Gastrointestinal development of male and female domestic canary (*Serinus canaria*) in the starter and grower periods

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**Abstract.** The nutritional requirements of domestic canary (*Serinus canaria*) for life is determined by one of the roles of gastrointestinal organs. Thus, the evaluation of the development of canary gastrointestinal organs of males and females needs to know. The research method used was an observational survey with purposive sampling. The study used forty-eight canaries divided into two groups (twenty-four males and twenty-four females). Each group was taken a sample of six birds discontinue every month for four months. One-way ANOVA analyzed data at 95% confidence level. An Independent t-Test was used to see differences in gastrointestinal development between the two groups. A correlation test was used to determine the relationship between body weight with the development of gastrointestinal. The results showed that proventricular weight, ventricular weight, liver weight, small intestine weight, jejunum length, and ilium length for the two groups were significantly different between data collection times ($P<0.05$). The development of proventriculus, ventriculus, liver, small intestine, duodenum was significantly different ($P<0.05$) between the two groups. The growth in body weight correlates with the development of all gastrointestinal organs. Thus, it is concluded that the weight and size of the gastrointestinal organs increases with canaries age and gastrointestinal development differs between male and female groups.

1. **Introduction**

The canary is one of the domesticated birds [1-2], has a melodious voice [3-5] and a variety of coat colors [6]. Optimal growth and development will produce quality birds, both in terms of sound and variations in feather color. This is inseparable from the role of the digestive system. Feeding habits in birds will correlate with the morphology and physiology of the digestive system [7,8]. So that the anatomy and size of the gastrointestinal tract of birds are influenced by the type and quality of feed [9,10] and flight habits [11].

In general, the digestive tract of birds is composed of a beak, esophagus, stomach, small intestine, large intestine and cloaca. However, digestive tract variations occur as a result of the adaptation of the feeding habit, habitat and nature of their life-style. The digestive organs and gastrointestinal tract have been studied extensively in a variety of bird species including granivores, omnivores, insectivores, carnivores and herbivores [10,12–19]. However, the morphological information on the domestic canary digestive system is incomplete. The canary as granivores and herbivores birds will certainly provide a different gastrointestinal variety from insectivores, carnivores and omnivores eating birds.

On the other hand, the digestive tract will undergo rapid morphological and structural changes during the post-hatching period with increasing age. Some information about the development of the
gastrointestinal tract after hatching has been reported in several types of chickens [20,22] but information on canary is not yet available. Thus, the study of the morphology and development of the gastrointestinal tract in canary of various ages is needed for both males and females. This aims to obtain information on the differences in the development of the gastrointestinal tract of male and female canary and their correlation with body weight gain. Evaluation with a morphological approach and gastrointestinal tract development will not only add to the literature on this bird species, but will also help in understanding the biology, mode of domestication, management and nutrition of these species and finding applications in the treatment of pathoanatomy of poultry.

2. Method

2.1. Material and methods
The material used in this study was forty-eight of one week old domestic canary. The research method used was an observational survey method with purposive sampling technique. The samples were divided into two groups (twenty-four male and twenty-four female canary). Samples were taken discontinuously every month from the age of one month to the age of four months. At each sampling time, six male and six female canaries were taken to be sacrificed. The variables observed for gastrointestinal development included beak length, proventriculur weight, gizzard weight, liver weight, small intestine weight, duodenal length, jejunal length, illium length and rectum length.

2.2. Procedure of animal care and samples collection
The canary bird were kept in eight cages with each cage filled with six canaries. The cage used in this study measuring 100x80x60 cm is made of iron. All birds are reared with the same system and the same type of feed. The feed used is canary seeds, quail eggs and pakchoy vegetables and young corn fruit. Every day, canary seed feed is given as much as 30 percent of body weight. Feed was given twice a day and drinking water ad-libitum. The lighting during the study was given in equal portions.

Samples were taken by sacrificing using the Halal method, namely cutting the carotid arteries, jugular veins, and esophagus without anesthesia. Before being sacrificed, the length of the canary beak was measured first. Subsequently, it was dissected and isolated from the gastrointestinal organs. Isolation of the proventricular organs, gizzard organs, liver and small intestine organs is done by dissecting the ventral surface of the animal and taking organ samples. Then each organ measured its weight using a digital scale with an accuracy of 0.01 g. The isolated small intestine also measured the length of the duodenum, jejunal length, ilieum length and rectum length by placing it on a 1 mm square graph paper.

2.3. Measurement and analysis of data
Data of beak length, proventriculur weight, gizzard weight, liver weight, small intestine weight, duodenal length, jejunal length, ileum and rectum length were analyzed by one-way analysis of variance (ANOVA) at a 95% confidence level using SPPS IBM version 23. An Independent t-Test was used to see differences in gastrointestinal development between male groups with female groups. A correlation test was used to determine the relationship between body weight with the development of gastrointestinal.

3. Results and discussion

3.1. Gross anatomy of gastrointestinal organs
Gross anatomy of gastrointestinal organs with dissection ventral region can see below figure 1. This study revealed that, the oesophagus is not ably long with a well developed crop; thus stomach is differentiated into a glandular proventriculus and a muscular ventriculus or gizzard. The small intestine is divided into area duodenum, jejunum and ileum, and the ileum was the longest part of the small intestine. The large intestine consists of a short rectum and caeca no developed. In general, the
digestive tract of domestic canary same with quail (*Coturnix coturnix*) [23] and other domestic canary [24].

Anatomically the gastric gland or proventriculus is a longitudinal expansion of the esophagus with the appearance of external gastric papillae. The location of the proventriculus is caudal to the gizzard. In generally, the stomach of birds anatomically composed of two chambers: a cranial chamber (proventriculus) which connect to the esophagus and caudal chamber (ventriculus) which connect with duodenum [20]. The proventriculus is varied in the size in different species of birds in which it appeared small in size in the graminivorous, whereas, it was found large in the carnivorous [25].

The anatomy of the ventriculus or gizzard is biconvex, not surrounded by adipose tissue and is located from the left side of the abdominal wall, posterior to the sternum margo caudalis and at the angle between the os pubicand the last rib. The gizzard is much more developed having a thick hard cuticle, its wall consists of two strong smooth muscles. The biconvex form of pars muscularis is also found in domestic birds and some wild bird species [13,20,26]. The gizzard in Laughing Dove and Rock Pigeon is in the form of a biconvex lens with a rhombic circumference and the Laughing Dove is more oval [27]. The observed location of the gizzard is similar to the location of the gizzard of the adult starling bird (*Sturnus vulgaris*) which is located posterior to the proventriculus to the left of the midline plane, which is covered through part of the liver lobe [28]. The muscular ventriculus (gizzard) is important for mechanical digestion of food because birds do not have teeth [29]. It grinds and prepares food for further digestion in the intestine which is facilitated by the cuticle layer, the waterproof layer appears brown, green or yellow due to reflux of bile pigments from the duodenum [30].

The small intestine is divided into area duodenum, jejunum and ileum. The duodenal small intestine is located on the right side of the median plane. The duodenum is divided into two parts, namely pars descendens and pars ascendens which form the letter U (*ansa duodenalis*). In this duodenal ansa there is a pancreatic structure that interacts with the descending and ascending pars. The anatomical structure of the super local canary duodenum is similar to that of the duodenum in Bustards [14]. The projection of the ileum is parallel to the duodenum and is located in the midline, directly against the ventral abdominal wall (figure 1). The anatomical position of the ileum is between the duodenal ansa and the wall of the right ventricle. The local canary ceaca was unobserved. It is possible that the structure of the ceaca is very rudimentary and without a clear transition with the rectum [24].
Some ceaca birds develop well and number a pair, for example in bustards [14], Japanese quail [31] and common pigeon [32].

3.2. Gastrointestinal development of male and female canary

The gastrointestinal development of male canary is presented in table 1 and the female gastrointestinal is presented in table 2. Independent t-test results between gastrointestinal development in male and female groups were significantly different (P<0.05). This indicates that sex differences in canaries affect the development of organs and gastrointestinal tract. Independent t-test on gastrointestinal development of female canaries grows faster than male canaries at four months of age. A similar thing was found in the development of small intestine weight in Collared Dove, Ruddy Shelduck and Owl, which differed significantly (P<0.01) between male and female groups [33]. However, previous studies on the development gastrointestinal of Nigerian indigenous chicken of male and female were not significantly different [34], small Intestine development of African Ostrich Chicks of male and female were not significantly different [21] and in the weight development of proventriculus and gizzard long-tailed duck Clangula hyemalis were not significantly different [35]. This indicates that each species has different characteristics in gastrointestinal development.

| Table 1. The average size of gastrointestinal development in male domestic canary based on different ages. |
|---------------------------------------------------------------|
| **Organs size**                      | **Age of male domestic canaries** |
|                                 | B1                        | B2                        | B3                        | B4                        |
| Beak Lenght (cm)                  | 0.875±0.042a              | 0.988±0.020b              | 1.083±0.040c              | 1.116±0.040c              |
| Proventriculus Weight (g)         | 0.095±0.005a              | 0.22±0.014b              | 0.25±0.014c              | 0.473±0.010d              |
| Gizzard Weight (g)                | 0.283±0.019a              | 0.585±0.025b              | 0.60±0.010b              | 0.655±0.020c              |
| Liver Weight (g)                  | 0.451±0.021              | 0.573±0.019b              | 0.651±0.029c             | 0.845±0.035d              |
| Small Intestine Weight (g)        | 0.746±0.032c              | 1.233±0.090b              | 1.301±0.050c             | 1.571±0.041c              |
| Duodenum Length (cm)              | 5.083±0.204e               | 5.05±0.234e               | 5.05±0.333e               | 5.166±0.408ee             |
| Jejunum Length (cm)               | 5.166±0.408d              | 5.333±0.516e              | 5.416±0.491e             | 7.166±0.408d              |
| Ileum Length (cm)                 | 14.166±0.408d             | 15.166±0.516b             | 15.166±0.258b            | 18.033±0.326c             |
| Rectum Length (cm)                | 1.483±0.075a              | 2.066±0.163b              | 2.066±0.103b             | 2.316±0.194c              |

Note: different letters above (superscript) show a significant difference between sampling times in the LSD test with an error rate of 5% while ns: is not significant. B1: age of one month, B2: age of two months; B3: three months of age; and B4: age four months.

Based on table 1 and 2, beak length, proventriculus weight, ventricular weight (gizzard), liver weight, small intestine weight, jejunum length, ileum length and rectum length were significantly different (P<0.05) between sampling times, except for duodenum length of male canary was not significantly different (P>0.05). The average gastrointestinal weight and size increases with the age of the canary bird (table 1 and 2). It shows that the growth of cells and tissues both in the development of organs and gastrointestinal tract.

Proventricular weight (table 1 and 2) increased more rapidly in canaries aged three months to four months of age than at one month of age two months (P<0.05). Gizzard weight (table 1 and 2) increased more rapidly in canaries aged one month to two months than at two months to four months (P<0.05). Previous studies on the development of proventriculus weight and gizzard weight in young turkeys continued to increase more rapidly postnatally until they remained relatively constant for eight days [36]. In both groups of male and female canaries, the development of proventriculus and gizzard has not reached a stationary development phase because at four months of age canaries are still included in the grower period.
Correlation of body weight with gastrointestinal parameters (beak length, ventricular weight, gizzard weight, liver weight and total small intestine weight) in male and female canaries during the age of four months are presented in Table 3.

### Table 2. The average size of gastrointestinal development in female domestic canaries based on different ages.

| Organs size          | Age of female domestic canaries |
|----------------------|---------------------------------|
|                      | B1                          | B2                          | B3                          | B4                          |
| Beak length (cm)     | 0.850±0.054<sup>a</sup>      | 0.966±0.103<sup>a</sup>      | 1.100±0.063<sup>b</sup>      | 1.166±0.082<sup>b</sup>      |
| Proventriculus weight (g) | 0.092±0.007<sup>a</sup>      | 0.136±0.008<sup>b</sup>      | 0.412±0.021<sup>c</sup>      | 1.302±0.018<sup>d</sup>      |
| Gizzard weight (g)   | 0.270±0.008<sup>a</sup>      | 0.316±0.028<sup>a</sup>      | 0.755±0.021<sup>b</sup>      | 2.783±0.194<sup>c</sup>      |
| Liver weight (g)     | 0.425±0.028<sup>a</sup>      | 0.585±0.026<sup>b</sup>      | 1.097±0.093<sup>c</sup>      | 2.551±0.086<sup>d</sup>      |
| Small intestine weight (g) | 0.730±0.021<sup>a</sup>      | 1.101±0.089<sup>b</sup>      | 2.93±0.051<sup>c</sup>       | 6.958±0.105<sup>d</sup>      |
| Duodenum length (cm) | 5.083±0.376<sup>a</sup>      | 5.783±0.402<sup>b</sup>      | 5.900±0.536<sup>b</sup>      | 6.108±0.382<sup>b</sup>      |
| Jejunum length (cm)  | 5.100±0.368<sup>a</sup>      | 5.416±0.491<sup>ab</sup>     | 5.967±0.505<sup>b</sup>      | 7.833±0.450<sup>c</sup>      |
| Ileum length (cm)    | 15.900±0.486<sup>a</sup>     | 16.733±0.723<sup>a</sup>     | 18.917±0.646<sup>b</sup>     | 20.283±0.504<sup>b</sup>     |
| Rectum length (cm)   | 1.500±0.063<sup>a</sup>      | 2.184±0.222<sup>b</sup>      | 2.216±0.271<sup>b</sup>      | 2.517±0.256<sup>b</sup>      |

Note: different letters above (superscript) show a significant difference between sampling times in the LSD test with an error rate of 5% while ns: is not significant. B1: one month; B2: two months; B3: three months; and B4: four months old.

Total small intestine weight increased faster at three months to four months old from one month to two months old (table 1 and 2). The relative lengths of the duodenum in male canaries were the same (P>0.05), while the relative lengths of the jejunum and ileum increased sharply from three months to four months from one month to two months old. Thus, the overall weight development of the gizzard, duodenum, jejunum and ileum as well as the total length of the small intestine for four months is increasing. Previous studies have reported on gastrointestinal weight gain in broilers [37] and chicks from crossing Pelung chickens with native chickens up to 28 days of age [38].

Gradually the development of the small intestine from the age of one month to the age of four months, there was a significant change in the parameters of the measured small intestine weight and length. The same pattern of small intestine weight gain was also found in chickens with native chickens up to 28 days of age [40]. In ostriches, it was also reported that the development of the small intestine which includes weight, length and surface area of the small intestine as well as the number of goblet cells gradually increased postnatal age from 1 day to 90 days [21].

The relative lengths of the duodenum, jejunum and ileum peak at four months of age. This can be explained that the longer the jejunal organ, the more villi will be owned so that the surface area of the villi will be wider to absorb nutrients. This is consistent with previously reported results on ostriches [41,21]. The increase in the length of the intestinal tract at the age of four months, especially the jejunum indicates a wider area of absorption of nutrients. This can be explained that the longer the jejunal organ, the more villi will be owned so that the surface area of the villi will be wider to absorb nutrients [42]. The number of villi in the intestinal villi and crypts in ostriches is influenced by age [21]. In crows, the number of villi is significantly different in each part of the small intestine and the most in the ileum then jejunum and the least in the duodenum [43]. Whereas in pheasants (Phasianus colchicus) villi develop very well in the duodenum [44]. The difference in the number of villi in each part of the small intestine is influenced by age, type of feed, feeding habits and the environment.

### 3.3. Correlation between body growth with gastrointestinal development

Correlation of body weight with gastrointestinal with parameters (beak length, ventricular weight, gizzard weight, liver weight and total small intestine weight) in male and female canaries during the age of four months are presented in Table 3.
Table 3. Correlation between body weight (BW) with gastrointestinal organ.

| Parameter                        | Female (%) | Male (%) |
|----------------------------------|------------|----------|
| BW with beak (mm)                | 86         | 93.9     |
| BW with proventrikulus (g)       | 89.9       | 91.2     |
| BW with gizzard (g)              | 86.6       | 95.2     |
| BW with liver (g)                | 91.3       | 92.3     |
| BW with small intestine (g)      | 93.1       | 97.2     |

Based on table 3, it shows that body weight correlates with proventricular weight and gizzard weight for both male and female canaries, respectively 86.0%; 93.9%; 89.9% and 91.2%. A similar positive correlation was reported between body weight with proventricular weight and gizzard weight in Long-tailed Duck (*Clangula hyemalis*) [35].

Intestinal weight was reported to increase proportionally to body weight in the case of ducks, broilers [45] and ostriches [21]. In addition, in poultry species it has been reported that gut growth is directly proportional to an age-related increase in metabolic rate [21,45,46]. Furthermore, several researchers have reported that the whole, body growth rate is determined in part by the distribution of tissues in the digestive tract [47]. In this study, we showed that total intestinal weight increased with increasing body weight (male \( r = 97.2\% \) and female \( r = 93.1\% \)). Canaries body weight and small intestine weight and length increase from one month to four months old. In broilers aged 10 days to 50 days it was reported that all parameters of weight and intestinal length were highly correlated with body weight and length of the digestive tract [48]. In addition, it was also reported that duodenal length and weight, jejunal length and weight, ileal length and weight, caecal length and weight, colon length and weight, length and weight of the digestive tract were related to body weight for Collard Dove, Ruddy Shelduck and Scops owl (*Otus brucei*) [33].

4. Conclusion
The weight and size of the gastrointestinal organs increases with canary bird age and gastrointestinal development differs between male and female groups. Body weights of both male and female groups correlated with gastrointestinal development.

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