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Effect of Different Feedstuffs on the Gastrointestinal Transit Time of 18-wk-old *Magang Geese*

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Abstract

Accurate gastrointestinal transit time was essential to the digestibility determination tests. However, the effects of different feedstuffs on intestinal transit time remain unclear. The aim of this study was to investigate the effect of different feedstuffs on the gastrointestinal transit time of 18-wk-old geese. A total of 80 male *Magang geese* of 18 weeks old were weighed individually and randomly divided into 10 groups with eight geese per group. Ten treatment groups were fed corn, sorghum, wheat, soybean meal, cottonseed meal, rapeseed meal, 25% rice bran and hulls (RBH), 50% RBH, 75% RBH, and 100% RBH, respectively. Fresh excreta samples were collected and weighed from each pen every 6 h during the next 48 h after being tube-fed. Excreta weight increased significantly during the first 24 h after tube-feeding of all feedstuffs ($P < 0.05$). From 24 to 48 h, no significant changes were observed in excreta weight following tube-feeding of cereal or protein source feedstuffs ($P > 0.05$). In contrast, birds tube-fed diets containing 25% to 100% RBH showed a progressive increase in excreta weight from 24 to 36 h post-tube-feeding, after which excreta output remained stable. No significant changes in TiO_2 recovery were observed in excreta following tube-feeding of cereal or protein source feedstuffs from 24 to 48 h, whereas birds tube-fed diets containing different levels of RBH showed an increase in TiO_2 recovery from 24 to 36 h, which then remained stable. In conclusion, for *Magang geese*, the optimal gastrointestinal transit time was 24 h for cereal and protein source feedstuffs, in which diets with different fiber contents require a relatively prolonged period of 24-36 h.

Introduction

Over the past several decades, the tube-feeding technique has been widely applied to determine the metabolizable energy (ME) of poultry feedstuffs (Sibbald, 1976; Dudley-Cash, 2009). This method is valued for its simplicity, accuracy, and independence from feed palatability (Farrell, 1978). Apparent metabolizable energy (AME) is defined as gross energy intake minus excreta energy, while true metabolizable energy (TME) further corrects AME for endogenous losses (Macelline *et al.*, 2020). Despite these advantages, the accuracy of ME determination depends on gastrointestinal transit time, which affects nutrient digestion and absorption (McNab and Blair, 1988). Most ME studies have been conducted in chickens, yet geese differ markedly in digestive anatomy and physiology, making extrapolation unreliable. Compared with chickens, geese have shorter intestines relative to body weight (Hallsworth *et al.*, 1992), but compensate with larger gizzards and ceca that enhance fiber breakdown and fermentation (Yan *et al.*, 2019). The goose gizzard can generate much higher pressures than that of chickens, enabling efficient grinding of fibrous material, while the developed ceca provide extended microbial fermentation (Jamroz *et al.*, 2001). These traits reflect

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the adaptation of geese to forage-rich diets, in contrast to chickens' limited fiber utilization.

Feed type is another key factor influencing gastrointestinal passage. High-fiber diets increase digesta bulk and slow passage, enhancing microbial fermentation, whereas highly digestible diets accelerate transit and shorten nutrient absorption time (Svihus *et al*., 2013). In geese, retention times of fiber fractions vary among segments, with the gizzard, duodenum, and ceca playing major roles in *NDF*, *ADF*, and hemicellulose digestion, respectively (Lou *et al*., 2010). Such anatomical and dietary effects make it essential to evaluate feed-dependent transit dynamics specifically in geese. Therefore, this study was conducted to investigate the effects of different feed types on intestinal transit time in *Magang geese*, aiming to provide a theoretical basis for more accurate ME determination in waterfowl.

Materials and Methods

The animal care and use protocol was approved by the Institutional Animal Care and Use Committee of South China Agricultural University (SCAU-10564), and the study was performed following the Regulations for the Administration of Affairs Concerning Experimental Animals.

Ingredients

A total of six feedstuff samples, including three cereal feedstuffs (corn, sorghum, and wheat), three plant protein sources (soybean meal, SBM, cottonseed meal, CSM, and rapeseed meal, RSM), and four diets with different fiber levels (10%, 20%, 29.9%, and 39.9%) consisting of 25%, 50%, 75%, and 100% rice bran and hulls (RBH), were applied in the study. All samples were ground through a 0.5-mm screen to ensure a fine particle size, and each sample was analyzed in triplicate for dry matter (DM, method 934.01), crude protein (CP, method 954.01), ether extract (EE, method 920.39), crude fiber (CF, method 978.10), ash (method 942.05), calcium (Ca, method 927.02), and total phosphorus (TP, and method 985.01) according to the classical procedures of the AOAC (2016) respectively, while the neutral detergent fiber (*NDF*) and acid detergent fiber (*ADF*) contents of feedstuff samples were determined according to the previous method (van Soest and Mason, 1991). Chemical composition of the feedstuff samples was presented in Table 1.

Table 1: Chemical composition of feedstuff samples in the present study % on DM basis

Items[1]	*DM*	*CP*	*EE*	*CF*	*Ash*	*NDF*	*ADF*	Ca	TP
Corn	87±0.3	8.40±0.05	3.60±0.02	1.60±0.02	1.30±0.01	9.30±0.51	2.70±0.08	0.02±0.002	0.27±0.001
Sorghum	87±0.2	9.10±0.03	3.40±0.01	1.40±0.01	1.80±0.03	17.40±1.33	8.00±0.57	0.13±0.001	0.36±0.011
Wheat	87±0.2	13.90±0.04	1.70±0.03	1.90±0.02	1.90±0.02	13.30±1.48	3.90±0.29	0.17±0.002	0.41±0.023
Soybean meal	89±0.1	42.80±0.02	5.80±0.02	4.80±0.03	5.90±0.02	18.10±1.02	15.50±1.32	0.31±0.001	0.50±0.025
Rapeseed meal	88±0.2	36.70±0.02	7.40±0.02	11.40±0.04	7.20±0.04	33.30±1.69	26.00±3.62	0.59±0.020	0.96±0.02
Cottonseed meal	90±0.4	43.30±0.05	0.50±0.04	10.50±0.02	4.90±0.06	28.40±1.35	19.40±2.16	0.28±0.018	1.04±0.101
Rice bran and hull	89±0.2	3.90±0.04	4.10±0.06	39.90±0.06	7.50±0.05	74.80±3.49	64.70±4.47	0.07±0.002	1.43±0.122

[1] The average data based on triplicate determinations.
DM, dry matter; *CP*, crude protein; *EE*, ether extract; *CF*, crude fiber, *NDF*, neutral detergent fiber; *ADF*, acid detergent fiber; Ca, calcium; TP, total phosphorus;

Experimental design

A total of 80 male *Magang geese*, 18 weeks of age, with an average body weight of 4.20 ± 0.24 kg, were individually weighed and randomly allocated into 10 treatment groups, with 8 geese assigned to each feedstuff sample. Cereal feedstuffs, including corn, sorghum, and wheat, were offered as the sole dietary ingredient to determine their effect on gastrointestinal transit time for geese. In contrast, plant protein feedstuffs including SBM, CSM, and, RSM were incorporated into a semi-purified basal diet composed of 60% corn starch and 40% test ingredient to ensure balanced nutrient supply while assessing the gastrointestinal transit time for geese.

The four fiber levels diet was tested as 25% RBH+75% corn starch, 50% RBH+50% corn starch, 75% RBH+25% corn starch, and 100% RBH. All test diets contained 1% TiO_2. The total excreta samples were collected during the next 48 h after the tube-feeding assay.

Tube-feeding assay

The procedure of tube-feeding assay was conducted according to the previous study (Sibbald, 1976). Firstly, pre-weighed geese were individually caged in a climate-controlled room (25°C) under constant light for 7 days of adaptation. After a 36-hour fast, an 80 g test diet with 1% titanium dioxide (TiO_2) was tube-fed directly into the crop using a 60-mL catheter-tip syringe and 35-cm long, 8-mm internal diameter Nalgene™ tubing. Finally, fresh excreta samples were collected and weighed from each pen every 6 h during the next 48 h after being tube-fed. The TiO_2 content in the ashed excreta was determined according to Hetland and Svihus (2001). TiO_2 was included in all experimental diets at 0.5% as an inert marker to monitor feed passage and excreta recovery. Excreta were collected at 24, 36, and 48 h after tube-feeding, and TiO_2 recovery was calculated as the ratio of TiO_2 recovered in excreta to the amount initially administered. High recovery rates indicate uniform marker distribution and reliable excreta collection, ensuring accurate metabolizable energy and nutrient digestibility measurements. Lower recovery, particularly in high-fiber diets, may result from prolonged digesta transit or uneven marker distribution and was considered when interpreting energy values.

Statistical analysis

Statistical analysis was performed using one-way ANOVA (General Linear Model procedure, SAS; **SAS Institute, Cary, NC**). Treatment means were compared for significant differences using the LSD test. Data are expressed as means ± SEM, where means lacking a common letter differ at $P < 0.05$. Figures were created with GraphPad Prism version 8.3.0 (GraphPad Software, USA).

Results

Temporal changes in excreta weight after tube-feeding are shown in Figures 1 and 2. For cereal (corn, sorghum, wheat) and protein (soybean, rapeseed, cottonseed) feedstuffs, excreta increased significantly from 6 to 18 h ($P < 0.05$) and plateaued thereafter, indicating gastrointestinal transit was largely completed within 24 h. Protein meals generated higher excreta output (21–23 g at 18 h) than cereals (~6–18 g), likely due to greater bulk and fiber content. For rice bran and hull diets, excreta output increased in a dose-dependent manner. Plateau values were ~20, 30, 35, and >50 g for 25%, 50%, 75%, and 100% inclusion, respectively. Excreta increased significantly from 6 to 18–24 h ($P < 0.05$) before stabilization, demonstrating that high-fiber feedstuffs prolong gastrointestinal transit and elevate excreta output proportionally to inclusion level.

TiO_2 recovery remained high (96–99%) for cereal- and protein-based diets across all sampling times ($P > 0.05$), confirming its reliability as an inert marker. Recovery declined at higher inclusion levels of rice bran and hull, from 96.8% (25%) to 81.2% (100%) at 24 h ($P < 0.05$), but improved to 96.97–98.47% at 48 h. These results suggest that excessive fiber reduces marker homogeneity and fecal recovery, likely due to prolonged digesta passage.

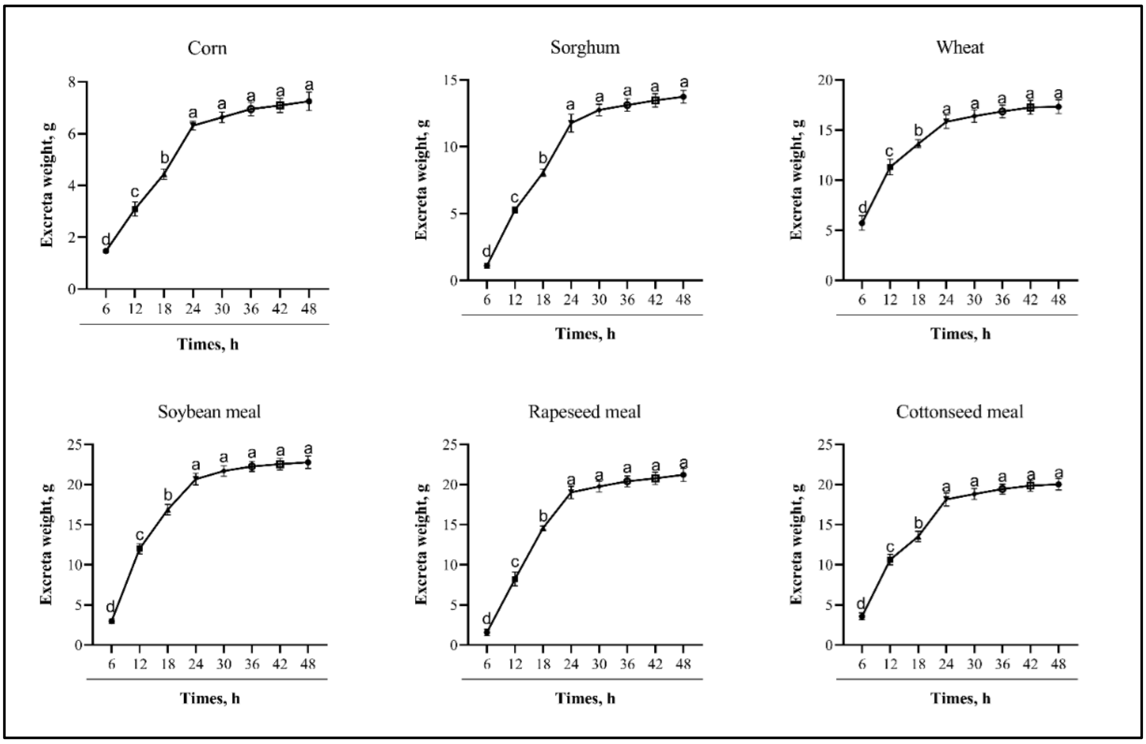

Figure 1. Weight of excreta after 6 to 48 hours of tube-feeding with cereal or protein feedstuffs
[*] No same letter between groups indicates a significant difference ($P < 0.05$). Error bars are SEM.

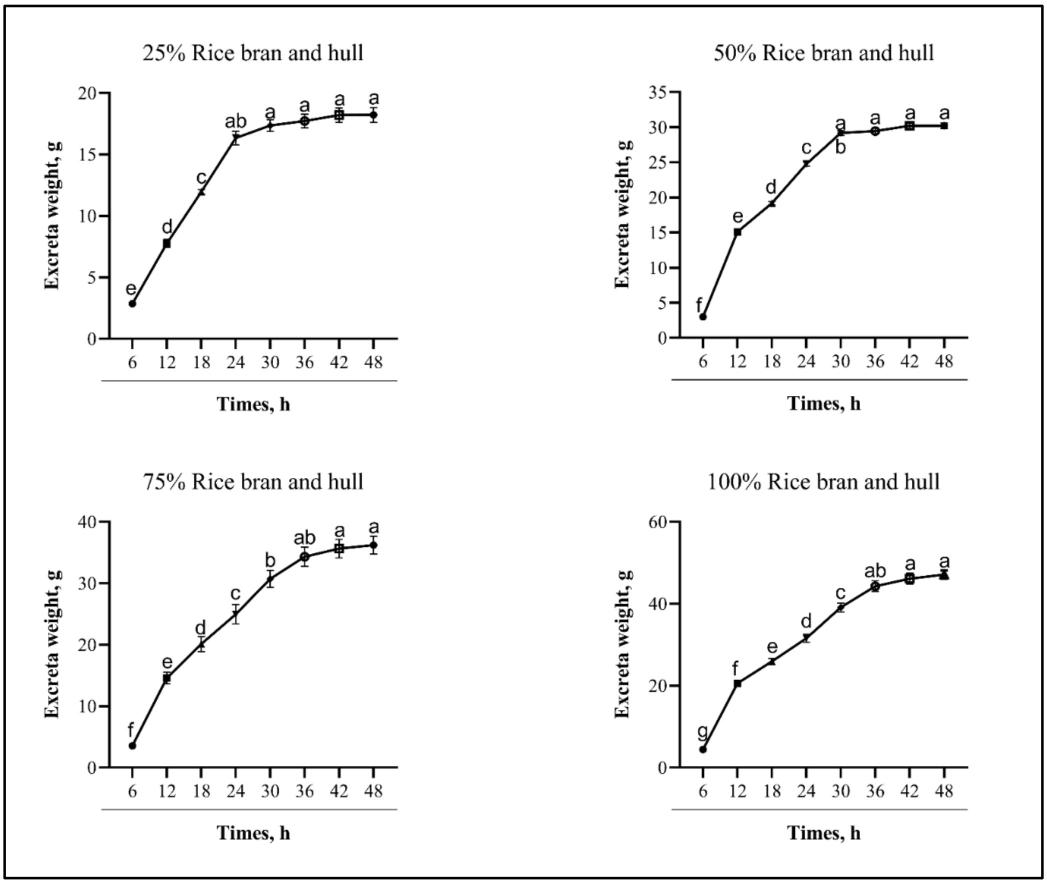

Figure 2. Weight of excreta after 6 to 48 hours of tube-feeding with diets containing different levels of rice bran and hull. * No same letter between groups indicates a significant difference ($P < 0.05$). Error bars are SEM.

Table 2: TiO_2 recovery (%) at 24 h, 36 h, and 48 h after tube-feeding

Items[1]	TiO_2 recovery rate (%)			SEM	*P* value
	24 h	36 h	48 h		
Corn	96.98	98.19	98.94	1.37	0.983
Sorghum	96.65	97.81	98.85	1.16	0.785
Wheat	97.48	98.63	99.31	1.13	0.776
Soybean meal	97.61	98.85	99.43	0.88	0.965
Rapeseed meal	96.12	98.10	99.05	1.32	0.758
Cottonseed meal	96.20	97.53	98.76	1.15	0.889
25% rice bran and hull	96.83	98.64	99.32	1.25	0.745
50% rice bran and hull	87.83[b]	97.24[a]	98.61[a]	1.08	0.032
75% rice bran and hull	82.37[b]	97.35[a]	98.67[a]	1.25	0.021
100% rice bran and hull	81.16[b]	96.97[a]	98.47[a]	1.05	0.019

[1]All data were presented as mean values with SEM.

Discussion

The accurate determination of true metabolizable energy (TME) relies on complete clearance of prior feed residues and full collection of excreta (Hartel, 1986). Factors such as feed amount, bird age, fasting duration, and gastrointestinal transit time can markedly affect ME estimates (Wu *et al*., 2020). Adult males are commonly used due to greater tolerance to feed deprivation and tube-feeding; nevertheless, inadequate feed allocation or improper fasting can lead to under- or overestimation of ME (Farrell, 1999; Pesti and Edwards, 1983; Wu *et al*., 2020).

In the present study, 18-week-old Magang ganders were fasted for 36 h and tube-fed 80 g of the test diet to standardize intake and minimize residual gut contents. Excreta were collected every 6 h over 48 h. For cereal- and protein-based diets, excreta output peaked within 24 h and remained stable thereafter, indicating that a 24-h collection period is sufficient for ME determination. These results are consistent with previous reports in geese fed corn and alfalfa (Shi *et al*., 2009), complete corn diets (Lu *et al*., 2011), mulberry leaf powder (Wang *et al*., 2017), moringa stem powder (Zhai *et al*., 2020), DDGS (Wang *et al*., 2018), and other unconventional feedstuffs (Zhang *et al*., 2013). Conversely, high-fiber diets prolong gastrointestinal transit. This aligns with findings in broilers fed sunflower meal, where over 80% of excreta was recovered within 36 h, with minimal change at 48 h (Villamide and San Juan, 1998). Such delays likely result from reduced interaction between chyme and digestive enzymes (Jha and Berrocoso, 2015) and limitations in nutrient absorption (Jimenez-Moreno *et al*., 2009). Interestingly, previous studies reported an optimal 48-h transit in cecum-excised geese (Wang *et al*., 2008; Yang *et al*., 2016), longer than the 36 h observed here, likely reflecting the ceca's critical role in microbial fiber fermentation (He *et al*., 2016), where its removal reduces fiber digestion and prolongs transit. These findings demonstrate that gastrointestinal transit and ME assessment are strongly influenced by both feed composition and bird species, highlighting the importance of adjusting excreta collection periods according to diet type and avian physiology.

Increased or decreased retention time of digesta in the gastrointestinal tract is not solely regulated by dietary fiber level, but also by its interaction with other dietary nutrients and gastrointestinal physiological activities (Müller *et al*., 2018). Specifically, soluble and insoluble fiber fractions differ markedly in water-holding capacity, bulking effect, and fermentability. Soluble non-starch polysaccharides (NSPs) can increase digesta viscosity, delay enzyme diffusion, and thereby prolong retention time, whereas insoluble fibers stimulate intestinal motility and accelerate passage rate (Hetland *et al*., 2001; Jha and Berrocoso, 2015). Beyond fiber, protein composition, starch digestibility, and fat inclusion also contribute to differences in gastrointestinal transit. For instance, undigested proteins may undergo microbial fermentation in the hindgut, producing metabolites that alter gut motility, while dietary fat has been shown to slow gastric emptying and extend digesta retention time (Gallier *et al*., 2014). Additionally, feed particle size and processing (e.g., pelleting, grinding) influence hydration, swelling, and breakdown of feed particles, thereby affecting physical actions in the foregut (wetting, softening, initial fermentation), followed by enzymatic digestion in the small intestine and mechanical propulsion through peristalsis (Thomas *et al*., 2020).

Collectively, these dietary and physiological interactions underline the complexity of determining the optimal excreta collection period for accurate ME assessment. While the present study focused primarily on dietary fiber effects in geese, future research should adopt a more integrative approach, considering soluble NSPs, protein quality, fat inclusion, and feed particle characteristics. Such a holistic perspective would better reflect the multifactorial regulation of gastrointestinal transit and ensure more precise standardization of ME determination across different poultry species and diet types.

Conclusion

Gastrointestinal transit time for different types of feed is essential to accurately determine the metabolizable energy of birds. For *Magang geese*, the optimal gastrointestinal transit time was 24 h for cereal and protein source feedstuffs, while test diets with different fiber contents required a relatively prolonged period of 24-36 h.

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Authors' Contributions

YueliangXie, Rongxi Li, and Wen Liu designed this study; Xiaohua Yao and Bin Peng acquired the data and performed theexperiments; YueliangXie, and Wen Liuwrote the manuscript. All authors haveread and approved the manuscript.

Conflicts of Interest : The authors declare no conflict of interest.

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