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Research article

The impact of replacing corn with elephant grass (*Pennisetum purpureum*) on growth performance, serum parameters, carcass traits, and nutrient digestibility in geese

Yi Liu [1], Xianze Wang [1], Guangquan Li, Shaoming Gong, Yunzhou Yang, Cui Wang, Huiying Wang [*], Daqian He [**]

Institute of Animal Husbandry and Veterinary Science, Shanghai Academy of Agricultural Sciences, Shanghai, China

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ABSTRACT

This study investigated the effects of partially replacing corn with elephant grass dry matter (air drass) on growth performance, serum parameters, carcass traits, and nutrient digestibility in geese. A total of 360 one-day-old Hortobágyi geese were randomly divided into three groups: control (basic diet), 12 % elephant grass, and 24 % elephant grass. The geese were raised for 70 days. The results showed that compared to the control, 12 % elephant grass had no adverse effects on final body weight, feed/gain ratio, mortality, serum liver and kidney function markers. However, 24 % elephant grass significantly reduced the final body weight ($P < 0.001$) and feed/gain ratio ($P = 0.026$) compared to the control group. Both experiment groups had decreased serum aspartate aminotransferase ($P < 0.001$), alanine aminotransferase ($P < 0.001$), alkaline phosphatase ($P < 0.001$), triglycerides ($P < 0.001$), and total cholesterol ($P < 0.001$). The addition of 12 % and 24 % elephant grass reduced abdominal fat ($P = 0.002$), but it had no significant effect on slaughter rate, half-bore rate, full-bore rate, breast muscle rate and leg muscle rate. For nutrient digestibility, 12 % elephant grass improved neutral detergent fiber digestibility compared to the control group ($P = 0.026$). The 24 % grass group had reduced Ca absorption ($P = 0.020$). Overall, the findings suggest that partially replacing corn with 12 % elephant grass in goose diet can maintain growth performance and carcass traits.It also has no negative effect on nutrient digestibility while improving serum parameters.

1. Introduction

As a cornerstone of world agriculture, poultry farming constantly looks for improvements in feed composition to sustainably improve production, health, and product quality. The need to investigate affordable, nutrient-dense, and ecologically friendly substitutes for traditional feed ingredients is crucial to this endeavor [1,2]. Corn stands out among the conventional ingredients as the main energy source for poultry [3]. The difficulties of its shifting costs, vulnerability to climatic conditions [4], and its competitive use for human consumption and the generation of biofuels, however, have made it essential for researchers to look into workable

* Corresponding author.
** Corresponding author.
E-mail addresses: yjshywang@sina.com (H. Wang), daqianhe@aliyun.com (D. He).
[1] Co-authors contributed equally to this manuscript.

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alternatives [5]-.

China possesses abundant forage resources. Compared to traditional crops, forage yields are substantial and have a clear price advantage [6]. Incorporating an appropriate amount of forage into feed can save on concentrated feed, reduce breeding costs, and is beneficial in enhancing the immunity of animals, ensuring their health [7,8]. Incorporating ryegrass into the dairy cows' diet can optimize the utilization efficiency of dietary nitrogen [9]. Furthermore, ryegrass supplementation has been shown to effectively reduce malodorous compounds in feces, likely through modulation of the carbohydrate-utilizing microbial community in the intestine [10]. Combining tall fescue with alfalfa enhances the nutritional profile of Angus cattle rations [11], leading to improved production metrics. This enhancement may be attributed to the potent antioxidants, specifically alfalfa flavonoids, which also hold promise as prospective feed additives for both poultry and livestock [12].

Originating from Africa, elephant grass is widely recognized for its rapid growth, resilience to pests, and adaptability to varying environmental conditions [13].The current applications of elephant grass in animals are primarily focused on ruminants, possibly due to its higher crude fiber content [14].

The Hortobágyi goose, developed by the Hungarian Hortobágyi Goose Joint Stock Company, stands out as a versatile breed for meat, down production. It stands out, experiencing a growing market demand in Central Asia and Europe, with a notable surge in popularity, especially in China [15]. Geese have a well-developed cecum and gizzard, which plays a crucial role in nutrient digestion: the plant cell walls can be broken down in the gizzard, and the cecum contains a large number of microorganisms capable of utilizing various types of crude fiber, especially when they are fed a low-energy and high-fiber diet [16]. It is generally believed that the appropriate level of crude protein for commercial geese is between 15 and 20 %, with methionine and cysteine at 0.5 %, and calcium at 0.6–1.0 % [17]. But the optimal level of crude fiber varies for geese of different ages and breeds [18]. Moreover, an excessively low level of crude fiber can negatively impact the growth performance, slaughter performance, serum biochemical parameters, and nutrient utilization in geese [19]. Incorporating 16 % ryegrass powder into the diet of Yangzhou geese can enhance growth performance, carcass traits, and blood biochemical composition. Moreover, a ryegrass to concentrate ratio ranging between 1.5 and 2 can ameliorate the muscle quality of goose breast [20]. The judicious addition of alfalfa powder to the diet can improve the slaughter performance, organ weight, and serum biochemical indices of geese [21]. However, applications of elephant grass in geese have yet to be discovered.

In this experiment, elephant grass was used as an unconventional feed to partially replace corn, aiming to investigate its impact on the growth performance, serum biochemical indices, slaughter performance, and nutrient digestibility of geese. The objective is to optimize the utilization of this resource, offering more efficient feeding strategies for animal production.

2. Materials and methods

2.1. Animal ethics

The experimental protocol adhered to the guidelines set forth by the Animal Protection Committee of China and was approved by the Committee for Animal Protection and Utilization at the Shanghai Academy of Agricultural Sciences (SAASPZ0522046). Throughout the study, while ensuring scientific accuracy, we aimed to minimize the number of geese used and endeavored to alleviate any potential discomfort to the geese during the experiment.

2.2. Experimental material

The elephant grass seeds used in the experiment were purchased from Green Pasture Agriculture Co., Ltd (Binyang, Guangxi, China). The cultivation of elephant grass and the rearing of geese are both carried out at Nanjing Changwo Agricultural Technology Co., Ltd. (Nanjing City, Jiangsu Province, longitude 118°21′ East, latitude 30°51′ North). Choose well-drained soil, deep plow about 20 cm, and remove weeds and stones. Plant elephant grass stem segments in ridges about 1 m apart, with each plant spaced about 50 cm apart. After planting, water once in the morning and once in the evening for the first seven days to keep the soil moist but avoid waterlogging. During the growing season, adjust the irrigation frequency according to the weather and soil moisture. The harvest of elephant grass is usually carried out when the plant height reaches 1.2 m. Use a sickle to harvest, leaving about 15 cm of stem stump to promote regeneration. The whole elephant grass is dehydrated in the sun for a week, then dried using a three-stage rotary drum dryer (Lunji, Shandong, China) at 65 °C. It was subsequently ground using a grinder (Jishun, Shandong, China) and sieved through a 2 mm

Table 1
Nutrient level of elephant grass (air-dried basis).

Items	Content
Crude protein, %	8.24
Crude fat, %	1.83
Crude ash, %	13.47
Neutral detergent fiber, %	54.71
Acid detergent fiber, %	34.25
Calcium, %	0.24
Phosphorus, %	0.38
Metabolizable energy, MJ/kg	15.76

mesh to obtain the powder form. This powder was mixed with commercial feed for the experiment. All experiments utilized the same batch of hybrid foxtail millet powder. The obtained elephant grass powder was sent to Inger Testing Technology Services Ltd. (Shanghai) for analysis. The results showed a crude protein content of 8.24 % and crude fat content of 1.83 %. The specific nutritional components and amino acid composition are presented in Table 1.

2.3. Animals and experimental design

The experiment utilized 360 one-day-old Hortobágyi geese, which were randomly divided into three groups (BD, EG12, EG24). Each group had six replicates, with each replicate consisting of 20 geese (half males and half females). The control group (BD) was fed a basic diet, formulated based on the NRC (1994) guidelines and adjusted according to the actual goose feeding formula in China [17]. The EG12 and EG24 groups were supplemented with 12 % and 24 % elephant grass in their diets, respectively. The proportion of corn and soybean oil was adjusted to ensure equivalent energy values across diets (Table 2) .

All geese were raised in open sheds with a stocking density of 2 m^2 per goose. The rearing method was ground-based, with rice husks spread on the floor, which were replaced every 15 days. The temperature was maintained at ambient conditions, and lighting was provided by natural daylight. In each shed, nipple drinkers are installed, spaced 20 cm apart. The height of these drinkers is adjusted in accordance with the growth of the geese, ensuring that they are always easily accessible. Regular water quality checks are conducted to guarantee that it meets the standards for animal drinking water. Feed is placed in the troughs twice daily, at 8:00 a.m. and 4:00 p.m. Throughout the experiment, the goose sheds were kept clean and sanitary, with geese having unrestricted access to feed and water. Vaccinations were administered regularly, and the health status of the geese was continuously monitored.

2.4. Growth performance

At the start (1 day old) and end (70 days old) of the experiment, each goose was weighed. During the trial period, record the feed intake for each replicate and calculate the average daily gain (ADG), average daily feed intake (ADFI), and feed/gain ratio (F/G). Based on replicates, compute the culling rate and mortality rate of geese during the trial.

2.5. Serum biochemical indicators

At the end of the experiment, two male and two female geese were selected from each replicate. 4 ml of blood was drawn from the wing vein and placed in vacuum-sealed tubes, then stored at 37 °C for 2 h. Afterward, the blood was centrifuged at 4500 rpm for 15 min to obtain serum. Several serum parameters were analyzed using an automatic biochemistry analyzer (HITACHI 7,180, Japan). The tested indicators included alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), calcium (Ca), creatinine (Cre), triglycerides (TG), glucose (Glu), phosphorus (P), total cholesterol (TC), and uric acid (UA).

2.6. Slaughter performance and organ index

In each replicate, a male goose approximately matching the average body weight of the was selected. After an 8-h fasting period, the fasting live weight of the goose is recorded. The goose is then euthanized using the cervical bleeding method, with efforts made to minimize the animal's distress. Post-complete bleeding and plucking, the carcass weight, half-bore weight, full-bore weight,

Table 2
Composition and nutrient level of experiment diets (air-dry basis).

Items	Groups		
	BD	EG12	EG24
Corn, %	70.75	60.82	49.37
Soybean meal, %	22.80	22.47	22.43
elephant grass, %	0.00	12.00	24.00
Soybean oil, %	2.13	0.45	0.00
Premix[a], %	3.0	3.0	3.0
Total, %	100.0	100.0	100.0
Nutrient level			
CP, %	16.00	16.00	16.00
ME[b], MJ/kg	12.00	12.00	12.28
CF, %	4.03	8.10	12.18
Ca, %	0.90	0.90	0.90
P, %	0.40	0.42	0.44

BD:basal diet group, EG12:12 % elephant grass group, EG24:24 % elephant grass group, CF:crude fiber, CP:crude protein, ME:metabolizable energy, P:phosphorus, Ca: calcium.

[a] One kilogram of the premix contained the following: Fe 100 mg, Cu 8 mg, Mn 120 mg, Zn 100 mg, Se 0.4 mg, Co 1.0 mg, I 0.4 mg, V_A 8330 IU, V_{B1} 2.0 mg, V_{B2} 0.8 mg,V_{B6} 1.2 mg, V_{B12} 0.03 mg, V_{D3} 1440 IU, V_E 30 IU, biotin 0.2 mg, folic acid 2.0 mg, pantothenic acid 20 mg, niacin acid 40 mg.

[b] Nutrient levels were all calculated values.

abdominal fat weight, leg muscle weight, and breast muscle weight are determined. The slaughter rate, half-bore rate, full-bore rate, breast muscle rate, leg muscle rate, and abdominal fat rate are calculated in accordance with the "Poultry Production Performance Terminology and Measurement Statistical Methods" (NY/T823-2004). Concurrently, the heart, liver (excluding the gall bladder), glandular stomach, muscular stomach (excluding keratin and contents), intestines, Fabricius' bursa, spleen, and thymus are weighed separately, and the organ indices are calculated. The formula for the organ index is as follows: Organ Index = Organ Weight (g)/Live Weight (Kg).

2.7. Apparent digestibility

We gathered feed samples over a continuous span of 5 days, commencing on day 65. These samples were then homogenized and hermetically sealed for preservation. Concurrently, through the comprehensive fecal collection method, we amassed fresh droppings from each goose daily for a consecutive 5-day period. After removing feathers and extraneous contaminants, the feces underwent weighing. We selected 10 % of the overall weight. For every 100g of this fresh fecal matter, we introduced 10 mL of a 10 % dilute sulfuric acid solution to facilitate nitrogen fixation. All feed and fecal specimens were transported to the lab where they were methodically dried at 65 °C until reaching a consistent weight, and then finely pulverized. The determination methods for crude protein (CP), crude fat (EE), crude ash (Ash), Ca and P were conducted following the procedure described by the Association of Official Analytical Chemists (AOAC) 990.3, 920.39, 942.05, 927.02 and 965.17 [22]. Refer to the method of Zhang et al. for the detection of neutral detergent fiber (NDF), acid detergent fiber (ADF), and metabolizable energy (ME) [23], with the calculation: $\text{Digestibility}(\%) = \left(\frac{\text{Nutrient intake-Nutrient output in feces}}{\text{Nutrient intake}}\right) \times 100$.

2.8. Statistical analysis

The original data regarding to the growth performance, serum biochemical indices, slaughter performance, and apparent digestibility of geese were organized by using Excel 2007. The one-way ANOVA method in SPSS 26.0 software was employed for analysis. Subsequently, the Duncan's multiple comparison method was utilized. A significance level of $P < 0.05$ indicates statistically significant differences. The analysis was conducted with the following model: $Y_{ijk} = \mu + \tau_j + e_{ijk}$ Where: Y_{ijk} = dependent variable, μ = overall mean value, τ_j = fixed effect of the jth of τ factor, and e_{ijk} = residual value from unpredictable error. $S\tau_{ij}$ and S_i are taken to be independent variables that are chosen at random. The validation test was regulated using the root mean square error (RMSE) following. $\text{RMSE} = \sqrt{\frac{\sum(O-P)^2}{NDP}}$ Note: O = actual value, P = estimated value, NDP = number of data point, σ_f^2 is the variant of a fixed factor, $\sum(\sigma_l^2)$ is the sum of all variants of the component, σ_e^2 is the variant due to the predictor dispersion and σ_d^2 is the specific distribution of the variant.

3. Results

3.1. Growth performance

There were no significant differences in the elimination ($P = 0.943$) and mortality ($P = 0.926$) rate among the groups. In comparison to the BD group, the addition of 24 % elephant grass led to a significant reduction in final body weight ($P < 0.001$) and F/G ($P = 0.026$) (Table 3).

3.2. Serum biochemical indicators

Adding 12 % and 24 % elephant grass notably decreased the levels of serum ALP, ALT, and AST ($P < 0.001$). Concerning markers for kidney function, Ca and P, the addition of 24 % elephant grass increased the levels of serum Cre ($P = 0.009$) and decreased the levels of

Table 3
The effect of replacing corn with elephant grass on the growth performance of geese.

Items	Groups			SEM	*P*-value
	BD	EG12	EG24		
Initial body weight, g	107.72	106.50	107.01	0.51	0.62
Final body weight, g	4341.83[a]	4443.25[a]	4022.41[a]	32.05	<0.01
Average daily gain, g/d	60.49[a]	61.95[a]	55.93[a]	0.46	<0.01
Average daily feed intake, g/d	353.04	351.01	351.11	1.93	0.901
Feed to gain ratio	5.85[a]	5.69[a]	6.29[a]	0.10	0.026
Elimination rate, %	11.67	11.67	12.50	1.08	0.943
Mortality rate, %	9.17	10.00	10.00	0.95	0.926

BD:basal diet group, EG12:12 % elephant grass group, EG24:24 % elephant grass group.
[a] The data in the table are compared in the same row, and different lowercase letters indicate that the difference has reached a significant level (P < 0.05).

Ca ($P = 0.006$), and P ($P = 0.002$). For lipid indicators, adding 12 % and 24 % elephant grass significantly decreased the levels of serum TG ($P < 0.001$) and TC ($P < 0.001$). There was no significant difference in UA levels among the groups ($P = 0.401$) (Table 4).

3.3. Slaughter performance and organ index

There was no significant difference among the groups in terms of Slaughter rate ($P = 0.526$), Half-bore rate ($P = 0.275$), Full-bore rate ($P = 0.178$), Breast muscle rate ($P = 0.063$), and Leg muscle rate ($P = 0.304$). The addition of 12 % and 24 % elephant grass significantly reduced the abdominal fat rate in geese ($P = 0.002$) (Table 5). In terms of the organ index, we observed a trend towards an increased liver index with the addition of 24 % elephant grass ($P = 0.053$). Compared to the BD group, EG24 group significantly elevated the Glandular stomach index ($P = 0.042$), Intestinal index ($P = 0.002$), Bursa of Fabricius index ($P = 0.008$), and Thymus index ($P = 0.037$) (-Table 6).

3.4. Apparent digestibility

The impact of the addition of elephant grass on the apparent digestibility in geese is presented in Table 7. Compared to the BD group, there was no significant difference in the CP digestibility rate among the groups ($P = 0.268$). The EG12 group had the highest Ash digestibility rate, but there was no significant difference compared to other groups ($P = 0.227$). However, the digestibility rate of EE in the EG12 group was significantly higher than both the BD and EG24 groups ($P = 0.001$). Compared to the BD group, there was no significant difference in the absorption rate of P among the groups ($P=0.555$). The Ca absorption rate in the EG12 group showed no significant difference, but the rate in the EG24 group was significantly lower than in the BD group ($P = 0.020$). For NDF, the digestibility rate in the EG12 group was the highest and significantly surpassed both the BD and EG24 groups ($P = 0.026$). However, there was no significant difference in the ADF digestibility rate among the groups ($P = 0.070$).

4. Discussion

Forage is the cheapest and most effective feed source in livestock production, serving as an essential feed for herbivores. Growth performance is an indicator reflecting the growth and development of animals. For breeding enterprises, improving animal growth performance is of great significance for enhancing economic benefits. Among them, F/G and final body weight are representative parameters of growth performance, which can reflect the quality of feed [24]. Adding 14 % elephant grass to the turkey diet has no negative impact on the growth performance [25], and adding 5 % elephant grass in the diet of laying hens has no negative effects on growth performance, and can enhance the yolk color [26]. Additionally, studies have found that under free-range conditions, supplementing laying hens' diet with 2.5 % elephant grass and 5 % palm oil can increase egg production and egg weight [27]. Adding 25 % ensiled elephant grass to the buffalo diet can increase the dry matter intake, enhance milk production, and improve feed efficiency [28]. In this experiment, we obtained similar results. Adding 12 % elephant has no negative effects in geese, but adding 24 % significantly reduced them. Studies indicate that the appropriate crude fiber level for commercial geese is between 4.5 % [29] and 7 % [30,31]. Excessively high crude fiber requires additional energy for digestion, leading to the waste of feed nutrients and subsequently affecting production performance. Conversely, too low crude fiber can also impair growth performance by reducing microbial diversity in the geese cecum [30].

Forage contains many bioactive components. One of the primary active ingredients in alfalfa and red clover is flavonoid compounds, which possess various functions including antioxidant, antibacterial, antiviral, and immunity-boosting properties [22]. Moreover, they can help in preventing parasites from infesting animals, reducing the need for antiparasitic medications. Research has shown that adding 300 mg/kg of alfalfa flavonoids can significantly improve the growth performance of 28-day-old Yangzhou geese,

Table 4
The effect of replacing corn with elephant grass on the Serum biochemical indicators of geese.

Items	Groups			SEM	*P*-value
	BD	EG12	EG24		
ALP, U/L	678.95[a]	441.08[a]	225.92[a]	24.59	<0.001
ALT, U/L	16.51[a]	13.63[a]	9.69[a]	0.70	<0.001
AST, U/L	28.13[a]	19.76[a]	16.71[a]	1.02	<0.001
Ca, mmol/L	2.47[a]	2.24[a]	1.97[a]	0.06	0.006
P, mmol/L	3.02[a]	2.74[a]	2.47[a]	0.07	0.009
Cre, μmol/L	2.31[b]	2.70[a]	3.23[a]	0.12	0.005
TG, mmol/L	1.17[a]	0.60[a]	0.60[a]	0.06	<0.001
TC, mmol/L	4.02[a]	2.60[a]	1.56[a]	0.15	<0.001
Glu, mmol/L	7.02[a]	4.88[a]	3.87[a]	0.25	<0.001
UA, μmol/L	153.61	151.64	160.17	7.86	0.401

BD:basal diet group, EG12:12 % elephant grass group, EG24:24 % elephant grass group, ALP: alkaline phosphatase, ALP: alanine aminotransferase, AST: aspartate aminotransferase, Ca: calcium, Cre: creatinine, TG: triglycerides, Glu: glucose, P: phosphorus, TC: total cholesterol, UA: uric acid.

[a] The data in the table are compared in the same row, and different lowercase letters indicate that the difference has reached a significant level ($P < 0.05$).

Table 5
The effect of replacing corn with elephant grass on the carcass traits indicators of geese.

Items	Groups			SEM	*P*-value
	BD	EG12	EG24		
Slaughter rate, %	80.02	81.87	83.36	0.57	0.526
Half-bore rate, %	74.31	77.29	78.15	1.00	0.275
Full-bore rate, %	64.97	68.61	69.29	1.01	0.178
Breast muscle rate, %	26.26	23.59	28.24	0.83	0.063
Leg muscle rate, %	29.91	25.94	28.27	1.03	0.304
Abdominal fat rate, %	5.51[a]	3.36[a]	2.35[a]	0.42	0.002

BD:basal diet group, EG12:12 % elephant grass group, EG24:24 % elephant grass group.
[a] The data in the table are compared in the same row, and different lowercase letters indicate that the difference has reached a significant level ($P < 0.05$).

Table 6
The effect of replacing corn with elephant grass on the organ index of geese.

Items	Groups			SEM	*P*-value
	BD	HP12	HP24		
Heart index, g/kg	6.69	6.42	6.82	0.16	0.622
Liver index, g/kg	27.24	29.67	32.34	29.75	0.053
Gizzard index, g/kg	44.87	41.64	49.13	1.59	0.158
Glandular stomach index, g/kg	3.18[a]	3.16[a]	3.66[a]	0.09	0.042
Intestinal index, g/kg	29.89[a]	27.16[a]	34.24[a]	0.94	0.002
Spleen index, g/kg	1.08	1.30	1.63	0.13	0.255
Bursa of Fabricius index, g/kg	0.55[a]	0.50[a]	0.74[a]	0.04	0.008
Thymus index, g/kg	2.15[a]	2.59[a]	3.37[a]	0.21	0.037

BD:basal diet group, EG12:12 % elephant grass group, EG24:24 % elephant grass group.
[a] The data in the table are compared in the same row, and different lowercase letters indicate that the difference has reached a significant level ($P < 0.05$).

Table 7
The effect of replacing corn with elephant grass on the apparent digestibility of geese.

Items	Groups			SEM	*P*-value
	BD	HP12	HP24		
CP, %	55.46	55.65	57.36	0.51	0.268
EE, %	44.16[a]	46.85[a]	45.04[a]	0.35	0.001
Ash, %	4.18	7.05	5.62	0.67	0.227
NDF, %	22.33[a]	31.33[a]	25.32[a]	1.44	0.026
ADF, %	34.19	28.71	29.63	1.06	0.070
Ca, %	47.61[a]	45.74[a]	41.15[a]	1.03	0.020
P, %	51.89	50.02	53.05	1.10	0.555
ME, MJ/kg	68.08[a]	65.59[a]	57.59[a]	1.41	<0.001

EE: crude fat, Ash: crude ash, CP:crude protein, ME:metabolizable energy, Ca: calcium, P:phosphorus, ADF:acid detergent fiber, NDF: neutral detergent fiber.
[a] The data in the table are compared in the same row, and different lowercase letters indicate that the difference has reached a significant level ($P < 0.05$).

promote nutrient metabolism, and notably elevate serum antioxidant and immune indicator levels [33]. Ryegrass contains soluble phenolic compounds, which can act as substrates for polyphenol oxidase and as antioxidants in the animal body [34]. Elephant grass is also rich in flavonoids and phenolic compounds [35,36], especially after ensiling [37]. Flavonoid compounds are potential drugs for treating non-alcoholic fatty liver in animals [38,39] and can reduce the levels of ALT and AST in mouse serum [40,41]. AST and ALT are closely related to animal liver function and are sensitive markers of liver cell damage [42]. When liver function deteriorates, the levels of ALT and AST increase in the blood, and the activity of these two enzymes also rises. Therefore, the functionality of the liver can be assessed by measuring the activity of AST and ALT in the serum.This aligns with the results of our experiment. The addition of elephant grass significantly reduced the levels of serum ALT and AST, indicating that liver damage in geese was alleviated after incorporating elephant grass. TG and TC are the main lipid components in the blood, typically used to assess an animals lipid metabolism status and health condition, and are often significantly correlated with visceral fat [43]. Meanwhile, Glu is a marker used to evaluate the body's energy status. Studies indicate that when the oxidation of fatty acids is impeded, the body's inherent glucose stability is often disrupted, leading to symptoms of hypoglycemia [44]. Conversely, when blood Glu levels rise, Glu can be converted into stored fat. In this experiment, we observed that the levels of Glu, TG, and TC were significantly reduced. This might be due to the limited crude fiber digestion rate of the goose for the object grass. The energy absorption of the experimental group was lower than that of the BD group. At the same time, the addition of elephant grass significantly reduced the abdominal fat rate of the geese. However, through growth performance, it was found that the addition of 12 % elephant grass did not reduce the growth performance of the geese. This indicates that adding 12 % elephant grass reduced excessive energy intake, thereby lowering the levels of serum TG and TC. Cre is a waste product produced by metabolism in animals, formed in the muscles and excreted by the kidneys. The level of Cre in the serum can reflect the kidney function of the animal [45]. When the kidney function is abnormal, Cre will accumulate in the body, leading to an increase in the level of creatinine in the serum. Therefore, the level of Cre in the serum can be used as one of the indicators to assess whether kidney function is normal [46]. Research has found that different proportions of elephant grass in the daily diet of sheep have no significant effect on the serum creatinine levels [47,48]. However, a certain proportion of elephant grass in the daily diet of horses and dairy cows will significantly increase the level of creatinine in the serum [49,50]. This may be related to the higher oxalic acid content in fresh grass [51]. Oxalic acid is a common component in plants. From the perspectives of environmental toxicology and feed nutrition, oxalic acid is considered a toxin and anti-nutritional factor [52]. In this experiment, as the level of elephant grass increased, the serum Ca level continued to decline, and the apparent digestion rate of Ca in feces also decreased. This might be because excessive soluble oxalic acid entered the body and combined with Ca to form calcium oxalate precipitate, reducing the absorption rate of Ca, thus affecting the absorption of soluble Ca [53]. However, adding 12 % to the diet showed no significant impact on the geese serum Ca and its apparent digestion rate. It's possible that the oxalic acid counteracts with mineral elements like Fe, Mg, and Cu present in elephant grass, thus decreasing its chelation with oxalic acid [54]. This aspect may warrant further investigation. Unlike mammals, birds do not excrete protein breakdown products in the form of soluble urea; instead, they excrete uric acid. The level of UA in the serum of birds can reflect the extent of protein degradation [55]. Some studies have indicated that serum UA levels are positively correlated with the presence of oxalic acid in feed [56]. However, in this experiment, we found no significant differences in UA levels among the different groups. This may be attributed to compounds like flavonoids in plants, similar to those in grass, promoting protein breakdown and inhibiting UA synthesis [57].

Goose meat is rich in high-quality protein, vitamins, and minerals. It serves as a premium source of protein, with relatively lower fat content compared to other types of meat [58]. Particularly, the fat in the subcutaneous layer of goose meat consists mainly of unsaturated fatty acids such as linoleic acid and oleic acid [59], which are beneficial for cardiovascular health [60]. Therefore, investigating the slaughter performance of geese holds economic significance. Adding 50 % elephant grass silage to the lamb's diet did not show a significant difference in its slaughter performance [61]. When *Orbignya speciosa* replaced some of the elephant grass in the lamb's diet, it led to an increase in abdominal fat content [62], this could be attributed to the relatively low crude fat content of elephant grass itself, in this experiment, the measured crude fat content was only 1.83 %. Therefore, we believe that adding elephant grass to the goose's diet may exhibit a trend of reducing abdominal fat.

Apparent digestibility rate refers to the rate at which nutrients in feed are digested and absorbed. This is a crucial indicator for assessing feed efficiency, as it reflects the extent to which animals utilize nutrients present in the feed [63]. Various factors such as feed composition, digestibility of feed ingredients, and the physiological condition of animals can all influence the apparent digestibility of nutritional components [64]. It is generally believed that grass, due to its higher content of crude fiber, requires a relatively complex digestive system [65]. Studies have indicated that an increase in the NDF content of the diet leads to a rise in crude fiber content. Excessive fiber content accelerates the passage rate of feed through the tract [66], reducing the degradation of dry matter, thereby lowering the intestinal and overall digestibility rates of non-fiber carbohydrates, CP, Ash, and other nutrients [67]. In this experiment, we observed that the highest digestibility rates for NDF and ADF in geese were achieved when 12 % elephant grass was added to the diet. This suggests that the 12 % addition of elephant grass reached the most suitable crude fiber level. Additionally, we observed a decreasing trend in the apparent digestibility of crude protein in geese as the proportion of elephant grass increased. This could be related to the characteristics of plant proteins in elephant grass, which typically have a lower digestion rate in the animal's digestive system [68]. Furthermore, anti-nutritional compounds like tannins present in elephant grass might affect protein bioavailability, resulting in a reduction in the digestibility of crude protein. However, differences in protein digestion capacity might exist among different species and ages of geese, which necessitates further research for clarification.

5. Conclusion

In summary, replacing 12 % of corn with elephant grass in goose feed maintained growth performance while improving serum parameters, and fiber digestibility. However, further increasing elephant grass to 24 % impaired growth and nutrient utilization.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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CRediT authorship contribution statement

Yi Liu: Writing – original draft, Data curation, Conceptualization. **Xianze Wang:** Formal analysis, Data curation, Conceptualization. **Guangquan Li:** Writing – review & editing, Investigation, Funding acquisition, Formal analysis, Data curation. **Shaoming Gong:** Validation, Supervision, Software, Resources. **Yunzhou Yang:** Visualization, Validation, Supervision. **Cui Wang:** Writing – review & editing, Project administration, Methodology. **Huiying Wang:** Writing – review & editing, Data curation, Conceptualization. **Daqian He:** Writing – review & editing, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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