (Welty,1982; Cunningham, 1997). Goblet cells secrete protects intestine mucosa from gastric juice and irritation caused by mechanical wound from hard food, and to simplify bolus transportation to caudal (Dellman, 1993). Blood and lymph vessels are important things in supplying the nutrition, oxygen, body immune and the circulation of lymphocyte cells. The lymphocyte cells are spread solitarily or colonially in lamina propria to submukosa. These cells are essential for the body immune. In ileum we can find the Peyer's patches, that are formed by groups of lymphocyte cells (Dellman, 1993).

The Brunner gland is not found in *C. fuciphaga.* This condition also refers to the efficiency of birds digestion system. According to Stevens (1996), birds need more energy to fly compared to other vertebrates that run or walk, so the absorption and the metabolism pace is high and fast. To fulfill the high needs of energy, the food must be digested and absorbed rapidly. Therefore, the Lieberkuhn gland grows better than the Brunner gland (Duke, 1984; McLelland, 1975). The Lieberkuhn gland secretes the digestive enzyme (Bailey, 1996) and facilitates the absorption process.

Further to the caudal, the villies is getting shorter, its density and the amount of Lieberkuhn gland decrease, while the amount of Goblet cells is increasing. This condition shows that the highest level of chemical digestion and food nutrient occurs in the small intestines, especially the duodenum, and the jejunum that reabsorbs missing nutrient (Duke, 1984).

Large intestine of *C. fuciphaga* is considered short and doesn't have a clear border between colon and rectum, that is why it is called the colorectum or rectum (Duke, 1984). This condition is related to the efficiency of digestion system where the residue of the digestion is no longer needed so they are rashly thrown out from the body. The primary function of large intestine is to absorb water and electrolyte, and also the waste of the digestion (Cunningham, 1997).

According to Bank (1986), the function of caecum is the base of water absorption and cellulose digestion. Therefore, in *C. fuciphaga* the caecum doesn't grow, because the main food of this bird is insects with chitin skin, so the function of caecum as the base of cellulose digestion is not required. This condition is different with the birds that eat beans or plants. Chicken for example, has a good growing caecum (McLelland, 1990), and *Hirundo rustica* has a pair of rudimenter caecum (Yuliati, 2002).

CONCLUSION

1. In general, the digestive tract of the *Collocalia fuciphaga* has the same morphology with the other bird, but failed in crop and caecum.
2. Morphology of the digestive tract of the *Collocalia fuciphaga* is influenced by the feeding behavior and sort of food.
3. *Collocalia fuciphaga* has a simple and efficient digestive tract.

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