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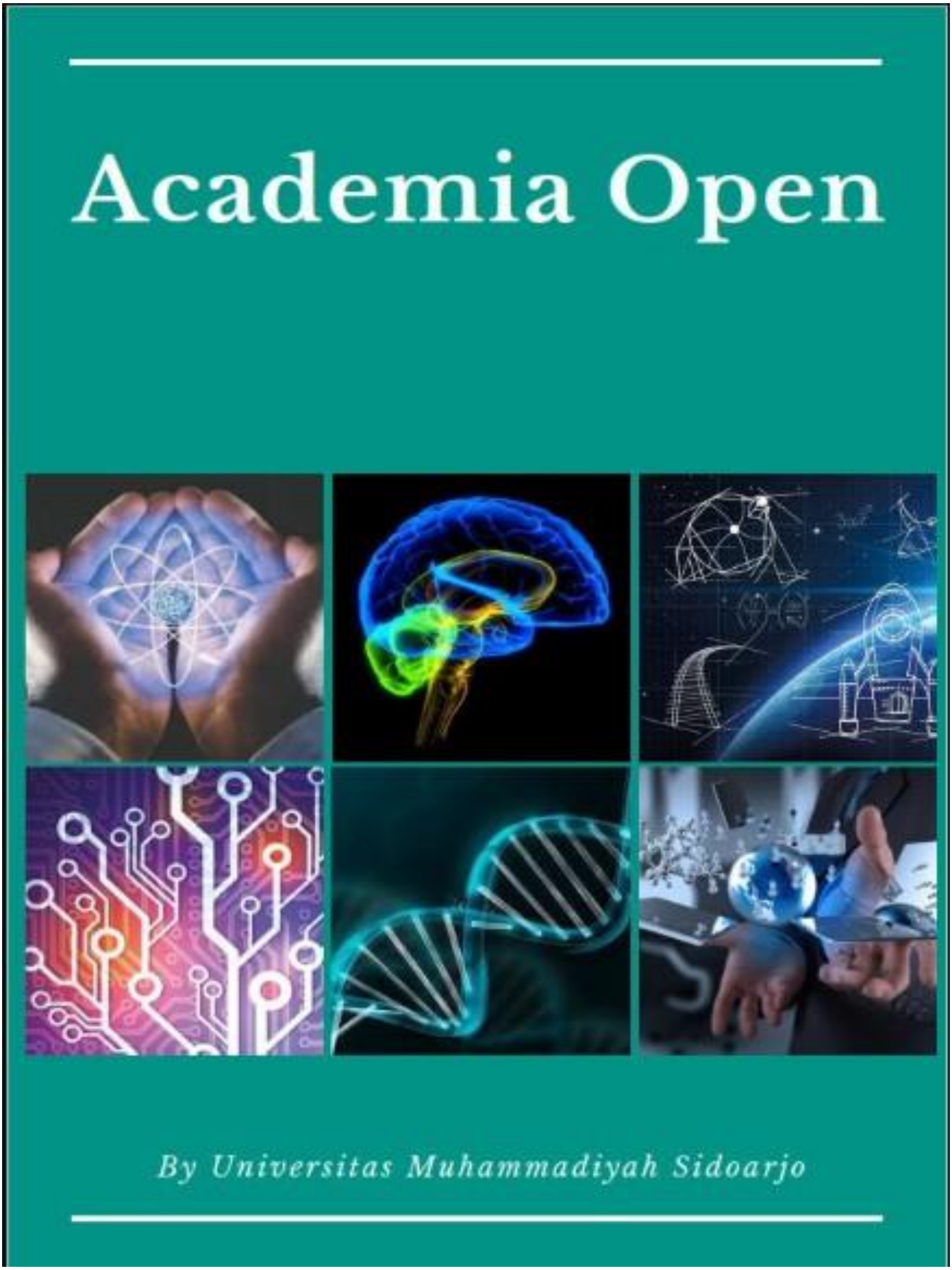

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Common Factors and Nutrients Affecting Intestinal Villus Height

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Abstract

General Background: The avian digestive system exhibits structural adaptations that enable rapid digestion and nutrient absorption from diverse food sources. **Specific Background:** The small intestine, consisting of duodenum, jejunum, and ileum, plays a central role in digestion, with morphological variations observed among bird species. **Knowledge Gap:** However, limited comparative data exist regarding how intestinal morphology, length, and weight differ among bird species with varying dietary patterns. **Aims:** This study aims to determine morphological characteristics and morphometric variations of the small intestine in seven bird species with different feeding types. **Results:** The findings reveal significant differences ($p \leq 0.05$) in intestinal length, weight, and structural configuration among species, with the mallard exhibiting the longest intestine and zebra finch the shortest, while variations in jejunum shape were identified as U-shaped, cone-shaped, or short and wide depending on species. The ratio of intestinal length and weight relative to body size also differed markedly. **Novelty:** This study provides a comparative morphological dataset linking intestinal structure with dietary variation across multiple avian species. **Implications:** These results contribute to understanding digestive adaptation in birds and provide anatomical references for veterinary and comparative physiology studies.

Highlights:
- Significant Variation in Intestinal Measurements Observed Across Seven Avian Species
- Jejunum Configuration Differs Into Three Distinct Structural Patterns Among Species
- Dietary Type Corresponds With Variation in Intestinal Proportions and Structure

Keywords: Avian Anatomy, Small Intestine, Morphology, Digestive System, Bird Nutrition.

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Introduction

In comparison to other animal species, the digestive system of basically all birds has experienced substantial changes in physiological structure, birds have evolved to make use of the chemical and physical qualities of a wide range of food sources [1][2].

In comparison to mammals, bird digestive tracts are comparatively short. The majority of this drop occurs in the intestine, implying that the bird has less area for digestion and absorption than its mammalian relatives. This results in shorter nutritional storage durations in the intestines and lower nutrient recovery efficiency [3].

Many birds have a narrow metabolic margin of safety and may require a steady supply of food to be active. Birds can't afford to keep large amounts of food for lengthy periods, and they digest their food much faster than mammals. Furthermore, in terms of body weight, the avian digestive system is lighter than that of mammals [4][5].

A lightweight beak has replaced the teeth and strong jaw muscles that birds once had. However, food particles can be temporarily held in the crop before being reduced in size by the muscular gizzard. However, birds and mammals are structurally very different, and nowhere is this distinction more apparent than in the way their digestive systems are organized [4].

Anatomically, the intestines occupy the caudal section of the body cavity, contacting the gizzard and reproductive organs extensively, they open into the cloaca and are made up of the duodenum, jejunum, ileum, and colon. In herbivorous birds, they show two ceca that start from the ileocolic junction and diversion accompanies the ileum [6].

Most of this is individual. In addition to the absorption of carbohydrates, fatty acids, and amino acids, the small intestine is the initial site where enzymes are broken down. As a function, it could play a significant role in increasing digestion pace while reducing digest mass, the small intestine's morphological modulations reflect a vital necessity for specialization to quickly break down food and absorb its contents [7].

Materials and Methods

Experimental Animal Preparation

Seven species of birds were collected for the purpose of the study. All of these birds are normal and clinically healthy. The study was based on the differences in their food types. Five of each type of birds were collected.

The birds were: falcon (Falco atriceps) , mallard (Anas Platyrhynchos) , domestic pigeon (Columba Livia domestica), white-eared bulbul (Pycnonotus leucotis), canary (Serinus canaria), european starling (Sturnus vulgaris) and zebra finch (Taeniopygia guttata). Birds were collected from the animal market in Basrah and Baghdad. All the birds were adults and without attention to their sex (male or female).

The birds have subsequently sedated with Ketamine at 15 mg/kg of body weight administered into the thoracic or femoral muscles using a 1cm3 syringe. The bird was then left for approximately five minutes to achieve total anesthesia [8].

Experimental design

Anatomical Measurement's

1 . The Length

The length of the body was measured in centimeters, starting at the front and going down to the back. The total length of the small intestine was calculated after extracting the entire small intestine from the abdomen and placing it in a straight line on a plate. Following the extirpation of the relative mesentery, the relative length of the small intestine was computed using the following equation.

$$Ratio = \frac{Length\ of\ small\ intestine}{lenght\ of\ bird} \times 100\%$$

2 . The Weight

Each bird's weight was measured using sensitive balance before anesthesia and the weight of the entire small intestine was calculated after emptying its contents and cleaning with normal saline slowly, the relative weight was calculated by using the equation below.

$$Ratio = \frac{Weight\ of\ small\ intestine}{weight\ of\ bird} \times 100\%$$

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Statistical Analysis

results were expressed as mean values (±SD) stranded deviation of studied measurement. The ANOVA was used to determine statistical difference (p≤ 0.05) among bird type models [9].

Result

1 . Shape and Position of the mall Intestine

The small intestine seems to be a long, convoluted tube that stretches from the gizzard to the point where it joins the large intestine. The small intestine of the investigated birds had three segments: the duodenum, jejunum and ileum. The small intestine was divided into multiple loops that took up the majority of the abdomen's caudal region. It is localized at the right side of the coelomic cavity and associated to the right side of both the proventriculus and the gizzard figures (7,9,11,13,15,17,19).

All birds had a U-shaped duodenum with two loops, descending or ventral limb and ascending or dorsal limb figures (8,10,12,14,16,18,20). The intestinal loops lie at the abdominal floor between this loop and the pancreas figures (7,9,11,13,15,17,19).

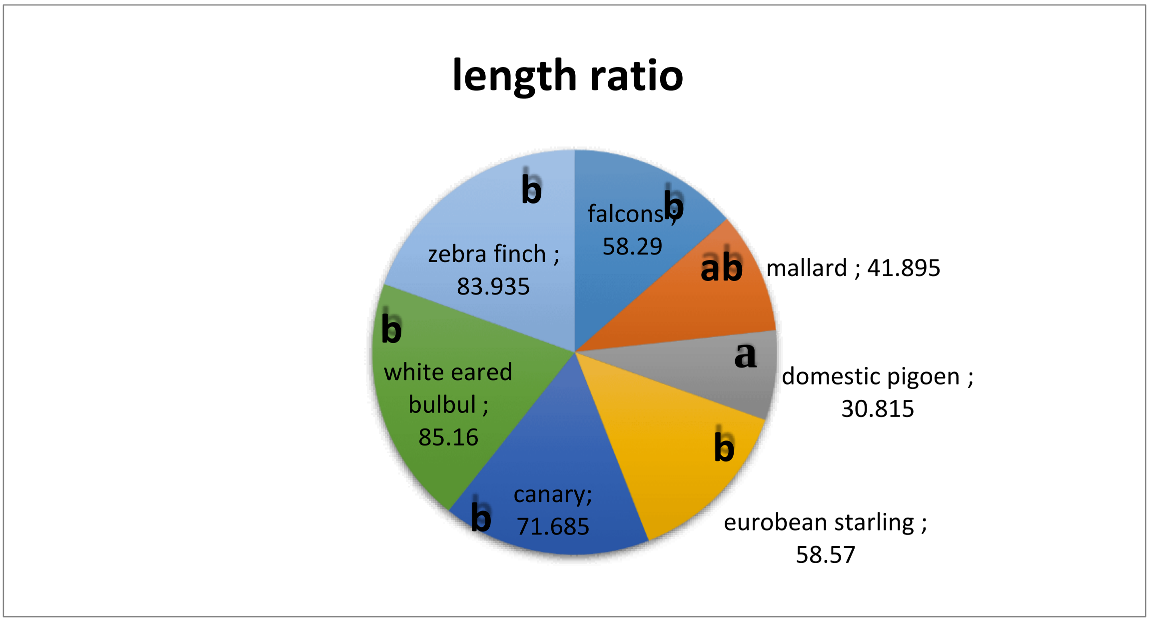
The second part of small intestines was the jejunum in mallard and falcon consists of multiple U-shaped loops figures (8,10) In domestic pigeon and canary, a cone contained centripetal coils, a sigmoid flexure, and centrifugal coil figures (12,18) whereas in white-eared bulbul, European starling, and zebra finch, the jejunum was wide and short figures (14,16,20).

The ileum continues without interruption from the jejunum and opposite the ceca apex figures (8,10,12,14,16,18,20). The falcon has a vitelline diverticulum or Meckel diverticulum found between the jejunum and ileum which is small outgrowth that is indicates the previous yolk sac attachment figure (8).

2 . The length

chart (1) shows that the falcon, mallard, domestic pigeon, European starling, canary, white-eared bulbul and zebra finch were all species whose average ratio of intestinal length to body length was observed. It is clear, that the length of ratio was varied markedly among the studied birds (P≤0.05), which high ratio in white-eared bulbul was (85.16%) and the low ratio in domestic pigeon it was (30.815%). The following birds are listed in decreasing order of range size: zebra finch (83.935%), European starling (71.685%), canary (58.57%), falcon (58.29%) and mallard (41.895 %)

Chart (1) The ratio of small intestine length / body length in selected bird (%) The different small letters refer to a significant deference (P ≤ 0.05) between selected birds .



The birds' length was recorded as represented in figure (2), which varied significantly (P≤0.05) as the following, the longest was the mallard (66 ± 2.82cm) followed by the falcon (61.5 ± 2.12cm), domestic pigeon (27.6 ± 0.84cm), canary (18.5 ± 0.70cm), European starling (14.5 ± 0.70cm), white-eared bulbul (11.5 ± 0.70cm) and the shortest was in the zebra finch (9.65 ± 0.21cm).

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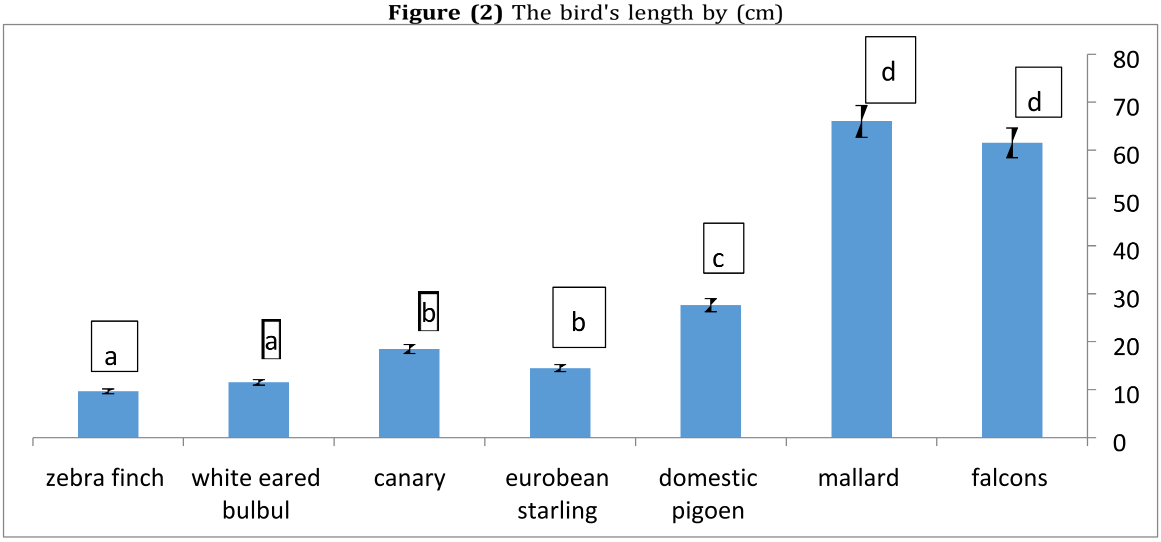
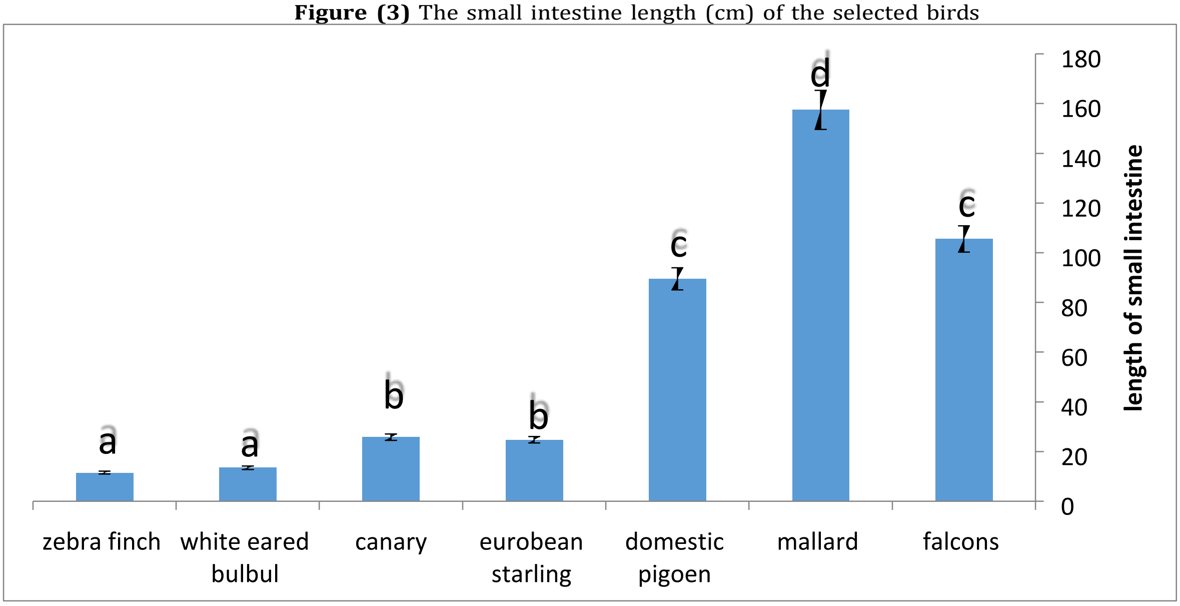
Figure (2) The bird's length by (cm)



The different small letters refer to a significant deference (P ≤ 0.05) between selected birds.

The length of the intestine in selected birds differs from one to another. It is large in mallard (157.5 ±3.53cm) followed by falcon (105.5 ±3.53cm), domestic pigeon (89.5±0.70cm), European starling(25.8±0.56cm), canary (24.75 ±0.35cm), white-eared bulbul (13.5 ±0.70cm) and the least was in zebra finch (11.5 ±0.42cm). It varied markedly among the studied birds (p≤0.05) figure (3)

Figure (3) The small intestine length (cm) of the selected birds



The different small letters refer to a significant deference (P ≤ 0.05) between selected birds

3 . The Weight

Chart (4) shows the average ratio of small intestine weights which differs from one to another, with varied significantly (P≤ 0.05) among the rest of birds, the heaviest ratio was in mallards; it was (3.125 %), and the lights was in canaries (1.27 %). The other selected birds in the study have different weights between mallards and canaries. Descending; white-eared bulbul (3.015 %), falcon (2.795 %), zebra finch (2.72 %), European starling (1.605 %) and domestic pigeon (1.41%).

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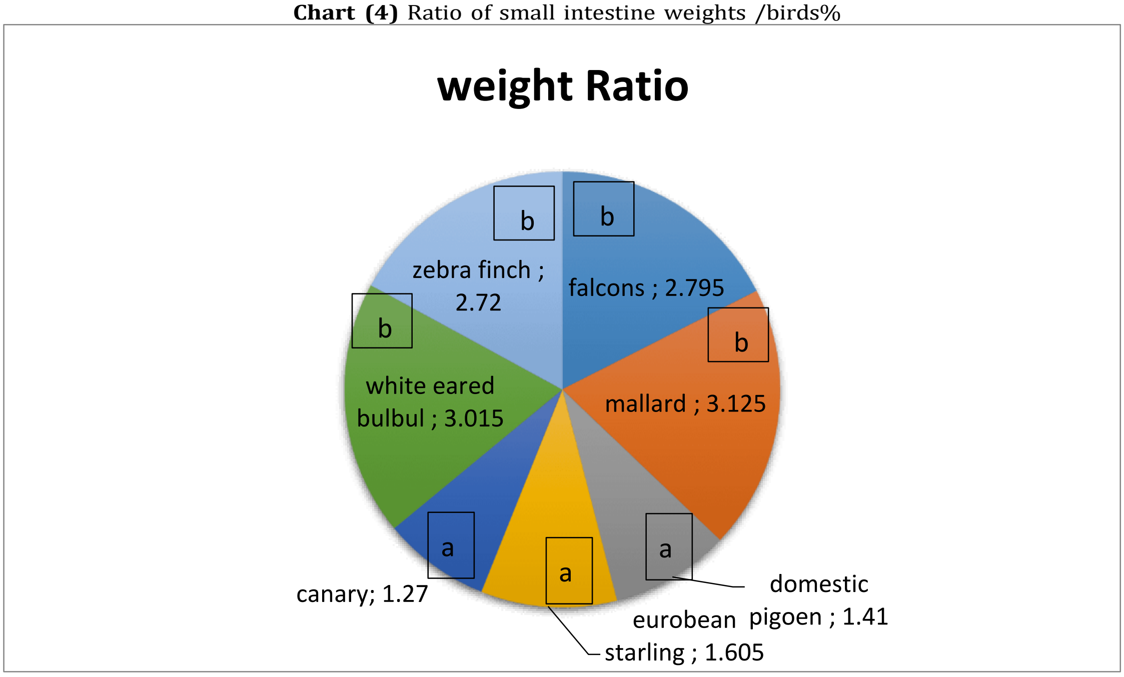
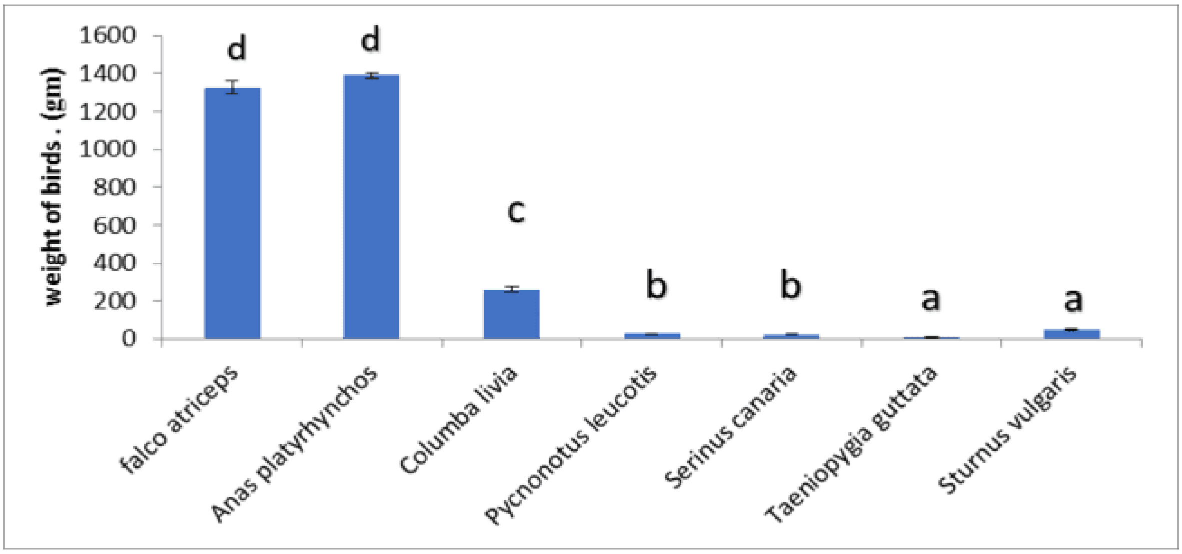
Chart (4) Ratio of small intestine weights /birds%



The different small letters refer to a significant deference (P ≤ 0.05) between selected birds

While the weights of the birds varied, the heaviest weight was found in the mallard (1390± 14.14gm), followed by falcon (1326 ± 33.9gm), domestic pigeon (260 ±14.14gm), European starling (50.33 ±1.18gm), white-eared bulbul (25.945 ± 0.9gm), canary (24.9 ±1.97gm) and the light weight in zebra finch (9.55 ± 0.6gm) it was a statistically significant difference (p≤0.05) figure (5).

Figure (5) Explain the weight of selected birds (gm). The different small letters refer to a significant deference (P ≤ 0.05) between selected birds.



The weight of the small intestine in birds is different in the selected birds and varied significantly (P≤ 0.05) among the rest of the birds. The falcon had the highest weight (47.5 ± 3.53gm) followed by mallard (44.5 ± 3.53gm), domestic pigoen (18.5 ± 2.12gm), european starling (3.125 ± 0.03gm), canary (1.95 ± 0.07gm), white-eared bulbul (0.86 ± 0.05gm) and the lightest weight was in zebra finch (0.35 ± 0.01gm) figure (6).

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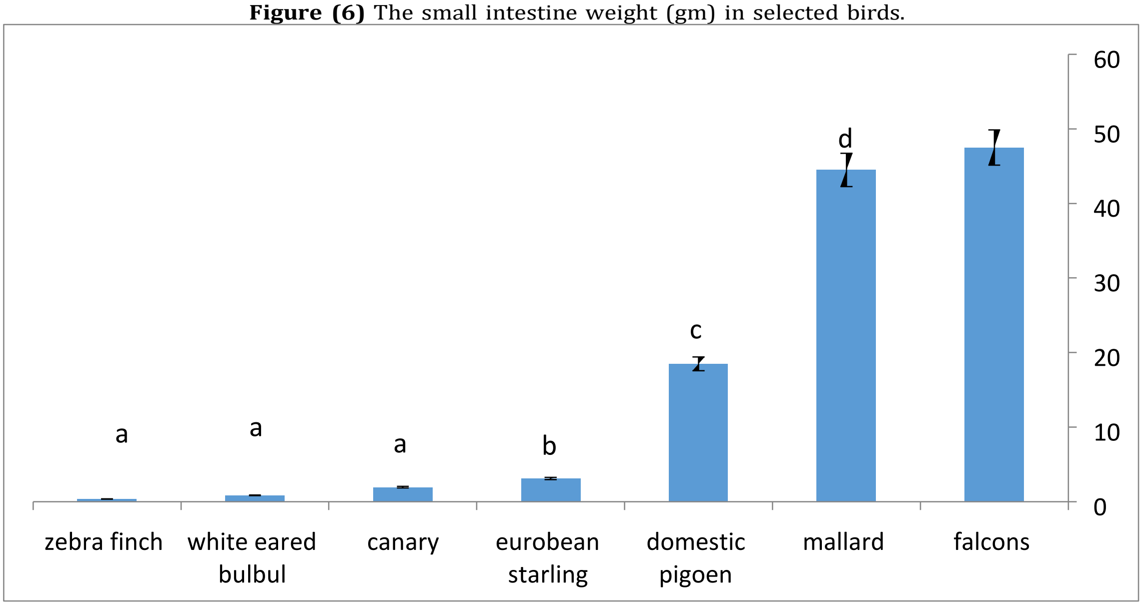
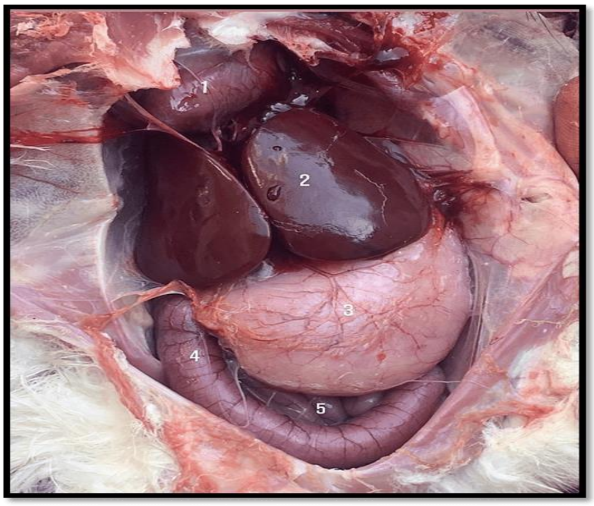
Figure (6) The small intestine weight (gm) in selected birds.



The different small letters refer to a significant deference (P ≤ 0.05) between selected birds



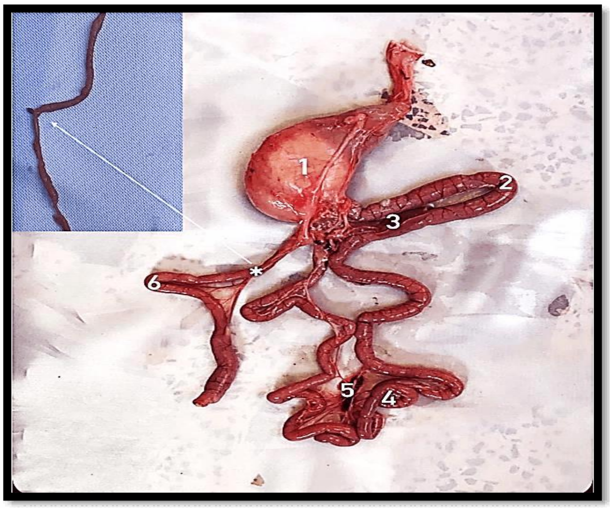


Figure (7) Visceral of falcon .1. heart, 2. liver, 3. Gizzard, 4. duodenal loop and 5. jejunum.

figure (8) The falcon small intestine and attached organs 1. Gizzard, 2. duodenal loop, 3. Pancreas, 4. Jejunum, 5. Mesenteric 6. Ileum, and star referred to Meckel diverticulum

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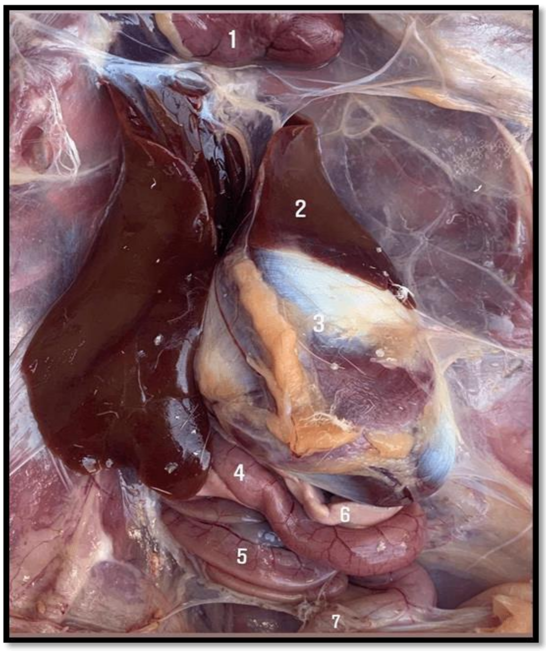

figure (9) Visceral of Mallard .1. heart 2. liver 3. Gizzard 4. duodenal loop 5 Jejunum 6. Pancreas 7. large intestine.

figure (10) The mallard small intestine and attached organs 1. Gizzard, 2. duodenal loop, 3. Pancreas, 4. Jejunum, 5. Mesenteric 6. Ileum

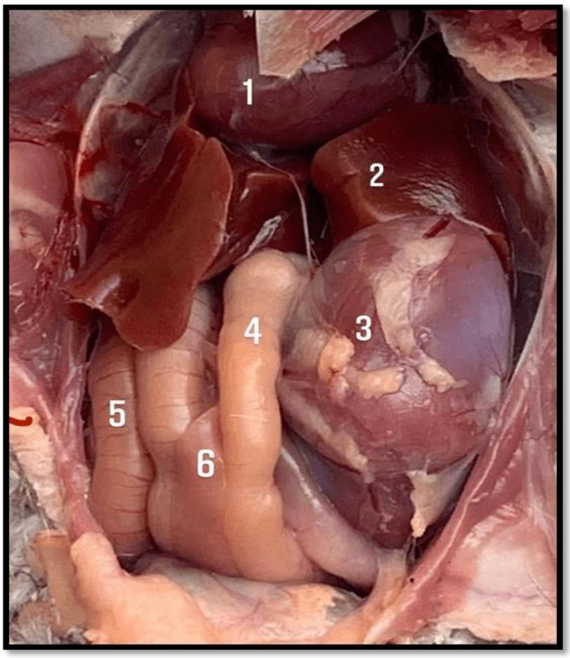

figure (11) Visceral of domestic pigeon 1. heart, 2. liver, 3. Gizzard, 4. duodenal loop 5. Pancreas and 6. jejunum.

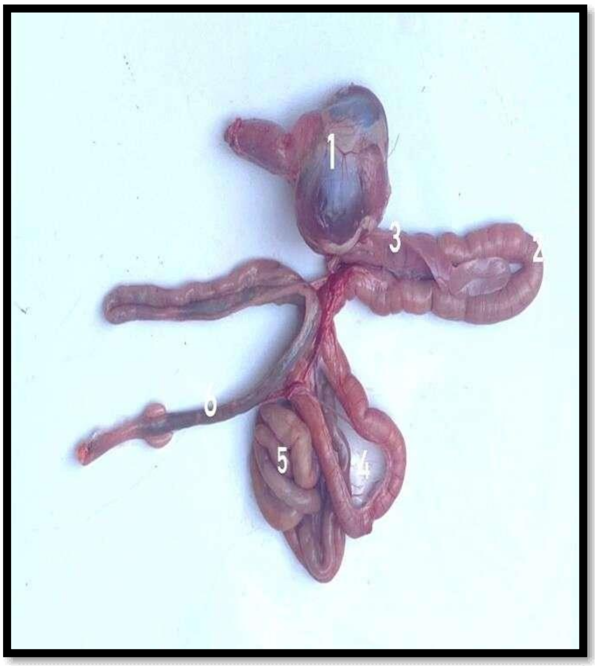

figure (12) The domestic pigeon small intestine and attached organs 1. Gizzard 2. duodenal loop, 3. Pancreas, 4. Mesenteric ,5. Jejunum and 6. Ileum

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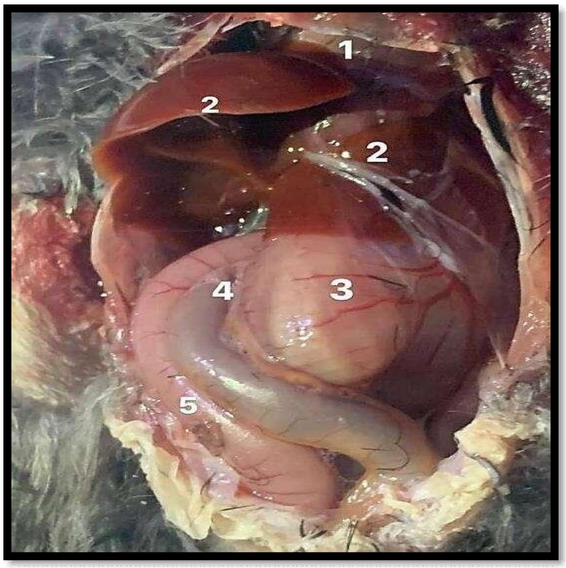

figure (13) Visceral of European starling.1. heart ,2. liver, 3. Gizzard 4. Duodenal loop 5. Jejunum.

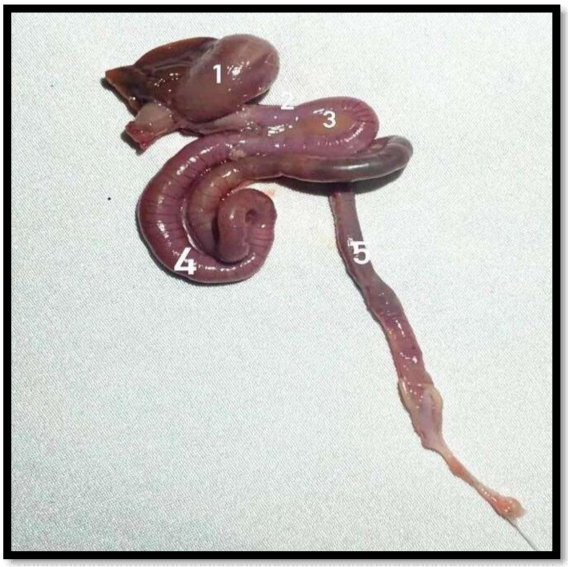

figure (14) The European starling small intestine and attached organs 1. Gizzard, 2. Duodenal loop, 3. Pancreas, 4. Jejunum and 5. Ileum

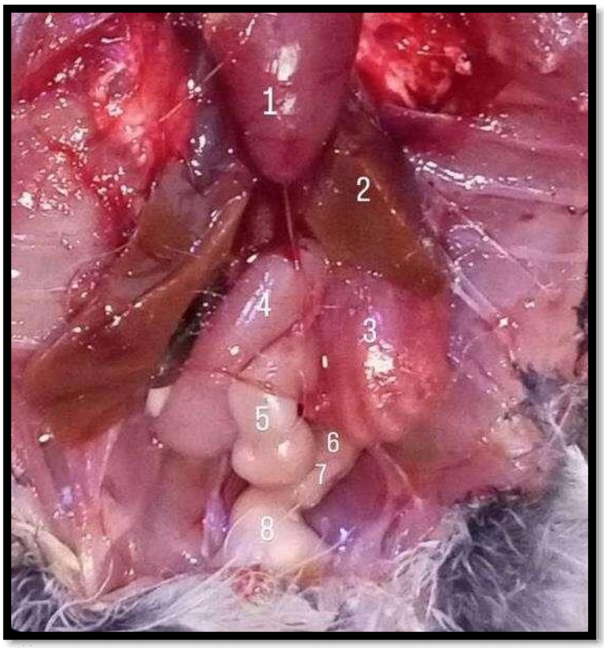

figure (15) Visceral of white-eared bulbul 1. heart, 2. liver, 3. Gizzard, 4. duodenal loop, 5. Jejunum, 6. Ileum, 7. cecum, 8. Large intestine

figure (16) The white-eared bulbul small intestine and attached organs 1. Gizzard 2. duodenal loop 3. Pancreas 4. Jejunum and 5. Ileum

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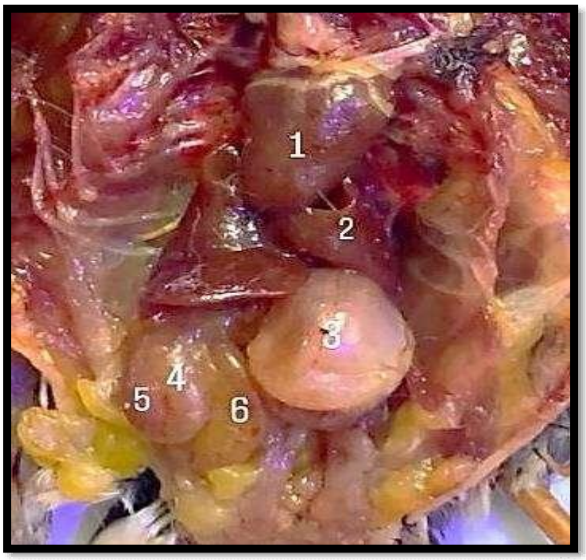

figure (17) Visceral of canary 1. Heart, 2. liver, 3. Gizzard, 4. Duodenal loop enclosing pancreas, 5. Pancreas and 6. Jejunum.

figure (18) The canary small intestine and attached organs ,1. Gizzard, 2. duodenal loop, 3. Pancreas 4. Jejunum and 5. Ileum.

figure (19) Visceral of zebra finch 1. Heart, 2. Liver, 3. Gizzard, 4. Duodenal loop, 5. Pancreas and 6. Jejunum

figure (20) The zebra finch small intestine and attached organs 1. Gizzard, 2. duodenal loop 3. pancreas, 4. Jejunum and 5. Ileum.

Discussion

The small intestine was cross morphologically divided into the duodenum, the jejunum and ileum, histologically was lined by a simple columnar epithelium with goblet cells, similar result was found [10].

The small intestine has a different morphological characteristic. The duodenum and ileum were similar in the selected birds while the different was found that the jejunum form of these birds is divided into three shapes and size with the mallard and the falcon having a U-shaped, the domestic pigeon and the canary having a cone-shaped and the white eared bulbul, the zebra finch and the European starling having a small and wide jejunum. These results agree with [6].

where was found in the duck and goose, the jejunum is arranged in several U-shaped loops; in the pigeon, it forms a cone-shaped mass with outer centripetal and inner centrifugal turns. In insect- and fruit eating birds the jejunum is very short and wide. The Meckel's diverticulum, (vitelline diverticulum) in falcon which shows as a small bump, incomplete yolk sac and a blind duct remnant that between the ileum and jejunum), this results similar with [11][12].

Around the pancreas, the proximal part of the duodenum forms a "U" shape. The parts of the intestine distal to the duodenum and anterior to the cecal junction, respectively, are referred to as the jejunum and ileum. A few anatomical characteristics can be used to distinguish these regions such as size and shapes of jejunum [11].

All birds don’t have anatomical features, except the falcon, that showed anatomical the Meckel's diverticulum between the jejunum and ileum, agreed this morphological results with our result. The white-eared bulbul (85.16%), zebra finch (83.935%), European starling (71.685%), canary (58.57%), falcon (58.29%), mallard (41.895%), and domestic pigeon (30.815%) were the species with the mean ratio of intestinal length to body length [13][14]. Where the results are close to [15], who showed that carnivorous birds had a smaller small intestine than herbivores or frugivores.

In this study, the pancreas encloses the U-shaped duodenum, and this finding was supported by [13]. On the other hand, the current findings are in agreement with those of [14], who revealed that birds that eat mostly herbivorous plants have longer intestines than those that eat meat.

found that the pigeons (Columba livia) small intestine is longer than the carnivorous Eurasian Sparrow hawk (Accipiter nissus) [16]. [17] found that the intestinal length to body length ratio in pigeons was 14%, 12% in chickens, 10% in ducks, and 9% in geese. These results, in different. But that does not match our previous results. This is in contrast to that of [18], who reported that the ratio of small intestinal length to the body length in herbivores such as pigeons (Columba livia) was 25%, while it was 50% in carnivores such as falcons (Buteo buteo vulpinus) [19]. While the results of this research were in mallards (3.125 %), white-eared bulbul (3.015 %), falcon (2.795 %), zebra finch (2.72 %), starling (1.605 %), domestic pigeon (1.41%) and canaries (1.27 %).

The present study revealed that, carnivorous birds (Falco Atriceps) have shorter intestines than the similar sized granivores or herbivorous species (Pycnonotus leucotis ,Taeniopygia guttata and Serinus canaria) this result agree with [1], the largely digestible nature of their diet is thought to be the cause of this phenomenon.

Conclusions

Anatomical and histological differences in selected birds may occur as a result of dietary differences, there was a difference in the shape of the small intestine in addition to a difference in the percentages of weight and length of the small intestine in relation to the length and weight of the bird

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