



Research article

Feeding effect of complete pellets with inclusions of *Sesbania grandiflora* leaf on feed intake, growth performance, digestibility and meat quality of growing rabbits

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Abstract

Importance of the work: *Sesbania grandiflora* leaf could reduce dependence on imported protein feed ingredients in rabbit production systems in Malaysia.

Objectives: To evaluate the effects of dietary *S. grandiflora* leaf inclusion on rabbit growth, digestibility, carcass composition and meat quality.

Materials and Methods: A completely randomized design was used to assign 15 male rabbits, aged approximately 2 mth after weaning, to three dietary treatments containing 0% (T1), 5% (T2) or 10% (T3) *S. grandiflora* (L.) Poir. leaves. The rabbits were fed *ad libitum* for 62 d, including a digestibility trial for 7 d. Carcass composition and meat quality were evaluated after slaughtering.

Results: The rabbits fed the T2 diet had higher dry matter, crude fiber (CF) and ether extract intake than the rabbits fed the T1 diet. CF digestibility was significantly higher in the rabbits fed the T3 diet compared with the rabbits fed the T1 and T2 diets, while no significant difference was observed between T1 and T2. Ash digestibility was higher in the rabbits fed the T2 and T3 diets than in the rabbits fed the T1 diet. Growth performance was improved in the rabbits fed the T2 diet, with higher total body weight gain (BWG) and daily BWG. Carcass composition and meat quality were not significantly affected, although the meat ash content was higher in the rabbits fed the T2 diet.

Main finding: Inclusion of 5–10% *S. grandiflora* leaves in the rabbit diets partially replaced imported feed ingredients without adversely affecting growth performance, nutrient digestibility, carcass composition or meat quality.

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Introduction

Nutrition and feeding techniques can greatly improve the productivity, welfare and health of rabbits (Birolo, 2023). Usually, conventional feed for rabbits is available in local markets; however, a concern for farmers is the high cost and importation of the feed from other countries (Malaysian Investment Development Authority, 2024). This conventional feed is indeed beneficial for the welfare and growth of the rabbits considering the composition and quality of the ingredients. However, other non-conventional feeds, such as legumes, can also be used by local farmers to minimize the initial cost of the feed. Usually, legumes contain a good amount of nutrients that can be beneficial for livestock (Hakem et al., 2025).

Sesbania grandiflora (L.) Poir. is a versatile tree that produces edible flowers and is used to produce a herbal medicinal product based on its antibacterial, anthelmintic and antitumor activity (Bhokre et al., 2022). In addition, it is considered an Ayurvedic medicine, as almost all parts of this plant are used to treat leprosy, gout, rheumatism, tumors and liver diseases (Arthanari and Periyasamy, 2020). As a legume, this plant offers numerous benefits such as the production of paper and pulp, animal feed and leaf fertilizer (Jamarun et al., 2021).

Many studies have reported on the effects of feeding *S. grandiflora* leaves to different types of livestock. For example, feeding *S. grandiflora* leaves to cattle can improve cattle productivity such as body weight gain (BWG; Ningsih et al., 2014; Vijayakumar et al., 2021), growth rate (Yuliana et al., 2013) and milk production (Vijayakumar et al., 2000). In goats, *S. grandiflora* leaves in the diet helps to reduce the number of nematodes without any observed mortality or abnormalities (Azrul et al., 2016). In sheep, supplementation with *S. grandiflora* dry leaf meal is reported to have led to cost-effective and sustainable lamb production in a semi-intensive grazing system (Ravi and Prasad, 2006).

The rabbit industry has played a major role in rural economic growth and social development in numerous countries over the past few decades. This can be explained by its positive attributes, which include adaptable investment, simple administration and start-up, preservation of grain and land resources, production of premium meat and employment opportunities for rural residents, particularly women and the elderly. Raising rabbits has assisted many impoverished

people in emerging nations to escape poverty (Wu, 2022). As an alternative to protein sources, such as beef, mutton and chicken, rabbit meat is becoming more and more in demand and is considered a worthwhile endeavor, especially to encourage youth entrepreneurship in Malaysia (Aminuddin et al., 2023). However, data are still limited regarding the effects of feeding *S. grandiflora* leaves to rabbits, particularly in terms of growth performance, nutrient utilization and meat quality (Raharjo and Cheeke, 1987; Heuzé et al., 2016; Lakshmi et al., 2020). Therefore, the objectives of the present study were to investigate the effect of feeding complete feed pellets containing different levels of *S. grandiflora* leaves on the nutrient intake, growth performance, nutrient digestibility, carcass composition and meat quality of growing rabbits.

Materials and methods

Study site

This study was conducted at the Rabbit Rearing Facility (5°56'04"N, 118°00'22"E) for the feeding trials and at the Nutrition Laboratory in the Faculty of Sustainable Agriculture (FPL), Universiti Malaysia Sabah, Malaysia. All procedures involving the rabbits were conducted in accordance with Universiti Malaysia Sabah's guidelines for animal welfare, handling and care during research. Climatic conditions during the experimental period were recorded at the Sandakan Meteorological Station, located approximately 10 km east of the experimental site (World Meteorological Organization, 2024) and are shown in Fig. 1. The highest rainfall was recorded in November (334.7 mm), followed by October (225.1 mm) and September (284 mm). In September 2024, the mean daily maximum and minimum temperatures were 32.1°C and 23.4°C, respectively. The mean daily maximum temperature during October 2024 and November 2024 decreased to 31.6°C and 30.8°C, respectively. In contrast, the mean daily minimum temperature slightly increased in October (23.5°C) and November (23.6°C). The mean humidity was 82%, 84% and 85% in September, October and November 2024, respectively.

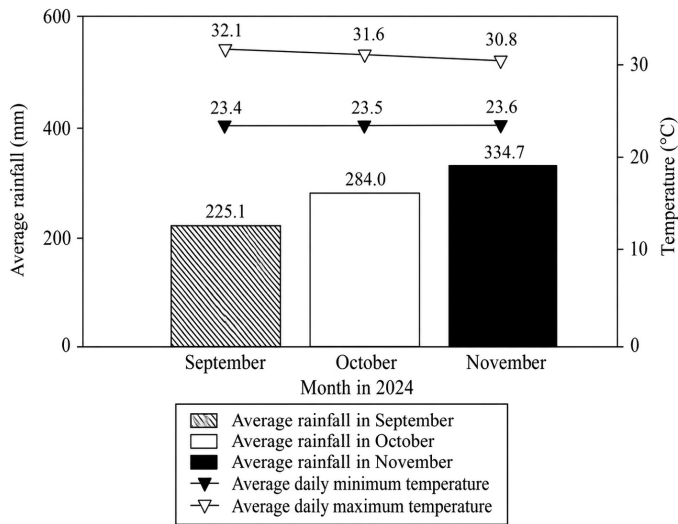


Fig. 1 Average rainfall, average daily minimum temperature and average daily maximum temperature during experimental period.

Pellet formulation

The isocaloric and isonitrogenous diet was formulated using Excel software (Microsoft Corp.; Redmond, WA, USA) based on the nutritional requirements of rabbits provided by National Research Council (1977) and Department of Veterinary Services (2005). The raw ingredients used to formulate the diet were corn, rice bran, soybean meal, molasses, limestone, salt and Napier grass (*Pennisetum purpureum* L.). Three rabbit diets were formulated using the above ingredients and *S. grandiflora* leaves at three levels: 0% (T1), 5% (T2) and 10% (T3).

The diets were given in pelleted form to the rabbits. The ingredients and the chemical composition of the experimental diets are shown in Table 1. The Napier grass and *S. grandiflora* leaves were harvested locally from the FPL area, sun-dried and ground using a grinding machine to pass through a 1 mm sieve before being mixed with the other ingredients for pellet preparation.

Experimental design and treatments

A completely randomized design (CRD) was used with 15 male New Zealand White rabbits aged approximately 2 mth (post-weaning). The rabbits were allocated randomly into one of the three dietary treatments with five replications per treatment. The experimental period lasted 62 days, including a 10-day adaptation period.

Animal management and experimental procedures

The rabbits were housed individually in meshed cages measuring 365.76 cm (length) × 91.44 cm (width) × 45.72 cm (height). The cages were placed in an open-house system, where natural sunlight was available during the day and artificial lighting (150 lux) was provided at night. The rabbits were fed their respective experimental diets *ad libitum*. Feed allowances were adjusted daily to reduce wastage, minimize feeding cost and maximize feed utilization. Throughout the experimental period, feces from individual rabbits were collected every morning from trays placed under the cages before fresh feed was offered.

Table 1 Ingredients and chemical composition of experimental diets containing different levels of *Sesbania grandiflora* leaves (dry matter basis)

Ingredient	Level of <i>Sesbania grandiflora</i> leaf inclusion (%)		
	Treatment 1 (0%)	Treatment 2 (5%)	Treatment 3 (10%)
<i>Sesbania grandiflora</i> leaf	0	5	10
Corn	40	40	42
Rice bran	19	15	12
Soybean meal	15	14	12
Molasses	7	7	7
Limestone	1	1	1
Salt	1	1	1
Napier grass	14	14	12
Palm oil	3	3	3
Total	100	100	100
Chemical composition (%; dry matter; mean value ± SD)			
Dry matter	92.34±2.03	91.81±2.48	90.28±1.33
Crude fiber	6.88±0.83 ^b	8.07±0.40 ^{ab}	8.78±0.21 ^a
Crude protein	14.00±0.05	13.40±0.07	13.67±0.31
Ether extract	6.86±0.02 ^a	6.64±0.23 ^a	5.57±0.68 ^b
Ash	6.32±0.07	5.88±0.48	6.27±0.31
ME* (MJ/kg)	11.20	11.20	11.20

ME = metabolizable energy.

Mean±SD within the same row followed by different superscript letters are significantly different ($p < 0.05$). *Calculated value from Department of Veterinary Services (2005).

Feed intake, growth performance and feed efficiency

Daily feed intake was estimated based on the difference between the feed offered and feed refusal on a dry matter (DM) basis. Feed samples were collected, dried and weighed according to Association of Official Analytical Chemists (2000). Body weight gain (BWG) was calculated weekly as the difference between the current and previous body weights using a weighing scale. The feed conversion ratio (FCR) was calculated as the BWG divided by DM intake during the experimental period.

Digestibility trial

Feed offered, feed refusal and feces output were recorded daily for 7 days of the feeding trial (Nordin et al., 2022). Feces were collected, weighed, frozen at -20°C and pooled. After thawing to room temperature, samples were dried in an oven at 60°C for 48 h, then ground using a 1 mm sieve for chemical analysis.

Chemical analysis

The nutritional contents of the *S. grandiflora* leaf, pellets, feces and meat samples were analyzed using the standard Association of Official Analytical Chemists (2000) procedures for DM, crude fiber (CF), ether extract (EE) and ash. The crude protein (CP) content was determined using a CHN analyzer (Model: CHN 628; LECO Corporation, St. Joseph, MI, USA), where the nitrogen content was measured and multiplied by a factor of 6.25 to estimate CP.

Carcass traits

At the end of the digestibility trial, all rabbits were slaughtered. Skin, genitals, bladder, gastrointestinal tract and distal leg segments were removed. Hot carcass (HC) weight was recorded 20 min post-slaughter, including head, liver, kidneys, perirenal and scapular fat, thymus, trachea, esophagus, lungs and heart. Carcasses were chilled at 4°C for 24 h after suspension from the tendon calcaneus for 1 hour in a ventilated area. The reference carcass (RC) included meat, bones and fat deposits after removal of the head, liver, kidneys and internal organs. Chilled carcass (CC) shrinkage was determined by comparing the chilled carcass weight with the hot carcass weight. The weights of the head, lung, liver and kidneys were expressed as a percentage of the CC, while the

weights of thigh muscle and dissectible fat were expressed as a percentage of the RC. Dressing percentage was calculated as $(\text{CC} / \text{live weight}) \times 100$. Weights of organs and carcass parts were expressed as percentages of CC or RC, as appropriate (Krun et al., 2021).

Meat quality analysis

The meat pH was measured using the biceps femoris muscle (right side of carcass) with a calibrated portable pH meter (buffer pH 4.0 and 6.88) at 24 h post-slaughter. Meat color was measured at 24 h post-slaughter using a colorimeter. Measurements were taken three times and averaged. Released water (RW) was determined using approximately 3.0 g of meat placed on pre-weighed filter paper (Whatman No. 1, 11 cm diameter), covered with plastic sheets and pressed between Plexiglass plates under a 2.5 kg load for 5 minutes (Joo, 2018). The percentage of RW was calculated using Equation 1:

$$\text{RW} = (\text{Damp filter paper weight} - \text{Filter paper weight}) / \text{Sample weight} \times 100 \quad (1)$$

Statistical analysis

All data were recorded using Excel (Microsoft Corp.; Redmond, WA, USA) and analyzed using the Minitab software (version 16.0; Minitab Inc., State College, PA, USA). Data were subjected to one-way analysis of variance to evaluate the effects of different inclusion levels of *S. grandiflora* leaves on feed intake, growth performance, nutrient digestibility and meat quality. Tukey's test was used to compare the treatment means at $p < 0.05$.

Results

Chemical composition of *Sesbania grandiflora* leaves and experimental diets

Table 2 shows the chemical composition of the *S. grandiflora* leaf, with a high level of CP (24.61%) compared to other nutrients in the leaf. The CF followed this level with 7.92% and ash with 7.23%. The lowest content of the nutrients in the *S. grandiflora* leaf was EE (3.28%). Its metabolizable energy (ME) value of 7.60 MJ/kg was derived from the nutrient composition of feedstuffs, as provided by Department of Veterinary Services (2005).

Table 2 Nutritional value of *Sesbania grandiflora* leaves.

Parameter	Mean $\pm$ SD
Dry matter (%)	28.57 $\pm$ 0.57
Crude fiber (%)	7.92 $\pm$ 0.85
Crude protein (%)	24.61 $\pm$ 0.10
Ether extract (%)	3.28 $\pm$ 0.31
Ash (%)	7.23 $\pm$ 0.26
Metabolizable energy* (MJ/kg)	7.60

*Data obtained from Department of Veterinary Services (2005).

The chemical composition of experimental diets with different inclusions of *S. grandiflora* leaves is shown in Table 1. The EE was lower in T3 (5.57) than in the two other treatments. The EE content was almost similar between T1 (6.86) and T2 (6.64) diets; however, the T1 diet had a slightly higher EE content than the T2 diet. In contrast, the T3 diet had a higher CF content (8.78%) than the T1 diet (6.88%) but was similar to the T2 diet (8.07). The DM, CP, ash and ME contents were not significantly different among these three treatments. The DM and CP contents slightly decreased as the level of *S. grandiflora* leaf inclusion increased from the T1 to T3 diets. The ash content was high in the T1 diet and low in the T2 diet. The ME level stated in the Table 1 was obtained from the feed formulation determined by Department of Veterinary Services (2005) nutrient composition of feedstuff. The level of ME was maintained during the formulation of these treatments.

Nutrient intake

Table 3 shows the daily nutrient intake of rabbits that had been fed with formulated pelleted feed consisting of different levels of *S. grandiflora* leaves. The DM intake was

significantly higher for the T2 diet (71.15%) than for the other two treatments. The DM intake tended to be higher in rabbits fed the T3 diet (53.99%) than in those fed the T1 diet (51.44%); however, the difference was not significant. The CF intake for the T2 diet (5.03%) was significantly higher than for the T1 diet (3.54%), but not significantly different from the T3 diet (4.61%). The CP intake did not differ significantly among treatments. The EE intake was significantly higher for T2 (4.42%) than for the T3 diet (3.01%). However, the EE intake for the T2 diet was not significantly different from the T1 diet (3.53%). Lastly, the ash intake was not significantly different among the three treatments. These findings indicated that the nutrient intake increased with increasing DM intake, except for EE, where the EE intake in the T1 diet was higher than in the T3 diet, despite the overall higher intake in the T3 diet.

Nutrient digestibility and growth performance

Table 4 shows the effect of different inclusions of *S. grandiflora* leaves in the pellet feed on the nutrient digestibility and growth performance in rabbits. The DM digestibility was not significantly different and ranged between 70.47% (T1) and 75.07% (T2). The CF digestibility differed significantly, with T3 having the highest value (35.43%) compared to T1 (5.87%) and T2 (16.29%). The CP digestibility was not significantly different, with values of although T2 had the highest value (73.28%), followed by T3 and T1. The EE digestibility differed significantly, with T1 (93.63%) and T2 (90.59%) being higher than T3 (83.66%). Ash digestibility was also significantly higher in T3 (76.61%) and T2 (76.49%) than T1 (66.96%).

Table 3 Daily nutrient intake (g/rabbit) and digestibility (%) of rabbits fed pellets with different inclusion levels of *Sesbania grandiflora* leaves

Parameter	Level of <i>S. grandiflora</i> leaf inclusion (Mean ± SD)			<i>p</i> value
	Treatment 1 (0%)	Treatment 2 (5%)	Treatment 3 (10%)	
Intake				
Dry matter	51.44±10.04 ^b	71.15±7.98 ^a	53.99±8.47 ^b	0.024
Crude fiber	3.54±0.69 ^b	5.03±0.89 ^a	4.61±0.72 ^{ab}	0.035
Crude protein	7.20±1.41	8.92±1.57	7.38±1.16	0.154
Ether extract	3.53±0.69 ^{ab}	4.42±0.78 ^a	3.01±0.47 ^b	0.023
Ash	3.25±0.63	3.91±0.69	3.39±0.54	0.256
Digestibility				
Dry matter	70.47±2.73	75.07±2.64	72.78±2.53	0.063
Crude fibre	5.87±3.18 ^b	16.29±9.88 ^b	35.43±9.35 ^a	0.004
Crude protein	69.43±3.33	73.28±3.80	68.56±4.61	0.197
Ether extract	93.63±2.06 ^a	90.59±3.18 ^a	83.66±2.55 ^b	0.001
Ash	66.96±6.86 ^b	76.49±2.21 ^a	76.61±5.59 ^a	0.027

Mean $\pm$ SD within the same rows followed by different lowercase superscript letters are significantly different ($p < 0.05$).

Table 4 Growth performance of growing rabbits fed experimental pellets containing different levels of *Sesbania grandiflora* leaves.

Parameter	Level of <i>S. grandiflora</i> leaf inclusion (Mean $\pm$ SD)			p value
	Treatment 1 (0%)	Treatment 2 (5%)	Treatment 3 (10%)	
Initial BW (g)	1475 $\pm$ 357.76	1550 $\pm$ 469.56	1375 $\pm$ 357.76	0.790
Final BW (g)	2000 $\pm$ 353.29	2350 $\pm$ 469.56	2025 $\pm$ 279.50	0.307
Total BW gain (g)	525 $\pm$ 190.95 ^b	866.7 $\pm$ 74.46 ^a	733.3 $\pm$ 149.14 ^{ab}	0.030
Daily BW gain (g)	8.47 $\pm$ 3.09 ^b	13.98 $\pm$ 1.21 ^a	11.83 $\pm$ 2.39 ^{ab}	0.030
FCR	6.55 $\pm$ 2.41	5.30 $\pm$ 1.41	5.42 $\pm$ 1.41	0.507

BW = body weight; FCR = feed conversion ratio.

Mean $\pm$ SD within the same row followed by different lowercase superscript letters are significantly different ($p < 0.05$).

The initial BW of the rabbits did not differ significantly among treatments, with mean values of 1,475 g for T1, 1,550 g for T2 and 1,375 g for T3. Similarly, the final BW did not differ significantly among treatments, although rabbits fed the T2 diet tended to show the highest mean value (2,350 g), followed by T3 (2,025 g) and T1 (2,000 g). The total BW gain differed significantly, with T2 (866.7 g) being significantly higher than T1 (525 g), while T3 (733.3 g) did not differ significantly from either T2 or T1. A similar pattern was observed for the average daily BW gain, where T2 (13.98 g) was significantly higher than T1 (8.47 g), whereas T3 (11.83) was not significantly different from the other two treatments. Based on these results, the BW gain increased with increasing daily BW gain. The FCR was not significantly different among the treatments, although it was the highest in the T1 diet, followed by the T2 and T3 diets.

Carcass composition

Table 5 shows the effects of different inclusion levels of *S. grandiflora* leaves in the pellet feed on the carcass composition of the growing rabbits. There were no significant differences among treatments for all measured parameters. However, numerically, live weight, HC, CC and RC were highest in T2 compared to the other treatments. The CC shrinkage was numerically higher in T1 (4.47%) than in T2 (4.23%) and T3 (4.37%). Similarly, the dressing percentage was numerically highest in T1 (67.80%).

Numerically, the heaviest skin and full DT were recorded in T2, with values of 245.0 g and 283 g, respectively. The proportion of head relative to CC was numerically highest in T3 (14.36% CC), while the lung (0.85% CC), liver (3.32% CC) and kidney (0.58% CC) proportions were numerically highest in T1. The proportion of thigh relative to RC was also measured, with T2 tended to show the highest value (26.98% RC), followed by T1 (26.46% RC) and T3 (25.58% RC). The fat content was slightly higher in T2 (5.95% RC) than in T1 (3.45% RC) and T3 (3.68% RC); however, the difference was not significant.

Table 5 Carcass composition of growing rabbits fed experimental pellets containing different levels of *Sesbania grandiflora* leaves

Parameter	Level of <i>S. grandiflora</i> leaf inclusion (Mean $\pm$ SD)			p Value
	Treatment 1 (0%)	Treatment 2 (5%)	Treatment 3 (10%)	
Live weight (g)	1980 $\pm$ 358	2325 $\pm$ 445	1989 $\pm$ 293	0.295
Hot carcass (g)	1407 $\pm$ 266	1619 $\pm$ 320	1403 $\pm$ 210	0.389
Chilled carcass (g)	1344 $\pm$ 322	1550 $\pm$ 309	1342.5 $\pm$ 208	0.388
Cold carcass shrinkage (%)	4.47 $\pm$ 0.98	4.23 $\pm$ 0.16	4.37 $\pm$ 0.69	0.870
Reference carcass (g)	1044.5 $\pm$ 202	1198 $\pm$ 242	1038.6 $\pm$ 164	0.413
Dressing percentage (%)	67.80 $\pm$ 1.30	66.64 $\pm$ 0.78	67.44 $\pm$ 1.50	0.350
Skin (g)	212.5 $\pm$ 51	245.0 $\pm$ 55	232.5 $\pm$ 49	0.548
Digestive tract (g)	234 $\pm$ 36	283 $\pm$ 85	253 $\pm$ 34.21	0.435
Head (% CC)	14.22 $\pm$ 0.85	13.46 $\pm$ 1.12	14.36 $\pm$ 0.51	0.264
Lung (% CC)	0.85 $\pm$ 0.29	0.80 $\pm$ 0.20	0.76 $\pm$ 0.09	0.816
Liver (% CC)	3.32 $\pm$ 0.36	3.08 $\pm$ 1.39	3.02 $\pm$ 0.58	0.690
Kidney (% CC)	0.58 $\pm$ 0.04	0.54 $\pm$ 0.04	0.56 $\pm$ 0.02	0.201
Thighs (% RC)	26.46 $\pm$ 1.23	26.98 $\pm$ 0.67	25.58 $\pm$ 0.87	0.116
Fat (% RC)	3.45 $\pm$ 0.74	5.95 $\pm$ 3.69	3.68 $\pm$ 0.65	0.195

CC = chilled carcass; RC = reference carcass.

Meat quality

The effect of different inclusions of *S. grandiflora* leaves in the pellet feed on meat quality of growing rabbits is shown in Table 6. Muscle pH did not differ significantly among treatments, with similar values observed for T1 (6.11), T2 (6.11) and T3 (6.09). In addition, the color parameters were not significantly different. However, numerically, the L* value was the highest in T3 (50.31), followed by T2 (47.99) and T1 (46.82). For a*, the highest value was in T2 (5.818), followed by T1 (5.25) and T3 (4.75), while b* was the highest in T2 (5.11), followed by T3 (4.98) and T1 (3.76). The RW was not significantly different among the treatments, although it was slightly higher in T2 (5.11%) and T3 (5.09%) than in T1 (3.27%).

Table 7 shows the nutritional composition of the rabbit meat from the three experimental groups. The DM content tended to be highest in T2 (29.96%), followed by T3 (27.70%) and T1 (25.11%); however, these differences were not significant. The CP content tended to be higher in T3 (77.94%), followed by T1 (75.71%) and T2 (75.39%), with no significant differences among treatments. The EE content was similar between T1 (13.01%) and T2 (13.02%), while it tended to be lower in T3 (11.93%). The ash content was significantly different, with T2 (3.97%) being significantly higher than T1 (1.76%) and T3 (1.48%).

Discussion

Nutrient intake

Based on the results, the daily DM intake in T2, with 5% *S. grandiflora* leaf inclusion, was significantly higher than in T1 and T3. This finding was supported by Lakshmi et al. (2020), who stated that *Sesbania* leaves are commonly preferred by farmers due to their higher palatability to livestock. In contrast, Raharjo and Cheeke (1987) reported lower DM intake for *S. grandiflora* compared to other legumes such as *Leucaena leucocephala* and *Albizia falcata*. These differences may be attributed to variations in feeding methodology, as Raharjo and Cheeke (1987) used legumes in a dried, unformulated form. In the present study, *S. grandiflora* was incorporated at different levels into a complete pellet diet formulated to provide balanced nutrients for rabbits. Feed formulation for commercial purposes is the process of determining the amounts of ingredients and additives required to generate compound feeds that meet the known nutrient requirements of the targeted species (Lall and Dumas, 2015). In general, feeds are composed of nutrients derived from multiple ingredients; therefore, an increase in feed intake is expected to increase nutrient intake. In the present study, the CF intake was significantly higher in T2 than in T1, while T3 did not differ significantly from the other treatments. The higher CF intake in T2 may have been associated with increased feed intake.

Table 6 Meat quality of growing rabbits fed experimental pellets containing different levels of *Sesbania grandiflora* leaves

Parameter	Level of <i>S. grandiflora</i> leaf inclusion (Mean $\pm$ SD)			p value
	Treatment 1 (0%)	Treatment 2 (5%)	Treatment 3 (10%)	
pH	6.11 $\pm$ 0.07	6.11 $\pm$ 0.11	6.09 $\pm$ 0.11	0.953
Color	L*	46.82 $\pm$ 5.93	47.99 $\pm$ 3.82	0.458
	a*	5.25 $\pm$ 3.02	5.818 $\pm$ 0.56	0.653
	b*	3.76 $\pm$ 1.25	5.11 $\pm$ 0.34	0.165
RW (%)	3.27 $\pm$ 2.06	5.11 $\pm$ 1.01	5.09 $\pm$ 1.48	0.159

RW, Released water, L*, lightness, a*, redness, b*, yellowness.

Table 7 Nutritive value of rabbit meat as affected by dietary inclusion levels of *Sesbania grandiflora* leaves.

Parameter	Level of <i>Sesbania grandiflora</i> leaf inclusion (Mean $\pm$ SD)			p value
	Treatment 1 (0%)	Treatment 2 (5%)	Treatment 3 (10%)	
Fresh basis				
Dry matter (%)	25.11 $\pm$ 0.72	29.96 $\pm$ 5.08	27.70 $\pm$ 1.59	0.097
Air dry basis				
Crude protein (%)	75.71 $\pm$ 3.42	75.39 $\pm$ 3.60	77.94 $\pm$ 1.16	0.441
Ether extract (%)	13.01 $\pm$ 2.59	13.02 $\pm$ 4.65	11.93 $\pm$ 2.53	0.824
Ash (%)	1.76 $\pm$ 0.18 ^b	3.97 $\pm$ 1.41 ^a	1.48 $\pm$ 0.18 ^b	0.002

Mean $\pm$ SD within the same row followed by different lowercase superscripts are significantly different ($p < 0.05$).

Although the T3 diet contained a higher inclusion level of *S. grandiflora* leaves, it did not differ significantly from T2. The CP intake was slightly higher in both T2 and T3, although the difference was not significant, which may be attributed to the relatively high CP content of *S. grandiflora* leaves (Heuzé et al., 2016; Patil and Auti, 2022; Dahanayaka et al., 2024). The EE intake differed, with T2 being significantly higher than T3. This difference may have been related to differences in overall feed intake and ingredient composition. In T3, ingredients with higher EE content, such as rice bran (Heuzé and Tran, 2015), were partially replaced by a 10% inclusion of *S. grandiflora* leaves, compared to 5% inclusion in T2. Consequently, T1 had a relatively high EE intake due to the presence of EE-rich ingredients such as corn (Ayaşan et al., 2020), rice bran (Heuzé and Tran, 2015) and soybean meal (Heuzé et al., 2020).

Nutrient digestibility

Published studies are limited on the effects of *S. grandiflora* leaf supplementation on nutrient digestibility in rabbits. However, similar studies have been conducted regarding its use as a feed ingredient in other livestock species, especially ruminants. For example, Thu and Dong (2017) reported that feed digestibility improved in buffaloes with the inclusion of *S. grandiflora* leaves. Similarly, Shahjalal and Topps (2000) fed *S. grandiflora* in combination with other fodders as a sole diet for goats and reported increased nutrient digestibility compared to other roadside forage. Furthermore, this finding was supported by Lam and Ledin (2004), who reported superior DM digestibility in growing goats fed *S. grandiflora* leaves as the sole feed. In the present study, DM digestibility was not significantly different among treatments. Nonetheless, diets containing *S. grandiflora* leaves had slightly higher values compared to T1. These results are generally consistent with previous reports on the favorable effects of *S. grandiflora* on feed digestibility in ruminants (Lam and Ledin, 2004; Thu and Dong, 2017). However, discrepancies among studies may be attributed to differences in feeding methods, experimental species and environmental factors (Lamy et al., 2012).

The CF digestibility was significantly different, with T3 being higher than T2 and T1. This difference may have been related to the ingredient composition of each treatment (Table 1). The primary fiber sources *S. grandiflora* leaves and Napier grass; notably, T3 contained a lower proportion of Napier grass than T2 and T1. Since Napier grass is known to contain relatively high levels of lignin, which negatively

affects fiber digestibility. The reduced inclusion in T3 may have contributed to the higher CF digestibility observed. Fiber is composed of cellulose, hemicellulose and lignin (Biradar et al., 2023), with lignin being the least digestible component due to its resistance to microbial degradation (Moore and Jung, 2001). Therefore, the improved CF digestibility in T3 was likely associated with its lower lignin contribution from Napier grass, which is known to contain relatively high lignin levels (Ansah et al., 2010). However, as the lignin content was not directly measured, this explanation remains speculative.

The CP digestibility was not significantly different among the diets indicating that the inclusion of *S. grandiflora* leaves maintained CP digestibility comparable to T1, which consisted solely of commercial feedstuff ingredients. Higher levels of plant-based protein sources may introduce anti-nutritional factors (ANFs), which can reduce protein digestibility and amino acid bioavailability (Gilani et al., 2005). Reported ANFs in *S. grandiflora* leaves include saponins and other secondary metabolites (Lakshmi et al., 2020). However, as the ANF content was not directly measured in the present study, this explanation remains speculative.

The EE digestibility was highly significant, where both T1 and T2 were higher than T3. This result was consistent with the EE intake discussed in the previous section, where the EE intake in T2 was also higher than in T3. This may be related to the proximate composition of T3, which had a lower EE content compared to T2 and T1. The ash digestibility showed a difference, where both treatments with *S. grandiflora* leaf inclusion were higher than T1. Ananthi and Jayasri (2021) stated that total ash content reflected the overall mineral composition, including both soluble and insoluble fractions. They also stated that *S. grandiflora* leaves are rich in minerals such as sodium, potassium and calcium.

Growth performance

The mean initial and final BWs were not significantly different among T1, T2 and T3. All rabbits were of the same breed (New Zealand White) and age (2 mth), which would explain the similarity in initial BWs. Furthermore, similar levels of initial BW help to minimize bias during the experiment.

The total BW gain of the rabbits fed the T2 diet had a higher value compared to T1, but it was not significantly different from T3. The daily BW gain followed the same trend, where T2 was higher than the T1 but not significantly different from T3. The improved growth performance in T2 may have been

associated with the relatively high protein content of the *S. grandiflora* leaves (Department of Veterinary Services, 2005), as supported by the CP value obtained from the proximate analysis (24.61%). In addition, another study reported that the inclusion of *S. grandiflora* leaves in animal diets improved nutrient digestibility (Thu and Dong, 2017), which may enhance nutrient utilization. Adequate nutrient supply in proper amounts and forms is essential for optimal animal performance (Lovell, 1998). The slightly lower BW gain observed in T3 than in T2 may have been due to the higher inclusion level of *S. grandiflora* leaves, which could have introduced greater amounts of ANFs. These compounds may impair nutrient bioavailability. For example, trypsin inhibitors and phytates, commonly present in legumes, can reduce protein digestibility and mineral absorption (Samtiya et al., 2020). However, the effect was not substantial, as the BW gain in T3 remained higher than in T1.

FCR did not differ significantly among T1, T2 and T3, with values of 6.55, 5.30 and 5.42, respectively. These values were slightly higher than those reported by Al-Amin et al. (2019), who observed an FCR of 4.6 in rabbits fed *Leucaena* leaf meal and by Abdelnour et al. (2018), who reported FCR values in the range 2.40–3.27. The higher FCR observed in the present study may be attributed to differences in feed composition, management conditions or environmental factors.

Carcass composition

There were no significant differences in all parameters for carcass composition among the rabbits in all treatments. This finding indicated that the inclusion of *S. grandiflora* leaves did not adversely affect carcass characteristics and suggests its potential as an alternative to imported feedstuffs, especially protein sources such as soybean meal. Zahari and Wong (2009) stated that maize and soybean meal are the primary imported energy and protein feed ingredients, respectively, with an annual import value into Malaysia of approximately US\$625 million, of which maize accounted for more than one-half. Adequate protein supply is important for maintaining growth and influencing carcass composition. For example, Xiccato (1999) reported that low-protein diets reduced muscle development in rabbits. Therefore, the identification of alternative feed ingredients is important to reduce dependence on imported feed resources. The present study demonstrated that diets containing *S. grandiflora* leaves produced comparable carcass composition to the T1, indicating its suitability as a feed ingredient.

S. grandiflora is a locally available plant and is distributed widely in Malaysia (Hasan et al., 2012), with the ability to grow under diverse environmental conditions, including open fields and marginal areas (Lim, 2014). The use of locally available feed resources has been reported to enhance sustainable livestock production, improve food security and support circular economy practices (Chisoro et al., 2023). Thus, the utilization of local tree leaves, such as *S. grandiflora* leaves, may help to reduce reliance on imported feed ingredients, while maintaining animal performance, although further studies may be required to confirm long-term effects.

Meat quality

There were no significant differences in muscle pH among treatments. Post-mortem muscle pH decline can be influenced by several factors, including adrenaline levels and stress prior to slaughter (Kozioł et al., 2015). Specifically, Kozioł et al. (2015) reported a pH value of 6.07 in rabbit meat at 24 h post-slaughter. Similarly, Rodríguez-Calleja et al. (2004) reported pH values ranging from 5.98 (abattoir samples) to 6.37 (supermarket pre-packed carcass). In contrast, Hulot and Ouhayoun (1999) observed a lower pH value (5.8), while Kumar et al. (2023) reported a range of 5.40–5.75 for New Zealand White rabbits and of 6.02–6.08 for crossbreds. The present findings are generally within the reported range; variations may arise due to differences in experimental design, handling conditions and sampling sites. Muscle type may also influence pH, as typically, thigh muscles have higher metabolic activity and may retain more residual blood than loin muscles (Kozioł et al., 2015).

In the present study, there were no significant differences among treatments in the meat color parameters (L^* , a^* and b^*), representing lightness, redness and yellowness, respectively. Kumar et al. (2023) reported L^* values in the range 46.09–63.71, a^* values from -1.07 to 6.9 and b^* values in the range 0.34–0.67. In the present study, the L^* and a^* values were within these reported ranges, while the b^* values were slightly higher. This may have been related to post-mortem changes, as Tarsitano et al. (2013) noted that meat color parameters, particularly a^* and b^* , increased with maturation time. Additionally, lipid oxidation may contribute to increased yellowness (Wójciak and Dolatowski, 2012). There was no significant difference in the RW values among treatments. The treatment with 5% *S. grandiflora* leaf inclusion (T2) recorded the highest RW, followed by T3 and T1. Released water is closely related to the water holding capacity,

which reflects the ability of meat to retain water and is an important indicator of meat quality (Watanabe et al., 2018).

The above variations observed among treatments can be explained by differences in dietary composition and their physiological effects on rabbits. Although the diets were formulated to be similar in metabolizable energy and CP, variations in the CF, EE and ash contents, as well as differences in ingredients composition, may have influenced nutrient intake, nutrient digestibility and subsequent animal performances. In particular, the fiber level and type can affect gut motility, microbial fermentation and nutrient utilization in rabbits, which are hindgut fermenters (Gidenne, 2015). Higher fiber fractions may enhance digestive function but can also dilute energy availability, while variations in EE can influence dietary energy density and palatability. Additionally, the different inclusion levels of *S. grandiflora* leaves may have contributed varying amounts of bioactive compounds and ANFs, which may potentially affect nutrient bioavailability (Gilani et al., 2005; Lakshmi et al., 2020). Therefore, the observed increases or decreases in measured parameters across treatments were likely due to the combined results of these compositional and physiological factors, rather than a single dietary component.

In conclusion, the present study has shown that *S. grandiflora* leaves have high potential for use as a rabbit feed ingredient with no detrimental effect on rabbit performance. Based on the nutrient intake, there were significant differences in DM, CP and EE for the treatments containing *S. grandiflora* leaves compared to the diet without supplementation. In addition, the treatments with the inclusion of *S. grandiflora* leaves were significantly different in DM, CF, EE and ash digestibility compared to T1. Furthermore, the average daily and total BW gain were significantly higher with the inclusion of *S. grandiflora* leaves. However, despite these differences in nutrient intake and digestibility, carcass composition and meat quality were not significantly affected, indicating that the improved nutrient utilization did not adversely alter carcass traits. This suggests that the inclusion of *S. grandiflora* leaves supports growth performance while maintaining meat quality. Therefore, the recommended inclusion level of *S. grandiflora* leaves in rabbit feed is 5–10%, as this range enhanced nutrient utilization and growth performance without compromising carcass composition and meat quality. The present study has provided new evidence supporting the use of *S. grandiflora* leaf as a sustainable alternative protein source in rabbit diets without compromising product quality.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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