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Original Article

Determination of the Gastrointestinal Passage Rate Using Dexa Technology and Barium Sulfate As a Marker in Japanese Quails

Author(s)

Raimundo EKM[I] https://orcid.org/0000-0001-7109-3273
Carvalho LC[I] https://orcid.org/0000-0002-7962-4670
Sousa MGBL[I] https://orcid.org/0000-0002-7741-8793
Veras AG[I] https://orcid.org/0000-0001-5123-565X
Lima MB[I] https://orcid.org/0000-0002-9002-3606
Amoroso L[II] https://orcid.org/0000-0001-9848-7803
Artoni SMB[II] https://orcid.org/0000-0003-4428-8838
Silva EP[I] https://orcid.org/0000-0001-8053-7681

[I] Animal Sciences, São Paulo State University, Jaboticabal, Brazil.
[II] Department of Animal Morphology and Physiology, São Paulo State University, Jaboticabal, Brazil.

Mail Address

Corresponding author e-mail address
Edney P. Silva
Animal Sciences, São Paulo State University, Jaboticabal, 14884-900, SP, Brazil.
Phone: +55 16 32097610
Email: edney.silva@unesp.br

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ABSTRACT

The objective of this study was to characterize the dynamics of food passage in the gastrointestinal tract (GIT) of Japanese quail. A randomized design was used with four treatments and four experimental units with one bird each, nine of which were measured in time. The ingredients used were albumin, starch, cellulose, and soybean oil. Suspensions containing barium sulfate and saline were prepared, except for soybean oil. For each bird, 2.5 mL of the suspension was administered directly to the crop. Dual-energy absorptiometry (DEXA) was used to quantify the passage of food. The birds were sedated and maintained under inhalation anesthesia during the scan. Measurements were taken at intervals of 0.5, 1, 2, 4, 6, 8, 10, 12, and 24 h. The variables identified were passage time, first quality, and the average time of each variable. Based on these results, the ingredients may show differences in dynamic passing on the Japanese quail GIT. The duration of the first attempt was 32 min, ranging from 21 to 44 min. The average time value of food choice was close to 10.8 h and varied according to the ingredient from 8.45–12.16 h. Among the variables, soybean oil presented values that denote a fast passage in the GIT, while albumin presented values that denote a slower passage. The dynamics of food passage in the GIT of Japanese quails varies according to the chemical composition of the ingredients.

INTRODUCTION

According to studies on energy (Silva *et al.*, 2020) and amino acid requirements (Silva *et al.*, 2019; Sarcinelli *et al.*, 2020), Japanese quail are less efficient than laying hens while using these nutritional resources. The difference in the efficiency of utilization between Japanese quails (45%; Jordão Filho *et al.*, 2011) and commercial layers (65%; Sakomura *et al.*, 2005) for metabolizable energy is close to 30% and greater than 50% for amino acids (Rostagno *et al.*, 2017).

The results of Batal & Parsons (2003) support research at the gastrointestinal (GIT) level to understand the genesis of the difference in utilization efficiency between Gallus and Coturnix. In newly hatched birds, these authors demonstrated that the limitations in using nutritional resources were related to the digestive processes.

The first results on the dynamics of food passage in the GIT of Japanese quails (Nóbrega *et al.*, 2020) were notable: the values of the first appearance time (FAT) and mean retention time (MRT) were lower than those of commercial layers, indicating a rapid passage of food in the GIT. In addition, diets with low and high concentrations of metabolizable energy showed differences in time ~~to~~ of first appearance and MRT. Therefore, the inefficiency of utilization may partly be related to digestive processes in the GIT of Japanese quails. The physicochemical characteristics of broilers and commercial layers influence intestinal motility (Kitazawa & Kaiya, 2019), dynamics of food passage (Hetland & Svihus, 2001), food digestibility, and nutrient absorption (Mateos *et al.*, 2012; Donadelli *et al.*, 2019). However, for Japanese quail, this understanding still needs to be established, as shown by Nóbrega *et al.* (2020).

The MRT of food is the time between ingestion and complete emptying of the food in the GIT. It is necessary to use markers and destructive methods with animal sacrifice to certify the emptying of food at the segments of the GIT (Kolakshyapati *et al.*, 2019; Kolakshyapati *et al.*, 2020; Nóbrega *et al.*, 2020). Traditional indicators (Cr_2O_3 and TiO_2) were evaluated by Nóbrega *et al.* (2020), but the collection time was extended to ensure the complete emptying of the food ~~at~~ in the GIT. A non-destructive methodological option to determine the emptying of food ~~at~~ in the GIT using images was proposed by Kolakshyapati *et al.* (2019). However, studies with Japanese quails were not found in the literature. Therefore, this study aimed to standardize an experimental procedure to determine the time to FAT, rate of passage (ROP), and MRT using barium sulfate as a radiological marker and DEXA technology to image the passage of albumin, corn starch, cellulose, and soybean oil in the GIT of Japanese quails.

MATERIAL AND METHODS

This research was performed at the Laboratory of Bone Densitometry, Universidade Estadual Paulista, Campus de Jaboticabal. A randomized design was used with replicated measurements over time. Four ingredients were used as treatments with four experimental units. Nine measurements were replicated over time.

The experimental unit consisted of quails with an average weight of 125 ± 5 g. Albumin, corn starch, cellulose, and soybean oil were used as representative ingredients with high protein, carbohydrate, fiber, and lipid contents, respectively. Four suspensions were prepared, one for each ingredient, containing barium sulfate as a radiological indicator and a saline solution, except soybean oil. The suspension was composed of 58% barium sulfate (radiological contrast), 38% tested ingredient, and 4% saline solution. A saline solution was not used for the suspension with soybean oil. Therefore, 42% of the ingredient was kept constant.

Before the procedure, the quails were subjected to a six-hour solid fast. For each quail, a suspension was administered directly into the crop using a gavage needle of 2.5 mL at the initial time or time zero. To quantify the rate of food passage, DEXA, a technology, was used to obtain images of the passage of food. Previously, the quails were anesthetized by inhalation of isoflurane between 2 and 4% during the scanning procedure. Nine measurements were performed at intervals of 0.5, 1, 2, 4, 6, 8, 10, 12, and 24 h. The variables analyzed were the first appearance time, food passage rate, mean retention time, velocity, and food passage acceleration.

The first appearance time (FAT) was defined as the time required to observe the first marked excreta after administering the suspension. The rate of food passage (ROP) was obtained by multiplying the amount of marker excreted by the time of excretion. The mean retention time (MRT) was determined as the time it took for the marker to be eliminated by the GIT. The FAT, ROT, and MRT were measured in hours. Subsequently, the length of the gastrointestinal tract (LGIT) was measured from the ingluvium to the cloaca. For this analysis, three quails were sacrificed by intracardiac administration of a combination of ketamine (50 mg/mL) and potassium chloride (4%). Therefore, the velocity was calculated as v = LGIT/t, mm/s, where LGIT is in mm and *t* is in seconds. To calculate acceleration, the following formula was used: α = v/t, mm/s². Data were analyzed using descriptive statistics (means and standard deviations).

RESULTS AND DISCUSSION

The primary objective of this study was to initiate the standardization of a non-destructive experimental protocol using DEXA to determine the variables that explain the dynamics of food passage (DFP) in the GIT. The use of barium sulfate as a radiological indicator allowed for a more accurate analysis of the DFP in the GIT, which could not have been obtained with other indicators used conventionally, such as titanium and chromium. Despite the use of conventional indicators, simple digestive responses could be evaluated (Nóbrega *et al.*, 2020).

To obtain more information about the DFP, these indicators require destructive collection. The radiological indicator (Bloch *et al.*, 2010) used in this study could be used to obtain relevant information to interpret the DFP without sacrificing the animals and represents a refinement for obtaining scientific information. We used the FAT, ROP, and MRT values of the ingredients (corn starch, cellulose, soy oil, and albumin) to evaluate the procedure. According to the results obtained for FAT (Table 1), some similarities were found with the

Table 1 – Mean and standard deviation for first appearance time (FAT), rate of passage (ROP), velocity (v), acceleration (α), and mean retention time (MRT) of corn starch, cellulose, soybean oil, and albumin in the gastrointestinal tract of Japanese quails in the production phase.

Variables	Ingredients			
	Corn Starch	Cellulose	Soybean oil	Albumin
FAT[1] (h)	0.725 ± 0.28	0.408 ± 0.21	0.341 ± 0.13	0.637 ± 0.07
ROP[2] (g/h)	0.19 ± 0.05	0.20 ± 0.02	0.24 ± 0.13	0.17 ± 0.003
v[3] (mm/s)	5.18 ± 3.23	9.22 ± 3.96	13.37 ± 8.35	4.79 ± 0.39
α[4] (mm/s²)	0.032 ± 0.004	0.009 ± 0.008	0.025 ± 0.038	0.002 ± 0.0004
MRT[5] (h)	12.16 ± 10.14	12.01 ± 9.68	8.45 ± 4.66	10.52 ± 3.67

[1]FAT: first appearance time; [2]ROP: rate of passage; [3]v: velocity; [4]α: acceleration squared; [5]MRT: mean retention time.

results of Nóbrega *et al.* (2020). The average in this study was 32 min similar to the results obtained by Nóbrega *et al.* (2020), who found that Japanese quails have the shortest time between entry and exit of food in the GIT when compared with other production birds such as broilers having a FAT of 80 to 90 min (Almirall & Esteve-Garcia, 1994; Yamanaga & Furuse, 2014) and commercial layers from 155 to 193 min (Mateos *et al.*, 1982; Rougière & Carré, 2010).

The FAT, ROP, and MRT measures are related to the velocity of food passage. It is possible to segregate the DFP from the ingredients using the values presented in Table 1. The results obtained in this study demonstrated that using ingredients that represent the macromolecules (protein, carbohydrate, fiber, and lipid) was appropriate for investigating the passage of food in the GIT, considering the different interactions with the pH, viscosity, hydration capacity, and anatomy of each organ.

The average for MRT was 10 h 47 min for total passage of food in the GIT of Japanese quails, ranging from 8 h 27 min for soybean oil to 12 h 10 min for corn starch. These results also confirm the difference between Japanese quails, broiler, and commercial layers presented by Nóbrega *et al.* (2020).

The *v* and α of the ingredients were calculated considering the GIT length of Japanese quails is 90.4 ± 5 cm (Table 2). Soybean oil presented higher velocity and acceleration and lower MRT among the evaluated ingredients. When comparing the images of the different ingredients evaluated after 30 min and 10 h of suspension administration (Figure 1), we observed that only soybean oil (Figure 1: OL1–OL2) passed through the GIT. The others were not identified in the GIT at 24 h after the first administration.

Table 2 – Mean length and standard deviation of each segment of the gastrointestinal tract (GIT) of Japanese quails in the production phase.

Segments of GIT	Length (cm)
Thoracic esophagus	4.16 ± 0.28
Proventriculus	1.9 ± 0.04
Gizzard	2.3 ± 0.11
Small intestine	57.63 ± 4.31
Cecum	22.26 ± 0.62
Large intestine	1.99 ± 0.14

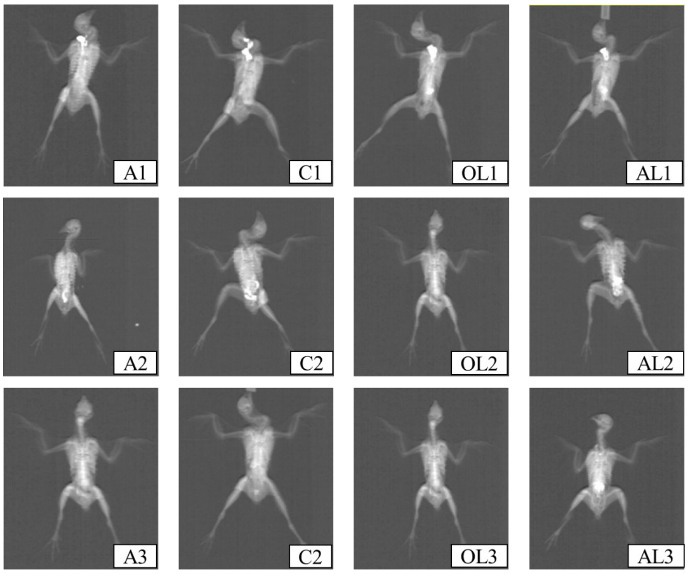

Figure 1 – Ventrodorsal overview by digital radiography after 30 minutes, 10 and 24 hours of administration of suspensions of corn starch (A1 to A3), cellulose (C1 to C3), soybean oil (OL1 to OL3) and albumin (AL1) to AL3), of Japanese quails in the production phase.

The average MRT of soybean oil was ~2 h lower than that of albumin and ~3.6 h lower than that of carbohydrates, corn starch, and cellulose (Table 1). Some studies report no effect of dietary lipids on the passage of food through the GIT (Golian & Maurice 1992; Andreotti *et al.* 2004). Several studies reaffirm the positive relationship between increased dietary lipid and MRT (Savory & Gentle 1976; Mateos & Sell 1980; Mateos *et al.* 1982; Shires *et al.* 1987) by inhibiting gastric emptying.

The average MRT of soybean oil supports that there are some differences between quails and commercial layers, as previously published studies found lower values for FAT when they used high levels of energy in the diet, as reported by Nóbrega *et al.* (2020) and reaffirmed by Castiblanco *et al.* (2022). These results indicate an acceleration in the passage of food through the GIT by increasing the lipid content of the diet, which increases the metabolizable energy of the diet (Nóbrega *et al.*, 2020; Castiblanco *et al.*, 2022). The variation found in this study limits a categorical statement that is exclusively attributed to differences in GIT motility between quails and hens. Therefore, more studies with larger sample sizes are required to confirm these results.

In this study, the MRT of cellulose (Figure 1: C1 and C2) did not differ from that of corn starch (Figure 1: A1 and A2) and albumin (Figure 1: AL1 and AL2) after 10 h of suspension administration (Figure 1). This similarity in MRT may be related to the particle size (Kolakshyapati *et al.*, 2019). The three ingredients had a powdery form. Although it facilitated suspension, it may have contributed to nullifying some action on the gizzard ~~in~~ and delayed the time of passage of the food in the GIT.

For acceleration, the highest average was found for corn starch, whereas albumin had the lowest value. The smaller the variation in acceleration, the more constant the velocity of the passage of the ingredient, related to the digestibility of the ingredient. Therefore, the greater the acceleration, the higher the change in the velocity of the ingredient in the GIT, justifying that each ingredient requires different time intervals for digestion in different sections or a greater impulse with peristaltic movements increasing the velocity. Thus, the ingredients evaluated individually in this study may have gone through stages in the digestion process because they do not require specific actions in different sections of the GIT, resulting in the different passage and retention times.

The dynamics of food passage in the GIT in Japanese quail showed divergence according to the ingredients. The different segments of the GIT interact differently with the ingredients and affect the velocity and acceleration of food passage. Studies are required to determine the dynamics of food passage in the GIT of quails, either with isolated ingredients or combined in practical diets.

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