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Article

Effects of Dietary Metabolizable Energy Level on Production Performance of Geese: A Dose-Response Meta-Analysis

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Simple Summary: Metabolizable energy is an important nutrient in goose feeding, but the optimal level of metabolizable energy in geese feeding has not been determined. Therefore, the purpose of this study was to analyze the effects of dietary metabolizable energy levels on geese by dose-response meta-analysis and determine the optimal level of dietary metabolizable energy. The results showed that there were optimal levels of metabolizable energy in medium-sized geese and small-sized geese, and further studies should be conducted on large-sized geese, small-sized geese, and higher levels of dietary metabolizable energy in the future.

Abstract: To determine the impacts of metabolizable energy levels on the performance indices of geese and to forecast the ideal range of dietary metabolizable energy levels, this study was carried out. Literature on the effects of dietary metabolized energy level on the performance of geese was searched from CNKI, Wanfang, VIP, PubMed, Web of Science, and ScienceDirect databases from January 1, 2000, to December 31, 2022. A dose-response meta-analysis was performed by STATA (14.0), data were calculated by the robust error meta-regression model (REMR), and nonlinear dose-effect curves were plotted by the restricted cubic spline method (RCS). 29 papers were chosen from the 1,475 literatures that fit the criteria and were included in the dose-response meta-analysis. There were 6,079 geese included in the sample. The following production performance indices included average daily gain (ADG), average daily feed intake (ADFI), feed-to-gain ratio (F/G), dressed percentage, percentage of half-eviscerated yield, percentage of eviscerated yield, percentage of breast muscle, percentage of leg muscle and percentage of abdominal fat. The Egger test assessed publication bias, while sensitivity analysis was used to examine the heterogeneity. The verified results are consistent and reliable. The results indicated that for each group, the optimal dietary metabolizable energy level was about 13 to 13.5MJ/kg for medium-sized geese aged 0 to 4 weeks, 12 to 13MJ/kg for medium-sized geese aged above 5 weeks, 12.5 to 13MJ/kg for small-sized geese aged 0 to 4 weeks, and 13 to 13.5MJ/kg for mall-sized geese over 5 weeks of age. Future research should be conducted on related diets of large-sized geese, small-sized geese, and higher metabolizable energy levels.

Keywords: dietary metabolizable energy; production performance; geese; dose-effect meta-analysis

1. Introduction

Geese, as a kind of waterfowl living on herbivores, are suitable for breeding because of their characteristics such as rough feeding resistance, low feed consumption, resistance to disease, ease of breeding, high investment return, and short return cycle [1]. Human beings have a long history of breeding geese. As early as 6,000 years ago, records of domesticating geese appeared in ancient Egyptian society. At present, China is the country that raises the most geese in the world, and its breeding quantity exceeds the sum of the other countries, so it is known as the "waterfowl kingdom" [2,3]. In recent years, the goose breeding industry has developed rapidly. However, compared with the rising consumer demand for related products and the rapid development of the goose breeding industry, the related research on geese is relatively backward, and the research on the digestive physiology and feed formulation technology of geese is not mature. At present, although there are

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geese breeding standards formulated by NRC (1994) in the United States, the standards are no longer applicable to the current production situation. Relevant scholars have made a lot of achievements in the research on goose breeding standards, but there are differences among them. At present, there is no unified feeding standard in the industry, which not only inhibits the growth of geese, reduces the income, but also causes a waste of resources [4].

Energy is an important nutritional factor in formulating diets, and all activities of animals require energy. For poultry, because their feces and urine are discharged from the cloaca together, digestible energy cannot be used to represent the available part of total energy intake. On the contrary, metabolizable energy is relatively easy to measure, so metabolizable energy is the most commonly used energy system for poultry feed [5]. Poultry has a strong instinct to "eat for energy" and will adjust feed intake according to the dietary metabolizable energy level. If the dietary metabolizable energy level is too low, geese will increase feed intake and waste diet; if the dietary metabolizable energy level is too high, feed intake will be restricted, which will affect daily gain and body health [6]. Therefore, metabolizable energy level is an important part of diet design and formulation for geese. There have been many studies on the effects of dietary metabolizable energy levels on the performance of geese, but no uniform conclusion has been reached. For example, Zhang Chunlei et al. [7] studied the effects of different metabolites on the production performance of Rhine geese aged 0 to 4 weeks, and the results showed that the ADG of goslings aged 0 to 4 weeks increased with the increase of metabolites level. Ye Baoguo et al. [8] reported that the ADG of Anding geese showed a trend of first increasing and then decreasing with the increase of dietary metabolized energy level, while the ADFI showed a trend of first decreasing and then increasing. Stevenson [9] studied the effect of metabolizable energy concentration of diet on the growth of goslings. No significant difference was found in ADG of goslings at 0 to 4 weeks of age or 5 to 9 weeks of age, but ADFI decreased with the increase of metabolizable energy concentration. Cheng Hongna [10] reported that the dressed percentage of Hepu geese aged over 5 weeks was significantly increased with the increase of dietary metabolizable energy level, while the percentage of eviscerated yield was significantly decreased with the increase of dietary metabolizable energy level, and other indicators had no significant effect. However, Ma Yanqun et al. [11] found that the improvement of dietary metabolizable energy levels had no significant effect on the slaughter performance of Hepu geese. These differences in results may be due to differences in breed and age of geese used in the experiments.

Given the current development needs of the goose breeding industry, the relevant studies from January 2000 to December 2022 were combined and analyzed by dose-response meta-analysis, to clarify the effects of dietary metabolizable energy level on goose production performance and its dose-response relationship, and to provide a scientific basis for the diet formulation of goose breeding industry.

2. Materials and Methods

2.1. Retrieval strategy

In this paper, relevant literatures were retrieved from CNKI, Wanfang, VIP, PubMed, Web of Science, and ScienceDirect databases from January 1, 2000, to December 31, 2022. Among them, the search strategy was shown in Table 1.

Table 1. Search strategy.

Database	Search Term	Number
CNKI	(geese) and (“production performance” or “growth performance” or “slaughter performance”) and (“diet” or “feed” or “metabolic energy” or “energy”)	901
Wanfang	(geese) and (“production performance” or “growth performance” or “slaughter performance”) and (“diet” or “feed” or “metabolic energy” or “energy”)	11
VIP	(geese) and (“production performance” or “growth performance” or “slaughter performance”) and (“diet” or “feed” or “metabolic energy” or “energy”)	549

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Pub Med	(geese) AND ((production performance) OR (growth performance) OR (carcass characteristics)) AND (dietary metabolic energy)	10
Science Direct	(geese) AND ((production performance) OR (growth performance) OR (carcass characteristics)) AND (dietary metabolic energy)	1
Web of Science	(geese) AND ((production performance) OR (growth performance) OR (carcass characteristics)) AND (dietary metabolic energy)	3

2.2. Inclusion and exclusion criteria

The inclusion criteria of the literature in this paper were as follows: 1) The experimental animal geese were about 0~12 weeks old; 2) Randomized controlled trials were used in the literature; 3) The metabolizable energy levels of experimental diets were provided in the literature; 4) The experimental results provided in the literature include at least one production performance index of geese.

The exclusion criteria were as follows: 1) the experimental animal geese were more than 12 weeks old; 2) There was no significant difference in dietary metabolizable energy levels among the experimental groups. 3) The production performance indexes of geese were not included in the experimental results provided in the literature; 4) Review literature.

2.3. Information and data extraction

The following information was retrieved from each included article: author information (first author, year of publication), goose breed, goose week age, dietary metabolized energy level, experimental group sample size, performance indicators (ADG, ADFI, F/G, dressed percentage, percentage of half-eviscerated yield, percentage of eviscerated yield, percentage of breast muscle, percentage of leg muscle, percentage of abdominal fat) and their standard deviation (SD). If the standard deviation was not marked in the literature, the standard deviation within the group was calculated according to the method in the literature [12,13].

According to the records in Poultry Genetic Resources of China, geese can be divided into three types: large-sized breed, medium-sized breed, and small-sized breed [14]. According to the geese breeding standards formulated by NRC (1994) in the United States, the nutritional requirements of geese were classified into two categories: 0 to 4 weeks old, 5 weeks old and above [15]. Since the number of geese included in this study was large (n=18) and the variety characteristics were heterogeneous, the goose varieties were classified according to their characteristics. According to the relevant information on goose breed characteristics (adult weight of gander, adult weight of female goose, annual egg number, and average egg weight), the hierarchical clustering method was used to analyze and finally complete the grouping.

2.4. Statistical method

In this paper, the robust error meta-regression model (REMR) was used to integrate relevant dose-response data from different studies, and the dose-response relationship between dietary metabolic energy level and various indicators of the production performance of geese was analyzed [16]. A nonlinear dose-response meta-analysis plot was drawn using the restricted cubic spline method (RCS), in which three fixed nodes were assigned to 10%, 50%, and 90% of the total dietary metabolized energy level [17]. For the above results, the Egger test was used to analyze whether there is publication bias, and sensitivity analysis was used to verify whether the results are stable and reliable. The above operations were analyzed using the remr and xblc packages of STATA 14.0 software.

Results

3.1. Result of information retrieval

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A total of 1475 literatures were retrieved, and 1366 literatures remained after the removal of duplicate literatures. After reading titles, abstracts, and original texts, 1337 irrelevant literatures were eliminated according to the inclusion and exclusion criteria, and a total of 29 literatures remained [5,10,11,18-43]. The information included in the literature is shown in Table 2.

Table 2. Information for the included literature.

Serial	First author (year of publication)	Breed of geese	N[1]	Weeks of age	Dietary metabolizable energy level (MJ/kg)	Production performance indicators[2]
1	Cheng Hongna (2005)	Hepu geese	30	0~4；5~10	10.5；11.3；12.1	A1; A2; A3; B1; B2; B3; B6
2	Ma Yanqun (2005)	Hepu geese	20	5~10	10；11；12	A1; A2; A3; B1; B2; B3; B6
3	Yang Jiahuang (2009)	Hepu geese	20	5~10	10；11；12	A1; A2; B1; B2; B6
4	Liao Yuying (2006)	Yangzhou geese*Rhine geese	20	5~10	10；11；12	A1; A2
5	Gu Wenjie (2022)	Yangzhou geese*Rhine geese	10	0~4	10.8；11.8；12.8	B1; B2; B3; B4; B5; B6
6	Zhang Shuangjie (2018)	Yangzhou geese	20	0~4；5~10	11；12	A1; A2; A3
7	Li Qin (2016)	Sichuan white geese	156	0~3	10；10.73；11.43；12.13；12.86	A1; A2; A3
8	Li Qin (2014)	Sichuan white geese	60	0~4	11.5；12；13	A1; A2; A3
9	Cao Aiqing (2007)	Landaise; Xupu geese	80	0~3；4~10	10.87；12.13；13.38；10.87；12.13；13.38	A1; A2; A3; B1; B2; B3; B4; B5; B6
10	Ye Baoguo (2018)	Anding geese	60	0~4	10.5；11；11.5；12	A1; A2; A3
11	Sun Liya (2014)	Sichuan white geese	80	0~4	11.5；12.5	A1; A2; A3
12	Mo Zhaoli (2013)	Yan geese	18	0~5	10.8；11.53	A1; A2; A3
13	Zhao Ayong (2004)	Landaise	24	0~4；5~11	12；12.5；13	A1; A2; A3; B1; B2; B3; B4; B5; B6
14	Wang Zongwei (2009)	Northeast China meat geese	24	0~4	10.9；11.7；12.5	A1; A2; A3; B1; B2; B3; B5; B6
15	Mo Xiaoling (2009)	Rhine geese	24	5~8	10.7；11.5；12.3	A1; A2; A3
16	Wei Zongyou (2009)	Yangzhou geese	50	6~10	10.11；11.19；12.37；13.45	A1; A2; A3; B1; B2; B3; B4; B5; B6
17	Hu Junpeng (2008)	Landaise; Xupu geese	10	4~10	11.3；12.55；13.81；11.3；12.55；13.81	B1; B2; B3; B4; B5; B6

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18	Yin Haicheng (2006)	Gushi white geese	30	5~9	10.5；11.3；11.8	A1; A2; A3
19	Yu Lihuai (2010)	Yangzhou geese	50	6~10	10.11；11.19；12.37；13.45	A1; A2; A3; B4; B5; B6
20	Wei Zongyou (2009)	Yangzhou geese	50	5~10	10.11；11.19；12.37；13.45	A1; A2; A3
21	Wu Shengli (2015)	Roman geese; Wanxi white geese	10	5~8	11.5；12.12；11.5；12.12	A1; A2; A3; B1; B3; B4; B5; B6
22	Shi Shourong (2006)	Yangzhou geese	20	5~10	10.5；11.5	A1; A2; A3; B1; B2; B3; B4; B5
23	Mo Xiaoling (2009)	Northeast China meat geese	24	5~8	10.7；11.5；12.3	A1; A2; A3; B2; B3; B5; B6
24	Zhang Shuangjie (2015)	Taihu geese	300	0~4；5~11	10.5；11；11.5	A1; A3
25	Wang Qingfeng (2017)	Zhijin white geese	30	0~4	10.34；11.49；12.64	A1; A2; A3
26	Min Yuna (2005)	Huoyan geese	24	0~4；5~8	10.87；11.37；11.87；12.37；12.87	A1; A2; A3; B3; B4; B5; B6
27	Zhang Ling (2015)	Sumu white geese	30	0~4	10.8；11.8；12.8	A1; A2; A3
28	Luo Huan (2016)	Zhijin white geese	30	5~10	10.53；11.72；13.2	A1; A2; A3
29	Mahmoud Alagawany (2020)	Egyptian geese	30	5~10	12.5；11.72；12.13；12.55	A1; A2; A3; B1

[1] Number of geese included in the study. [2] Experimental indicators included in the study: A1 = average daily gain (g/d); A2 = average daily feed intake (g/d); A3 = feed to gain ratio; B1 = dressed percentage (%); B2 = percentage of half-eviscerated yield (%); B3 = percentage of eviscerated yield (%); B4 = percentage of breast muscle (%); B5 = percentage of leg muscle (%); B6 = percentage of abdominal fat (%).

3.2. Data treating

The goose breeds included in the literature were grouped by hierarchical clustering method, and combined with the records in Poultry Genetic Resources of China, they could be divided into medium-sized geese and small-sized geese. The animal groups and characteristics were shown in Figure 1 and Table 3. Then they were divided into brooding period (0-4 weeks of age) and fattening period (over 5 weeks of age) according to the week age, and on this basis, they were analyzed respectively. The statistical description of all the data is shown in Table 4.

Table 3. Animal groups and their characteristics.

Subgroup	N[1]	Adult male goose weight (g)		Adult female goose weight (g)		Average eggs per year		Average egg weight (g)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Medium-sized breed	3644	6158.46	790.49	5329.23	819.19	45.15	16.41	158.08	21.27
small-sized breed	2435	4760.00	433.59	3980.00	476.45	66.00	21.62	145.80	13.29

[1]Number of geese included in the subgroup.

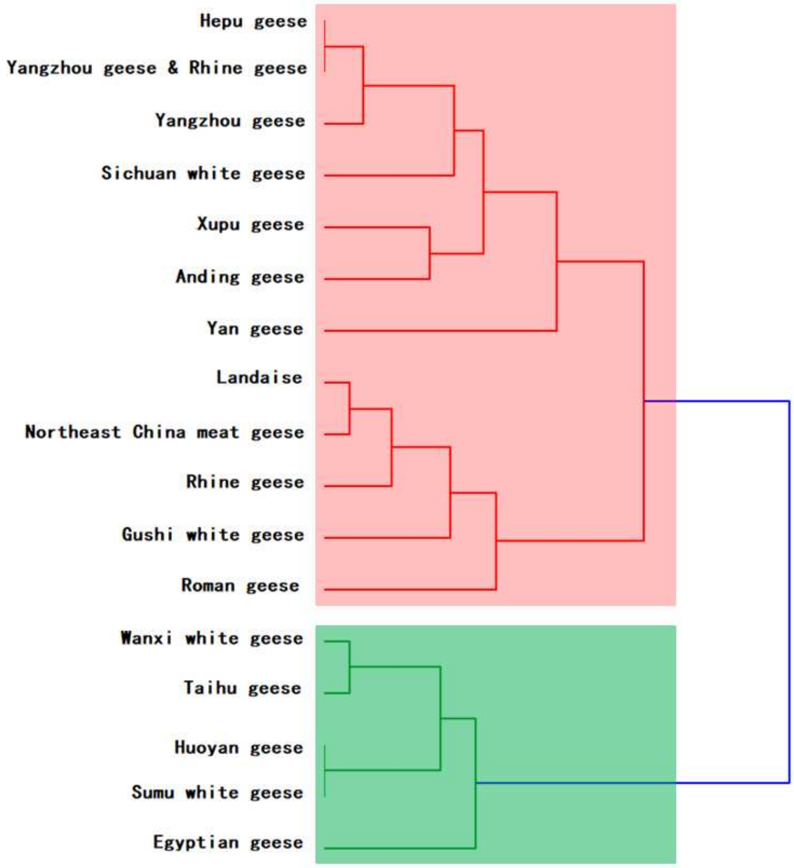

Figure 1. Hierarchical clustering tree diagram.

Table 4. A statistical description of the main variables in the database.

Subgroups and Indicators[1]		0-4 weeks of age			5 weeks of age or older		
		N[2]	Mean	SD	N[3]	Mean	SD
Medium-sized geese	ADG (g/d)	2150	43.78	5.21	1494	58.45	13.23
	ADFI (g/d)	2110	83.81	13.59	1454	247.61	47.7
	F/G	2150	2.26	0.27	1374	4.47	0.89
	Dressed percentage (%)	195	87.44	2.10	328	85.61	1.91
	Percentage of half-eviscerated yield (%)	195	77.32	1.16	306	76.74	1.77
	Percentage of eviscerated yield (%)	195	59.76	7.51	337	66.07	4.56
	Percentage of breast muscle (%)	150	1.73	0.17	347	8.15	2.19
	Percentage of leg muscle (%)	168	14.09	7.33	365	12.06	3.41
	Percentage of abdominal fat (%)	195	1.29	0.19	438	3.25	1.05
Small-sized geese	ADG (g/d)	1200	3.75	5.28	1235	41.18	4.21
	ADFI (g/d)	400	91.70	14.21	435	183.35	38.39
	F/G	1200	2.48	0.63	1235	4.91	1.14

[1]Subgroups and indicators of study. [2] Number of geese included in the subgroup and indicator. [3] Number of geese included in the subgroup and indicator.

3.3. Results of dose-response meta-analysis

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3.3.1. Medium-sized geese

In this paper, a dose-response meta-analysis was performed on the data of 2,150 medium-sized geese aged 0 to 4 weeks in 11 literatures, and the analysis results were shown in Figure 2. Dietary metabolizable energy level in the range of 10.5 to 13.5MJ/kg was negatively correlated with ADG and F/G of medium-sized geese aged 0 to 4 weeks but was positively correlated with dressed percentage and percentage of thigh muscle. When the dietary metabolizable energy level was 13 to 13.5MJ/kg, F/G reached the lowest level and still maintained a downward trend. The indexes of slaughtering performance were at a high level and had an upward trend. In conclusion, 13 to 13.5MJ/kg is the optimal dietary metabolizable energy level for medium-sized geese aged 0 to 4 weeks.

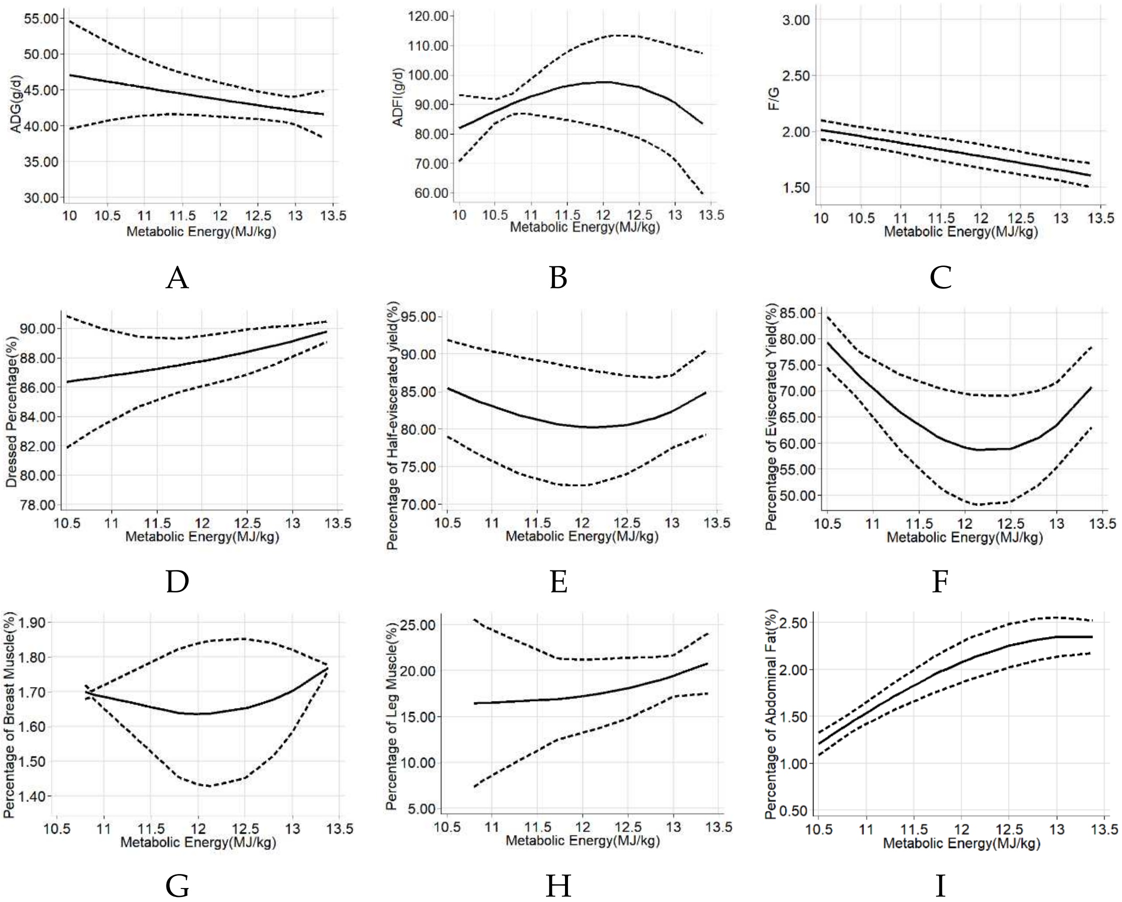

Figure 2. Results of dose-response meta-analysis of the effects of dietary metabolizable energy level on performance of medium-sized geese aged 0 to 4 weeks. (A): ADG; (B): ADFI; (C): F/G; (D): Dressed percentage; (E): Percentage of half-eviscerated yield; (F): Percentage of eviscerated yield; (G): Percentage of breast muscle; (H): Percentage of leg muscle; (I): Percentage of abdominal fat.

Then, a dose-response meta-analysis was performed on the relationship between dietary metabolizable energy level and production performance of medium-sized geese aged above 5 weeks. Data from 1,494 geese in 16 literatures were included in the analysis, and the analysis results were shown in Figure 3. When dietary metabolizable energy level was between 10 and 14MJ/kg, it was negatively correlated with ADFI, percentage of half-eviscerated yield, and percentage of eviscerated yield of medium-sized geese aged 5 to 10 weeks, but positively correlated with the percentage of chest muscle. When the dietary metabolizable energy level is 12-13MJ /kg, the F/G of geese reaches the lowest value, and the dressed percentage, percentage of thigh muscle, and percentage of abdominal fat reach the maximum value. In conclusion, when the dietary metabolizable energy level is 12-13MJ /kg, the production performance of medium-sized geese above 5 weeks of age can reach the best level.

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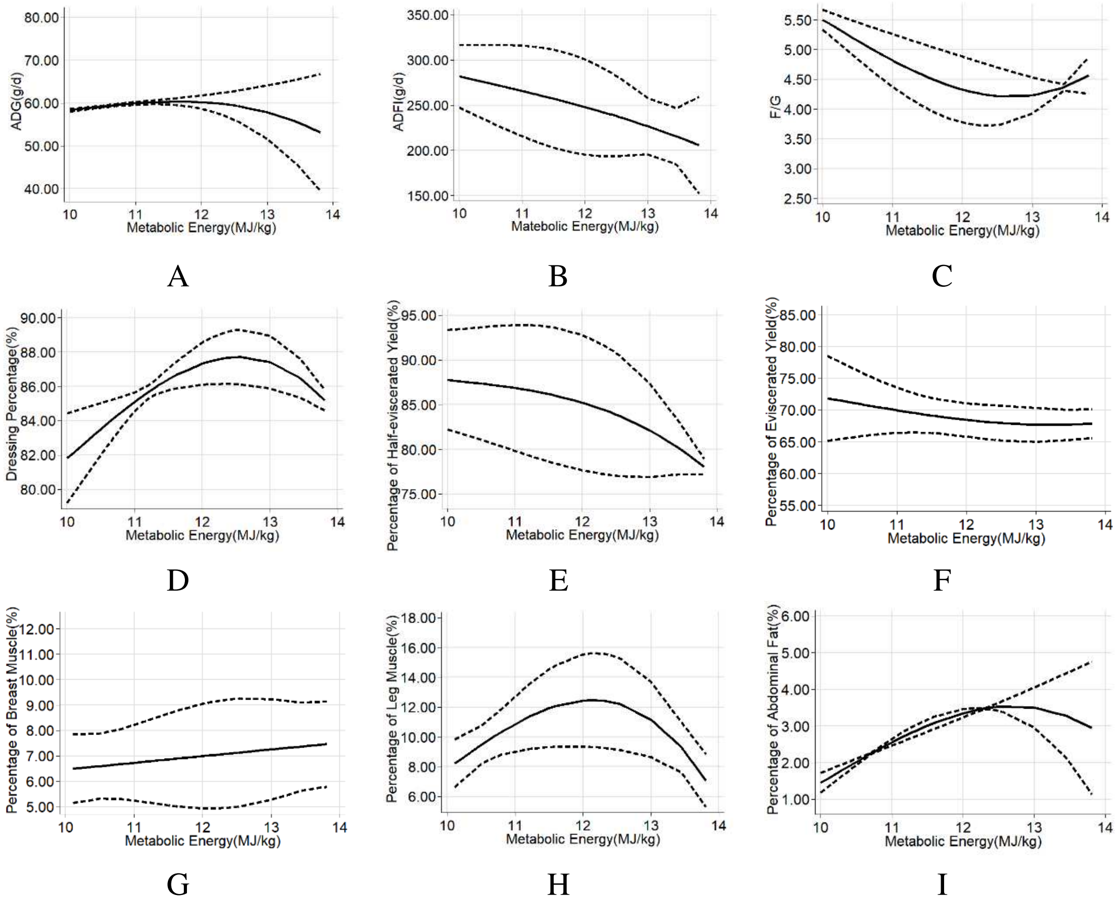

Figure 3. Results of dose-response meta-analysis of the effects of dietary metabolizable energy level on performance of medium-sized geese aged over 5 weeks. (A): ADG; (B): ADFI; (C): F/G; (D): Dressed percentage; (E): Percentage of half-eviscerated yield; (F): Percentage of eviscerated yield; (G): Percentage of breast muscle; (H): Percentage of leg muscle; (I): Percentage of abdominal fat.

Based on the above analysis results, the Egger test and sensitivity analysis are carried out in this paper. The results showed that there was no significant publication bias in all studies (P_{Egger}>0.05). After sensitivity analysis, all the results showed no significant change after excluding any experimental group, which proved that all the analysis results were stable and reliable.

3.3.2. small-sized geese

As can be seen from Table 2, a total of 6 literatures on small-sized geese were included in this paper. Due to the small number of experimental groups in the literatures, only dose-response meta-analysis of ADG, ADFI, and F/G in each group could be conducted in this paper.

In this paper, experimental data of 1,200 0-4-week-old small-sized geese from 4 literatures were included. The results were obtained through dose-response meta-analysis, as shown in Figure 4. When the dietary metabolizable energy level of geese was between 10 and 13MJ/kg, there was a significant nonlinear relationship with the ADG, ADFI, and F/G of geese aged 0 to 4 weeks ($p<0.05$), which was positively correlated with the ADG, and negatively correlated with the ADFI and F/G. When the dietary metabolizable energy level was 12.5 to 13MJ/kg, the lowest F/G was obtained for small-sized geese aged 0 to 4 weeks, and the F/G still showed a downward trend, which should be the best metabolizable energy level.

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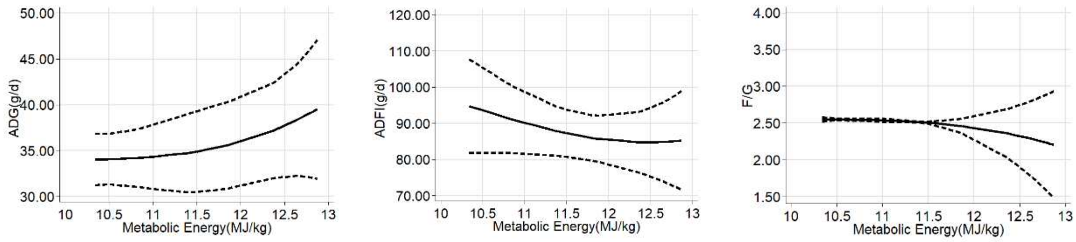
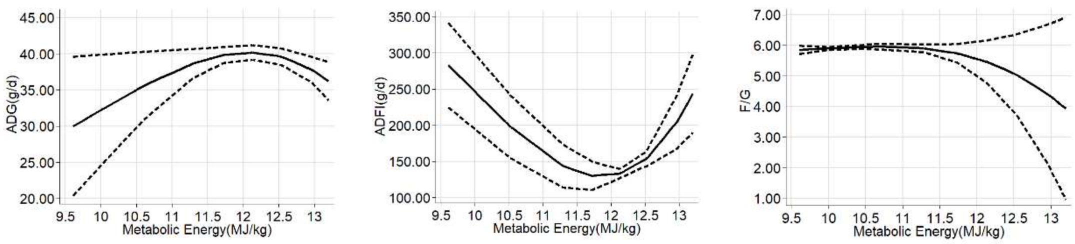


A B C

Figure 4. Results of dose-response meta-analysis of the effects of dietary metabolizable energy level on performance of small-sized geese aged 0 to 4 weeks. (A): ADG; (B): ADFI; (C): F/G.

In this paper, a dose-response meta-analysis was performed on the relevant data of 1,235 small-sized geese over 5 weeks of age in 4 literatures, and the results were shown in Figure 5. There were significant nonlinear relationships between the dietary metabolizable energy level of geese and the ADG, ADFI, and F/G of geese aged above 5 weeks when the dietary metabolizable energy level was between 9.5 and 13MJ/kg ($p<0.05$). The ADG and ADFI of geese aged above 5 weeks reached their minimum values at the dietary metabolizable energy level of 11.5 to 12.5MJ/kg, respectively, while the F/G reached the minimum values at the dietary metabolizable energy level of 13 to 13.5MJ/kg, and the F/G showed a decreasing trend. Therefore, 13 to 13.5MJ/kg should be the optimal dietary metabolizable energy level for small-sized geese aged above 5 weeks.



A B C

Figure 5. Results of dose-response meta-analysis of the effects of dietary metabolizable energy level on performance of small-sized geese aged over 5 weeks. (A): ADG; (B): ADFI; (C): F/G.

Egger test and sensitivity analysis were carried out for the above analysis results. In the Egger test, the results of each index showed no significant publication shift ($P_{Egger}>0.05$). The sensitivity analysis results showed no significant difference from the original analysis results, which proved that the analysis results of each index were stable and reliable.

4. Discussion

4.1. Effects of dietary metabolizable energy level on growth performance of geese

Energy is the key factor to regulate the growth and development of poultry, and only when the energy needs are met, other nutrients such as protein, crude fiber, and vitamins can play their physiological roles.

The results showed that the ADG of geese aged 0 to 4 weeks showed an upward trend, while those aged 5 to 10 weeks showed an upward trend and then a downward trend. This may be because the relative growth rate of young geese in the early growth period is relatively fast, the metabolizable energy concentration requirement is large, and the energy tolerance is strong, so the ADG doesn't show a downward trend. However, after 5 weeks of age, the growth rate of young geese reaches its peak and begins to decline, and the demand for energy decreases accordingly. At this time, if the geese are fed at a high metabolic energy level for a long time, they will appear morbid, resulting in slow growth, weight loss, reduced fat deposition, and even death [44].

Because poultry has a strong instinct to "eat for energy", geese will maintain the total energy intake at a relatively stable level by controlling feed intake. With the increase of dietary metabolizable energy levels, geese should reduce the ADFI. The above analysis results partially verified this conclusion, but the data of medium-sized geese aged 0 to 4 weeks and small-sized geese aged 5 to 10 weeks did not support this conclusion, which may be due to the small number of included data.

Due to the needs of actual production, the F/G in growth performance is more important than other indicators. Therefore, when there are differences in the optimal metabolizable energy levels of each indicator of growth performance in the results of this study, the F/G results are mainly analyzed. According to the results of the previous studies, with the increase of dietary metabolizable energy level, the ADG and ADFI of geese have different upward and downward trends, but F/G has the same downward trend, which is consistent with the research results of Li Qin, Cao Aiqing and Ye Baoguo [23-25] et al. The decreasing trend of F/G may be because the influence of metabolizable energy level on the ADG of geese is weaker than that on the ADFI of geese.

4.2. Effects of dietary metabolizable energy level on slaughter performance of geese

The results showed that with the increase of dietary metabolizable energy level, the percentage of half-eviscerated yield, percentage of eviscerated yield, and percentage of breast muscle of medium-sized geese aged 0 to 4 weeks were firstly decreased and then increased, while the dressed percentage, percentage of thigh muscle and percentage of abdominal fat were increased. The dressed percentage, percentage of thigh muscle, and percentage of abdominal fat of medium-sized geese over 5 weeks of age increased first and then decreased, the percentage of half-eviscerated yield and percentage of eviscerated yield decreased, and the percentage of breast muscle increased. This situation may be related to the growth stage of geese, fat deposition, and metabolism. Geese, as waterfowl, can deposit a large amount of fat, especially in the abdomen, as an insulation layer to prevent heat loss in cold water [45]. For poultry, fat deposition speed is different in different parts of the body. Cahaner et al. [46] discussed and found that in broilers, the deposition speed is the highest in the abdomen, followed by the neck fat and then the legs. This is consistent with the changing trend of the percentage of abdominal fat in this study. When metabolizable energy level reaches a certain point, the rate of fat deposition in the abdomen begins to slow down, and abdominal fat percentage decreases accordingly. On the other hand, it may be related to the different energy requirements and tolerance of geese at different growth stages. Like the influence of energy on ADG, for geese aged 5-10 weeks, too high metabolized energy level will also reduce the rate of fat deposition, and eventually lead to the reduction of abdominal fat percentage.

4.3. Boundedness

In this study, geese were grouped according to their breed and age. The results showed that the trend of the dose-effect curve of the same index and the range of optimal dietary metabolizable energy levels predicted among different groups were inconsistent. The results suggest that the breed and age of geese may be responsible for the differences between the results of the relevant studies.

The number of relevant literatures included in this paper is still too small, which makes it impossible to perform dose-response meta-analysis on all the existing data on large-sized geese and slaughter performance data of small-sized geese, so no analysis results are available. Some of the analysis results in this paper may not reach the optimal level of metabolizable energy due to the limitations of the maximum dietary metabolizable energy level in the existing studies.

5. Conclusions

The results of dose-response meta-analysis showed that the optimal dietary metabolizable energy levels were obtained within the range of existing dietary metabolizable energy levels. The optimal dietary metabolizable energy levels were about 13 to 13.5MJ/kg for medium-sized geese aged 0 to 4 weeks, about 12 to 13MJ/kg for medium-sized geese aged above 5 weeks, and about 12.5 to 13MJ/kg for small-sized geese aged 0 to 4 weeks, small-sized geese over 5 weeks of age are about 13 to 13.5MJ/kg. Future studies should be conducted on related diets of large-sized geese, small-sized geese, and higher metabolizable energy levels.

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