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Winter diet and digestive tract of the Golden Pheasant (*Chrysolophus pictus*) in the Qinling Mountains, China

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Abstract The winter diet and morphological structure of the gastrointestinal tract of the Golden Pheasant (*Chrysolophus pictus*) was investigated in the Qinling Mountains, Shaanxi Province in 2002/2003. Individual food items in crops were identified by species, where possible, using standard taxonomic methods. The Golden Pheasant consumes exclusively vegetarian foods in the winter, of at least 14 plant species, such as crops and other vegetable species. The digestive tract of the Golden Pheasant is composed of an oesophagus, a stomach, a relatively long intestine measuring 3.4 × standard body length, two fully-developed caeca and a relatively short colon, typical for herbivorous birds. Pebbles of different sizes (0.5–3 mm in diameter) were very frequent in the gizzard. The average dry weight of the pebbles was 10.4±2.5 g and was positively correlated with the weight of digesta in the gizzard (Pearson $r = 0.747$, $p < 0.01$, $n = 37$). The mucosa surface pH of the digestive tract of the Golden Pheasant was slightly acidic, but higher in the crop and gizzard.

Keywords Golden Pheasant, digestive tract, diet, Qinling Mountains

Introduction

The Golden Pheasant (*Chrysolophus pictus*), a species endemic to China, is found in 12 provinces of central China (Lei and Lu, 2006). This distinctive species has received much attention lately, primarily due to the rapid decline of its numbers during the 20th century. Because of its colorful plumage, rampant hunting has been recognized as one of the important factors leading to a population decline of this species in China (Zheng and Wang, 1998).

For this species, concern about conservation has been well documented in China (Lu et al., 1992; Jiang et al., 1996; Yu et al., 1997; Shao, 1997, 1998; Zhang et al., 2001, 2002; Li and Zhang, 2006). Research of its digestive system was carried out on stomach vas (Zhang and Yu, 2000a), microstructure of digestive tract and liver (Zhang et al., 2000; Zhang and Yu, 2000b; Zhang et al., 2002) and immunohistochemistry of endocrine cells in the digestive tract (Li and An, 2009). However, little information has been published about the diet of the Golden Pheasant (Yao, 1991; He et al., 1994; Yu and Liang, 1996; Shao, 1998), especially with respect to the anatomical structure of its digestive tract. A study on the gastrointestinal tract of the Adélie Penguin (*Pygoscelis adeliae*) by Olsen et al. (2002) indicated that the digestive system has anatomical and functional adaptations typical for carnivorous birds. In birds that do have a crop, its size and shape differ between species according to feeding habits and digestive strategies. One extreme example is the leaf-eating Hoatzin (*Opisthocomus hoazin*), in which the crop has replaced the proventriculus and the gizzard as the primary site of digestion, allowing microbial foregut fermentation of dietary structural carbohydrates (Grajal et al., 1989). The gizzard of this bird develops from the posterior part of the stomach called the ventriculus. Pebbles that have been swallowed are often retained in the gizzard of grain-eating birds and facilitate the grinding process (Miller et al., 2002).

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Here, we present a study on the diet in winter and a morphological description of the gastrointestinal tract of the Golden Pheasant. We also consider the implications of our results for the conservation of the species in China.

Methods

Sixty-two pheasants, fifty-two males and ten females, were confiscated from poachers by the Shaanxi Nature Reserve and Wildlife Administration Station during the 2002/2003 winter season. Thirty-seven birds were collected at Shuangmiaozi, Zhouzhi County (108°14′–108°18′E, 33°45′–33°50′N) and the others at Yingge, Taibai County (107°38′–107°40′E, 34°03′–34°05′N), Shaanxi Province in the Qinling Mountains. Necropsy of these birds confirmed that they were all captured by trapping. Because most birds were relatively fresh and not scavenged, their entire corpses were frozen at –4°C.

Corpses were left to thaw overnight, crops and gizzards were removed and their contents were weighed on an electronic balance to ±0.1 g. Individual food items in crops were identified by species where possible, using standard taxonomic methods. Because the material contained in the gizzards was too digested to identify, it could only be used for analysis of their pebbles.

Total body mass (BM, $n = 62$) was recorded to nearest 0.1 g and standard body length (SBL, $n = 62$) (tip of the beak to base of the tail) to 1 cm. At the distal end of the oesophagus the expanded crop is found that contains food temporarily. The proventriculus is considered part of the gastric region, shaped like a funnel situated between the crop and the gizzard. The muscular gizzard is defined as part of the gastric region between the proventriculus and the pyloric sphincter. The contents of each of the principal sections of the digestive tract i.e., the oesophagus ($n = 15$), crop ($n = 62$), proventriculus ($n = 15$), gizzard ($n = 37$), small intestine ($n = 15$), cecum ($n = 15$) and colon ($n = 15$), were weighed to 0.1 g with an electronic balance. The wet tissue weight of each part, as well as the liver, was weighed to within 0.1 g. The length of the oesophagus, proventriculus and intestine was measured to within 1 mm with each segment fully extended, but not stretched. Both length and width of the gizzard were measured to 1 mm. The pH of the contents and the mucosa of the different sections of the digestive system for only five individuals ($n = 5$) were measured with a digital pH electrode (PHS-25B, Shanghai, China) and special indicator pH paper.

Variations in the content of crops of individual birds were statistically analyzed using One Sample T test assuming equal variances. Pearson correlation analyses (two-tailed) were used to determine the significance between: 1) the wet weight of the gizzard and body mass; 2) dry weight of the pebbles and weight of digesta in the gizzard. A probability of <0.05 was considered statistically significant. All values were reported as means ± SD.

Results

Only three out of 62 crops were empty. The mass of the contents ranged from 0 to 91.8 g with an average of 24.9±20.4 g ($n = 62$) and varied markedly significant among individuals ($t = 8.80$, df = 61, $p = 0.000$). The Golden Pheasant eats exclusively vegetarian items in the winter, with at least 14 species of vegetables, including crops and other plant species (Table 1). Wheat leaves, maize seeds and Chinese goose-

Table 1 Frequency of food items and percentage of biomass by taxa in crops of the Golden Pheasants in winter

Species	Frequencies of items ($n = 85$)	Percent biomass ($\Sigma = 1144.6$ g)
Wheat leaves (*Triticum aestivum*)	24	55.91
Wheat seeds (*Triticum aestivum*)	9	0.75
Maize seeds (*Zea mays*)	17	6.05
Soybean seeds (*Glycine max*)	2	0.23
Chinese gooseberry leaves (*Actinidia chinensis*)	11	17.88
Southernwood leaves (*Artemisia* sp.)	6	3.88
Turnip leaves (*Brassica rapa*)	5	7.25
Bromegrass leaves (*Bromus japonicus*)	2	1.05
Oat leaves (*Avena sativa*)	3	0.89
Fern (*Cryptogramma* sp.)	1	0.87
Oak seeds (*Quercus* sp.)	1	0.57
Firethorn fruit (*Pyracantha fortuneana*)	2	0.24
Grass roots (not identified)	1	3.92
Poplar leaves (*Populus davidiana*)	1	0.52

berry accounted for 61.2% of the items and almost four-fifth of the biomass consumed. Other items were too infrequent to be important.

Mean standard body length was 32.6±4.7 cm (n = 62) while the mean total body mass was 738.6±75.7 g (n = 62). The digestive tract of the Golden Pheasant is composed of an oesophagus, a stomach and a relatively long intestine. There is an ellipsoidal crop, which holds food temporarily, at the distal end of the oesophagus. The stomach consists of two closely adjacent compartments: an infundibular proventriculus and a deep purple-red muscular gizzard, shaped like a flattened sphere. The intestine consisted of a very long small intestine, two fully-developed caeca and a short colon. The wet tissue weight of the total gastrointestinal tract represented 10.04±1.07% (n=15) of BM.

The wet tissue weight of the oesophagus (Table 2) ranged from 1.5 to 2.5 g and contributed 0.30±0.06% (n=15) to BM. It is relatively short, ranging from 81 to 107 mm, i.e., 0.29±0.04 × SBL (n = 15). The surface pH of the mucosa of the oesophagus was slightly acidic, with a drop in acidity from the proximal to the distal part (Table 3). The birds have a crop (expandable pouch) at the end of the oesophagus, where its many food items were easily identified. The crop measured 57.8±10.4 mm in length (n = 62). The tissue wet weight averaged at 5.3±1.4 g and contributed 0.79±0.19% to BM (n = 62). The mean surface pH of the mucosa of the crop was 3.8±1.0 (n=5).

The proventriculus shaped like a funnel contained 0.91±1.1 g (n = 15) digestive mucus. It ranged from 71 to 82 mm, with an average of 74.5±4.3 mm in length and its wet tissue weight contributed 0.59± 0.16% (n=15) to BM. The contents of the proventriculus were acidic (average pH 4.7±0.7, n = 5).

The gizzard is located between the proventriculus and the duodendum and contains much digestive

Table 2 Contents, tissue wet weights and size [means ± SD (n)] of different parts of digestive tract in the Golden Pheasant (gender combined)

Parameter	Content (g)	Weight (g)	Length (× width) (mm)
Oesophagus	–	1.9±0.3 (n=15)	96.9±11.1 (n=15)
Crop	24.9±20.4 (n=62)	5.3±1.4 (n=62)	57.8±10.4 (n=15)
Proventriculus	0.9±1.1 (n=15)	3.8±0.9 (n=15)	74.5±4.3 (n=15)
Gizzard	16.5±4.3 (n=37)	35.9±4.7 (n=37)	60.0±4.4 × 49.2±5.5 (n=62)
Small intestine	12.9±6.5 (n=15)	11.2±2.3 (n=15)	1147.9±70.9 (n=15)
Caecum	5.0±2.9 (n=15)	5.6±1.6 (n=15)	203.5±25.2 (n=15) (left)
			215.5±23.2 (n=15) (right)
Colon	1.0±0.8 (n=15)	2.3±0.6 (n=15)	103.3±10.2 (n=15)

–, no contents

Table 3 The mucosa surface pH of the digestive tract in the Golden Pheasant

Pheasant no.	Oesophagus	Crop	Proventriculus	Gizzard	Small intestine	Caeca	Colon
48	5.1 (P)	3.0	4.0 (P)	4.1	5.1 (Duo)	4.8	6.0 (D)
	3.8 (D)		4.0 (D)		5.4 (DJ)		
49	5.4 (P)	3.5	4.5 (P)	3.5	5.4 (Duo)	5.5	6.5 (D)
	5.1 (D)		5.4 (D)		5.1 (DJ)		
50	5.4 (P)	4.3	5.1 (P)	3.5	5.4 (Duo)	4.8	5.8 (D)
	5.4 (D)		4.1 (D)		5.1 (DJ)		
51	4.8 (P)	3.0	4.0 (P)	3.8	5.4 (Duo)	5.4	6.1 (D)
	3.5 (D)		4.5 (D)		5.1 (DJ)		
52	5.4 (P)	5.4	5.4 (P)	4.1	5.4 (Duo)	5.1	6.4 (D)
	5.4 (D)		5.4 (D)		5.5 (DJ)		

P, proximal; D, distal; Duo, duodenum; DJ, distal jejunoileum.

material which was more difficult to identify than that in the crop, with the wet weight of its contents as much as 16.5±4.3 g (n = 37). The deep purple-red gizzard was 60.0±4.4 × 49.2±5.5 mm (n = 37) in size. This tissue, with an average wet weight of 35.9±4.7 g (n = 37), contributed 4.6±0.5% (n = 37) to BM, was the largest part of the digestive tract. The wet tissue weight was positively correlated with the BM (Pearson r = 0.566, p < 0.01, n = 37). Pebbles of different sizes (0.5–3 mm in diameter) were very frequent in this section of the stomach. The average dry weight of the pebbles was 10.4±2.5 g and positively correlated with the weight of digesta in gizzard (Pearson r = 0.747, p < 0.01, n = 37). The mean number of pebbles was 652.3±137.7, ranging from 400 to 1000 (n = 37). The mean surface pH of the mucosa of the gizzard ranged from 3.5 to 4.1 (Table 3).

The small intestine comprised a duodenum and an ileojejunum, measuring 3.4±0.5 × SBL (n = 15). It contained, on average, 12.9±6.5 g (n = 15) of digesta (Table 1). The wet tissue weight of the small intestine contributed 1.75±0.37% (n = 15) to BM. The mucosa surface pH of the small intestine at the distal end ranged from 5.1 to 5.5, which was higher than that of the gizzard (Table 3). The average of the fully developed paired caecum was 203.5±25.2 mm long for the left and 215.5±23.2 mm for the right (n = 15), measuring 0.60±0.11 and 0.64±0.11 × SBL (n = 15) respectively. The length of the right caecum was longer than that of the left, but this difference was not significant (t = 1.357, p = 0.1857, n = 15). The colon was relatively short (103.3±10.2 mm, n = 15), contributing only 0.36±0.09% (n = 15) to BM. The surface pH of the caeca and the colon was slightly acidic (Table 3).

Discussion

This study provides information on the wintering diet of the Golden Pheasants in the Qinling Mountains, as assessed by an analysis of the crop contents. Crop contents of the breeding Golden Pheasant sampled ten years ago in the Qinling Mountains contains almost all vegetable items, such as fruits and seeds (59%), lower plants, twigs and leaves (27%) and a few insects (14%) (Yao, 1991). There were also regional variations in the diets. Wintering Golden Pheasant on the south slopes of the Qinling Mountains fed mainly on bamboo leaves and mosses (80%) (He et al., 1994), but the pheasant consumed largely fruits of *Pyracantha fortuneana* in Mt. Xianrenshan in Guizhou Province during the winter (Shao, 1997). The Golden Pheasant is mostly found in coniferous-deciduous evergreen mixed forests and fall-leaf mixed forests. Our data presented here indicated that the wintering Golden Pheasant lived near human settlements in flocks on the edge of forests and relied primarily on seeds and leaves of crops and it is likely that they are easily captured by traps or poisoning baits during this period. An extra investigation indicated that a large number of Golden Pheasants were poached by local farmers, especially on snowy days. So the managers of the nature reserves should focus their energy on the bird in the areas near human settlements in the winter. Due to its colorful plumage, illegal over-hunting is still the main threat to the species. For example, the number of skins purchased by animal-products companies in areas of western Hunan Province has reached 6000–8000 since the 1960's (Zheng and Wang, 1998).

The digestive system of the Golden Pheasant also has anatomical and functional adaptations, typical for herbivorous birds. The bird has a crop (expandable pouch) in the end of the oesophagus, which differs both from the carnivorous Adélie Penguin (Olsen et al., 2002) and the extreme leaf-eating Hoatzin (Grajal et al., 1989). The gizzard of the Golden Pheasant is characterized by a massive muscular wall and has a lining that appears to be keratinous. The gizzard grit of the Golden Pheasant observed occurred often, as also seen in seabirds (Cowan, 1983; Olsen et al., 2002) and grain-eating birds (Miller et al., 2002). The markedly significant correlation between the dry weight of pebbles and the weight of digesta in the gizzard indicates specialization of the herbivorous diets. Studies of the Japanese Quails (*Coturnix coturnix*) have shown that the gizzard could double in size in response to an increased proportion of fiber in the diet (Starck, 1999). The wet tissue weight of the gizzard accounted for 4.6% of body mass in the Golden Pheasant, compared with 1.8% in the Temminck's Tragopan (*Tragopan temminckii*), 2.0% in the Blood Pheasant (*Ithaginis cruentus*) (Hou, in litt.), found in regions with relatively higher elevations, which relies mainly on ferns (Shi et al., 1996; Jia and Sun, 2008). The wet weight of this tissue is much lower in several carnivorous penguin species (Olsen et al., 1997 2002; Jackson, 1992).

The relative length of the small intestine is generally shorter in carnivorous birds, such as the Procellariidae (1.4–2.8 × SBL) (Olsen et al., 2002) than

that of herbivorous species, including that of the Golden Pheasant (3.4 × SBL). The mean retention time of digesta in seabirds is significantly correlated with intestinal length (Jackson, 1992), indicating a relatively long intestinal passage time in the Golden Pheasant.

Hanssen (1979) compared the microbial conditions in the caeca of wild and captive willow ptarmigan. The function of the caecum may vary, but symbiotic microbial fermentation to some degree is expected to occur in most birds. Wild herbivorous birds such as ptarmigans and grouse (weight 400–1400 g) have large paired caeca with a combined length of 70–150 mm (Pulliainen, 1976) and are much longer (about 420 mm) in the Golden Pheasant as mentioned above, predicated on high concentrations of plant cell-wall carbohydrates (Hanssen, 1979).

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中国秦岭地区红腹锦鸡的冬季食性和消化道

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摘要：于 2002–2003 年对陕西省秦岭红腹锦鸡（*Chrysolophus pictus*）的冬季食性和消化道的形态结构进行了研究。利用标准分类法鉴定了嗉囊中的食物种类。红腹锦鸡冬季为植食性，食物包括农作物和其他种类等至少 14 种植物。红腹锦鸡消化道由食道、胃、小肠（标准体长的 3.4 倍）、两个发达的盲肠和较短的直肠组成，具典型的植食性鸟类的特征。肌胃中含有大小不等（直径为 0.5–3 mm）的石粒，石粒的平均干重 10.4±2.5 g，与肌胃中食糜的重量成正相关（Pearson $r = 0.747$, $p < 0.01$, $n = 37$）。红腹锦鸡消化道粘膜呈弱酸性，尤以嗉囊和肌胃粘膜酸性较强。

关键词：红腹锦鸡，消化道，食性，秦岭