Special Issue (UniSZA), Malaysia:
ICAFT 2023: 3rd International Conference on Agriculture, Animal Sciences & Food Technology

Evaluating Growth Performance of Saanen Doe Fed Napier Pak Chong (*Pennisetum purpureum* × *Pennisetum glaucum*) Silage with *Azolla microphylla* Supplementation

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Abstract | Ruminant growth performance is significantly dependent on adequate nutrient intake, as these animals obtain essential nutrients from their diets. This study aims to determine the nutrient composition of a basal diet supplemented with *Azolla microphylla* and measure its effects on the growth performance of Saanen doelings. The feeding treatments consisted of Control (100% Pak Chong Napier), T1 (90% Pak Chong Napier + 10% *A. microphylla*), T2 (80% Pak Chong Napier + 20% *A. microphylla*), and T3 (70% Pak Chong Napier + 30% *A. microphylla*). The mixture of treatment feeds was analysed using proximate analysis. For feeding experiments, twelve 4-year-old female Saanen doelings were chosen for this study and were divided into four groups, with each group containing three doelings of similar weight. Each group was given a different diet for three weeks. Weekly data were recorded on growth performance, including body measurements, live weight, feed intake, average daily gain (ADG), and feed conversion rate (FCR) and body condition score BCS. For nutritional composition analysis of treatment feed, the results revealed that Treatment 3 exhibits the highest protein content (12.11%) among the treatment groups, surpassing Treatment 1, Treatment 2, and the control group, which have protein levels of 8.9%, 10.08%, and 6.53%, respectively. Treatment 1 showed the best growth results. It produced an average daily gain of 0.36 ± 0.07 kg, increased body length by 4 cm to 81.00 ± 4.58 cm, raised wither height by 4.00 cm to 72.67 ± 2.52 cm, and boosted chest height by 2.34 cm to 78.00 ± 2.65 cm. It also had the highest body condition score (BCS) at 2.33 ± 0.29 and the lowest feed conversion ratio (FCR) at 3.25 ± 0.64. Therefore, it can be confidently stated that Treatment 1 is an optimized formulation that could be effectively used as livestock feed.

Received | February 21, 2024; **Accepted** | August 30, 2024; **Published** | October 09, 2024
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Citation | Kamaruddin, N.A., N.Q.A.M. Asri and N.A.A. Rosli. 2024. Evaluating growth performance of saanen doe fed Napier Pak Chong (*Pennisetum purpureum* × *Pennisetum glaucum*) silage with *Azolla microphylla* supplementation. *Sarhad Journal of Agriculture,* 40(Special issue 1): 89-100.
DOI | https://dx.doi.org/10.17582/journal.sja/2024/40/s1.89.100
Keywords | Azolla, Growth performance, Napier Pak Chong, Nutrient analysis, Protein, Saanen doe

Introduction

Livestock production is crucial in satisfying the increasing global demand for animal protein. However, conventional feeding practices, which heavily depend on traditional feed ingredients like grains and forages, encounter challenges related to sustainability, cost, and environmental impact.

Consequently, it becomes imperative to investigate alternative feed sources that can optimize animal performance while addressing these concerns. The Asian region faces low self-sufficiency rates in milk and meat (MARDI, 2019). However, there has been a noticeable increase in the demand for goats bred for milk, such as the Saanen breed. While Asia remains the leading producer and consumer of dairy goats globally, a broader perspective of the industry offers valuable insights for developing a modern dairy goat sector. With population expansion in many countries, the worldwide dairy goat industry is experiencing rapid growth. Goat meat and milk products are gaining popularity due to their health and nutritional benefits, including enhanced digestion, lipid metabolism, and flavour (Wang *et al*., 2022). The Saanen goat (*Capra hircus*) originated in Switzerland's Saanen Valley and has been referred to as Holstein Friesian due to their high daily milk yield and relatively low milk fat content (Bosman, 2014).

The basal diet in livestock refers to the primary diet consisting of forages, grains, and essential nutrients, which serve as the principal source of energy, protein, fibre, and carbohydrates. The composition of the basal diet varies depending on the type of livestock and production goals. Extensive studies aim to comprehend the nutritional requirements and optimal formulation of the basal diet for diverse livestock species. In ruminant livestock, the primary diets typically consist of forages like grasses, legumes, and browse. These diets are supplemented with grains and minerals. It is crucial to strategically and efficiently use small amounts of these supplements to address nutrient deficiencies, enhance rumen function, and improve feed utilization from low-quality roughages (Tolera *et al*., 2000). Additional feeds or supplements may be provided based on specific requirements and goals.

In Malaysia, Napier grass (*Pennisetum purpureum*) is widely cultivated as a forage crop for basal diet livestock due to its high productivity, adaptability to tropical conditions, and nutritional value. Several studies have been conducted to assess agronomic practices (Kebede *et al*., 2017), nutritional composition (Halim *et al*., 2013), feeding value (Habte *et al*., 2022), and utilization of Napier grass in the Malaysian context (Halim *et al*., 2013; Kamaruddin *et al*., 2020). Napier Pak Chong is a hybrid grass resulting from the crossbreeding of Elephant Napier (*Pennisetum purpureum*) with pearl millet (*Pennisetum glaucum*), aimed at enhancing the productivity of Napier grass plantations (Bangprasit *et al*., 2017). Napier Pak Chong exhibits adaptability to various environments, although it thrives best in soils rich in organic matter (Sirichaiwetchakul *et al*., 2016). This pasture species of Napier grass is widely distributed in tropical and subtropical regions worldwide and demonstrates exceptional productivity in areas with fertile soil and abundant rainfall, even growing well at altitudes up to 2,000 meters above sea level (Wangchuk *et al*., 2015). According to Somjai and Suwan (2020), this hybrid Napier grass exhibits specific characteristics, including fast growth with high forage production, elevated carbohydrate and protein content, and a broad range of adaptability.

A. microphylla, commonly known as water fern or duckweed fern, is a small, free-floating aquatic plant that has gained attention as a potential feed ingredient for livestock (Chatterjee *et al*., 2013; Kamaruddin *et al*., 2020; Ting *et al*., 2022). It has a high protein content, ranging from 20% to 30%, making it a valuable protein source (Kumari *et al*., 2021). Additionally, *A. microphylla* exhibits rapid growth rates and can be easily cultivated in a wide range of climates, including tropical and subtropical regions. These characteristics make it a promising candidate for sustainable livestock feed supplementation. The nutritional composition of *A. microphylla* contributes to its potential as a livestock feed ingredient. It contains essential amino acids, including lysine, methionine, and tryptophan, which are often limiting in conventional feed sources (Kumar *et al*., 2019). It also provides vitamins, minerals, and bioactive compounds such as phenolic compounds and flavonoids that can benefit animal health and productivity (Rashad, 2021).

Research on the supplementation of *A. microphylla* in livestock feed has predominantly concentrated on ruminants, particularly cattle and sheep (Singh, 2016). These studies have consistently showcased the favourable impacts of including *A. microphylla* in the feed, resulting in increased weight gain, improved feed efficiency, and enhanced milk production (Kumari *et al*., 2021). These benefits are attributed to the high protein content and improved nutrient digestibility of *A. microphylla*, as well as it, is potential to modulate rumen fermentation and microbial activity. In monogastric animals, including pigs and poultry, the supplementation of *A. microphylla* has shown promising results as well. It has been found to enhance growth performance, nutrient utilization, and egg production (Gouri *et al*., 2012). The unique composition of *A. microphylla*, including its amino acid profile and bioactive compounds, contributes to these positive effects (Kumari *et al*., 2021).

Although there is increasing of research on the utilization of *A. microphylla* as a feed ingredient for livestock, further investigations are needed to address key knowledge gaps. There is a need for studies to determine the optimal inclusion levels of *A. microphylla*, examine its long-term effects on animal health and productivity, and evaluate the economic feasibility of incorporating it into animal diets (Kumari *et al*., 2021). Additionally, expanding research to include different livestock species and diverse production systems would offer valuable insights into the broader applicability of *A. microphylla* as a feed ingredient. Thus, this study aims to measure and compare the growth performance of *Saanen does* feed with Napier Pak Chong (*Pennisetum purpureum* x *Pennisetum glaucum*) supplemented with *A. microphylla*.

Materials and Methods

Study site

The site of this study is located on the east coast of Peninsular Malaysia. The study was conducted at Kaprima Hulu Seladang Valley Farm, Kampung Seladang, Terengganu, Malaysia (5° 46.0316' N, 102° 37.9862' E). This location is used for Napier planting, Azolla cultivation and feeding treatments. Hence, for the nutrition analysis, the experiment was carried out at Universiti Sultan Zainal Abidin (UniSZA), Besut, Terengganu, Malaysia (5° 45' 53.8" N, 102° 37" E). Kaprima Farm serves as a dairy goat breeder and produces animal feed, including haylage. Additionally, the farm supplies natural fresh goat milk. The distance between Kaprima Farm and the University of Sultan Zainal Abidin Besut Campus is approximately 46.7 kilometres, which can be covered in a 45-minute drive.

Plant sample

The plant samples utilized in this study included Napier Pak Chong and *A. microphylla*. Both forages were acquired from Kaprima Hulu Seladang Valley Farm Setiu, Terengganu.

Animal sample

This study employed Saanen does, approximately 4 years old (±1), as the research subjects. The goats were divided into four groups, with each group comprising three randomly selected Saanen does (n = 3) weighing between 30-40 kg. The primary objective of this study was to evaluate various growth performance parameters of the selected does, including Live Weight, Body Measurements, Body Condition Score, Average Daily Gain (ADG), and Feed Conversion Ratio (FCR).

Pak Chong Napier silage preparation

The Pak Chong Napier stems cutting was acquired from Kuala Berang Farm, Hulu Terengganu, and planted at Kaprima Hulu Seladang farm. Fresh matured Pak Chong Napier is cut and sundried for an hour to remove excess water. The sun-dried Pak Chong Napier is chopped using a chopper and then mixed with Effective microbial (EM) and molasses before being put in a vacuum-sealed beg. The Pak Chong Napier Silage is fermented after two weeks (Kamaruddin *et al*., 2019). After fermentation, Pak Chong Napier silage is weighed and oven-dried at 80°C for 24 hours (Kamaruddin *et al*., 2019).

Azolla preparation

The fresh *A. microphylla* was obtained by harvesting it from the canvas Azolla pool. After harvesting, the Azolla was carefully sealed in a zip lock bag before being transported to the laboratory. Upon arrival, the freshly harvested Azolla underwent a thorough washing process under running tap water to eliminate any residual soil and debris. The damp Azolla was then exposed to sunlight for approximately 10 minutes to facilitate the evaporation of excess water. Next, the Azolla was weighed and subjected to oven-drying at 70 °C for 24 hours (Kamaruddin *et al*., 2019). Once the Azolla had been completely dried, it was finely ground using a Waring Blender to acquire a homogeneous powder suitable for analysis.

Feed formulation

The ground Pak Chong Silage and *A. microphylla* were mixed according to the feed formulation specified in Table 1. The formulated feeds were categorized into four groups which are Control, Treatment 1, Treatment 2, and Treatment 3. The composition of the feeds consisted of 100% Pak Chong Silage for the Control group, followed by 90% Pak Chong Silage and 10% *A. microphylla* for Treatment 1, 80% Pak Chong silage and 20% *A. microphylla* for Treatment

2, and 70% Pak Chong silage and 30% *A. microphylla* for Treatment 3. The formulated feeds were stored in appropriately labelled zip lock bags before undergoing proximate analysis.

Table 1: *Feed formulation ration of Pak Chong silage and A. microphylla.*

Groups	Feed percentage (%)	
	Pak Chong Napier silage	***A. microphylla***
Control group	100%	0%
Treatment 1	90%	10%
Treatment 2	80%	20%
Treatment 3	70%	**30%**

Nutritional analysis

The formulated feed was analysed for nutritional composition using proximate analysis at Universiti Sultan Zainal Abidin Nutrition Laboratory according to the AOAC (2005) method. The analysis encompassed parameters such as moisture, ash, protein, fat, crude fibre, carbohydrate, and energy.

Feeding treatment

The Saanen does undergo a 7-day adaptation period during which they were provided with the treatment diets before data collection. They were fed twice daily, at approximately 9 am and 5 pm, following the ratios specified in Table 1. The goats' daily feed intake was recorded, and their weekly feed consumption was monitored to ensure it met their daily requirements. To maintain cleanliness and prevent fungal growth, the feeding troughs were cleaned before introducing fresh feed. Once a week, each goat was weighed in the morning before feeding to calculate their average daily gain (ADG).

Statistical analysis

The collected data were analysed by one-way variance (ANOVA) to determine the significant differences between chemical compositions at different percentages by groups. The Statistical analysis was done using Microsoft Excel, Microsoft Corporation (2018). The significant difference in data tested is used to compare the mean difference between each group's treatments, and the $p < 0.05$ value was considered a significant difference.

Results and Discussion

Proximate analysis of feed formulation

Figure 1 displays the proximate composition results for each group. The results indicate significant differences (p<0.05) between the groups for each parameter. Figure 1a illustrates there is a significant difference ($p<0.05$) in energy levels between treatments. Energy is crucial for maintaining fundamental life functions in animals, including respiration, circulation, digestion, and temperature regulation (Schmidt-Nielsen *et al*., 1997; Cooper and Withers, 2008). Sufficient energy intake is necessary to meet their maintenance requirements. The control group exhibits the highest energy levels at 348.72%, followed by Treatment 2 (345.08%), Treatment 3 (331.28%), and Treatment 1 (332.63%). The results of this study correlate with previous studies by Kamaruddin *et al*. (2022) that recorded that energy in Napier grass solely ranged from 300 kcal to 350 kcal.

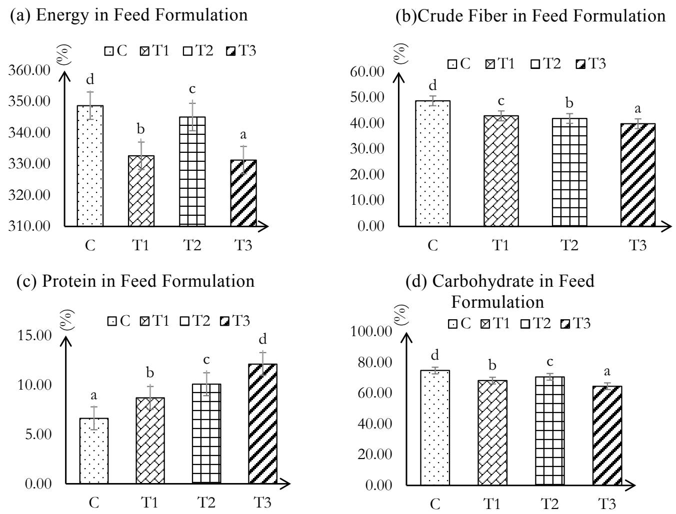

Figure 1: *Nutritional compositions are based on parameters in each treatment. The values with different superscript letters ([a,b,c,d]) in the graphs indicate a significant difference ($p<0.05$) among groups.*

Crude fibre is a measure of the indigestible carbohydrates, primarily consisting of cellulose, hemicellulose, and lignin, present in livestock feed. Figure 1b illustrates that the control group has the highest amount of crude fibre at 48.73%, compared to Treatment 1, 2, and 3 groups with levels of 42.90%, 41.88%, and 39.87%, respectively. The results for feed formulation for each treatment are significantly different ($p<0.05$). The reduction in the percentage of Pak Chong Silage in the feed formulation contributes to the decrease in crude fibre content, as the Napier Pak Chong plant contains up to 25.66% crude fibre at 45 days (Mohamad et al., 2022).

Proteins play a vital role in various biological processes such as tissue growth and repair, muscle development, enzyme production, and hormone and antibody synthesis (Rattan, 1996). In milk-producing dairy animals, protein is particularly crucial for milk production. Milk contains significant quantities of proteins, including casein and whey proteins, which provide essential amino acids and nutrients for nursing offspring (Verduci *et al*., 2019). Adequate protein nutrition is essential for maintaining milk production levels, milk quality, and the growth of nursing young. Protein deficiency can result in symptoms such as swelling, fatty liver, and stunted growth in young animals (Owens *et al*., 1993). Fresh *A. microphylla* has been found to contain up to 30.50% crude protein (Kamaruddin *et al*., 2021). Figure 1c reveals that Treatment 3 exhibits the highest protein content (12.11%) among the treatment groups, surpassing Treatment 1, Treatment 2, and the control group, which have protein levels of 8.9%, 10.08%, and 6.53%, respectively. The protein content in the treatment groups gradually increases by the percentage of *A. microphylla* supplementation: 10%, 20%, and 30% for Treatments 1, 2, and 3, respectively. The control group displays the lowest protein content at 6.63%. The addition of Azolla as a supplement enhances the protein content in the formulated feed, which is crucial for muscle development, particularly in growing animals.

Carbohydrates serve as the primary energy source in livestock diets which are required for metabolic processes, muscle activity, growth, milk production, and other physiological functions (Herdt, 2000; Belhadj *et al*., 2016). Figure 1d highlights a significant difference ($p < 0.05$) in carbohydrate content among the groups. The control group exhibited the highest carbohydrate content at 74.86%, followed by Treatment 2 (70.71%), Treatment 1 (68.28%), and Treatment 3 (64.60%). It is crucial to consider the type and quality of carbohydrates in livestock diets to ensure optimal nutrition. Different animals have distinct carbohydrate requirements, and the balance between non-structural carbohydrates and structural carbohydrates must be carefully managed to meet specific animal needs and production goals (Drackley *et al*., 2006). Proper formulation and management of carbohydrate sources in feed can contribute to enhanced energy utilization, growth, reproduction, and overall animal health (Hocquette *et al*., 1998; Nafikov and Beitz, 2007).

Live weight

The live weight of animals is a crucial factor in livestock production systems, as it directly impacts market value, feed efficiency, reproductive performance, and overall profitability (Young *et al*., 2010; Krupová *et al*., 2016). Efficient monitoring and management of live weight enable producers to maximize productivity, ensure the well-being of the animals, and make informed decisions that contribute to the success of their operations. **Table 2** shows the live weight of Saanen does fed with four treatment levels of Napier Pak Chong grass supplemented with *A. microphylla*.

Table 2: *Live weight of Saanen does feed at four treatment levels.*

Items	Control	Treatment 1	Treatment 2	Treatment 3
Initial	37.67±1.53^{a}	26.33±2.52^{b}	33.33±4.16^{ab}	29.00±3.61^{ab}
Week 1	39.33±1.53^{a}	28.33±3.51^{b}	35.33±5.13^{ab}	31.00±3.61^{ab}
Week 2	41.00±2.00^{a}	31.31±3.51^{a}	36.67±5.51^{a}	32.33±3.51^{a}

^{ab} means with common superscripts are significantly different (p < 0.05).

Different treatments of Napier Pak Chong and *A. microphylla* were used to feed the subjects, and it was observed that each treatment had varying effects on live weight. Following the study period, a significant difference (p<0.05) in live weight was found between the control group and the treatment group during the Initial and Week 1 stages. However, no significant difference (p>0.05) was observed between Treatment 2 and Treatment 3. Nevertheless, during Week 2, there was no significant difference (p>0.05) in live weight between the control group and any of the treatment groups. These statistical findings may have been influenced by analytical errors encountered when using the weighing scale for measurements during the Initial and Week 1. Additionally, there are no significant differences among the groups in week 2 indicating that all groups experienced similar weight gain during that week. This aligns with the findings of Kumar *et al*. (2012) and Kumar and Chander (2017), who observed that Azolla supplementation had no impact on monthly body weight fluctuations in buffalo bulls and male kids.

Body measurement

Body length: Table 3 shows the body length of Saanen Does feed with four treatment levels of Napier Pak Chong grass supplemented with A. microphylla.

Feeding different treatments of Napier Pak Chong and *A. microphylla* resulted in varying effects on body length. Throughout the study period, a significant difference (*p<0.05*) in body length was observed between the control group and the treatment groups during the Initial and Week 1 measurements. However, no significant difference *(p>0.05)* was found between Treatment 2 and Treatment 3. Additionally, in Week 2, there was no significant difference *(p>0.05)* in body length between the control group and any of the treatment groups. These statistical findings are likely attributed to similar body length gains observed during the Initial and Week 1 measurements. Furthermore, the lack of significant differences in Week 2 suggests minimal body weight gain across all groups.

Table 3: *Body length of Saanen does feed at four treatment levels.*

Items	Control	Treatment 1	Treatment 2	Treatment 3
Initial	84.00±1.73[a]	74.33±3.06[b]	77.33±4.04[ab]	80.67±s2.31[ab]
Week 1	86.33±1.16[a]	77.00±3.61[b]	80.33±4.51[ab]	82.67±3.06[ab]
Week 2	88.00±1.00[a]	81.00±4.58[a]	82.67± 5.03[a]	84.33±2.52[a]

[ab] *Means with common superscripts are significantly different (p < 0.05).*

Wither height

Table 4 shows the wither height of Saanen does feed with four treatment levels of Napier Pak Chong grass supplemented with *A. microphylla*.

Table 4: *Wither height of Saanen does feed at four treatment levels.*

Items	Control	Treatment 1	Treatment 2	Treatment 3
Initial	69.67±5.03[a]	68.67±2.52[a]	75.33±5.03[a]	70.33±4.16[a]
Week 1	71.33±5.13[a]	70.67±2.52[a]	76.67±5.03[a]	72.00±3.61[a]
Week 2	73.00±4.58[a]	72.67±2.52[a]	78.00±6.56[a]	72.67±2.89[a]

[a] *Means with common superscripts are non-significantly different (p > 0.05).*

Feeding different treatments of Napier Pak Chong and *A. microphylla* revealed that all treatments had a similar effect on wither height. At the end of the study period, there was no significant difference (*p>0.05*) in wither height between the control group and the treatment groups. These statistical results could be attributed to the relatively short duration of the study and the possibility of physiological changes that contribute to the slower growth rate. A limited experimental period can decrease the statistical power of a study. With a shorter experiment duration, the sample size may be reduced, thereby limiting the statistical power to detect significant effects or relationships in the study. This can impact the ability to detect significant effects or relationships accurately. Apparently, the growth of an older goat tends to slow down compared to younger goats which are still in a grower state. As goats age, their growth rate naturally slows down. Ageing goats experience several physiological changes that contribute to a slower growth rate. As goats age, their digestive system may be affected, leading to impaired nutrient absorption. This can result in reduced efficiency in absorbing nutrients, leading to lower availability of essential nutrients for growth and development (Webb *et al.*, 2012). Consequently, this contributes to the slower growth rate observed in ageing goats. Ageing is associated with an increasing inability to sustain the functional integrity of cells, organs and systems (Webb and Casey, 2005).

Chest height

Table 5 shows the chest height of Saanen does feed with four treatment levels of Napier Pak Chong grass supplemented with *A. microphylla*.

Table 5: *Chest height of Saanen does feed at four treatment levels.*

Items	Control	Treatment 1	Treatment 2	Treatment 3
Initial	81.33±2.31[a]	73.33±2.31[b]	80.00±2.00[ab]	79.33±4.16[ab]
Week 1	82.00±2.00[a]	75.00±2.65[b]	81.33±1.16[a]	80.67±3.06[ab]
Week 2	82.67±3.06[a]	78.00±2.65[a]	83.33±1.16[a]	82.00±4.00[a]

[ab] *Means with common superscripts are significantly different (p < 0.05).*

Feeding different treatments of Napier Pak Chong and *A. microphylla* resulted in varied effects on chest height. Throughout the study period, a significant difference (*p<0.05*) in chest height was observed between the control group and the treatment groups during the Initial and Week 1 measurements. However, based on Table 5, there is no significant difference (*p>0.05*) was found between Treatment 2 and Treatment 3 in the Initial measurement, and between the control group and Treatment 2 in Week 1. Additionally, in Week 2, there was no significant difference (*p>0.05*) in chest height between the control group and any of the treatment groups. These statistical findings are likely attributed to the similar body length observed during the Initial and Week 1 measurements. Furthermore, the absence of a significant difference between the groups in Week 2 suggests that all goats had similar abdominal cavity and digestive tract measurements. This is in line with findings by Kusminanto *et al.*

(2020), which state that chest height is also related to the abdominal cavity and digestive tract, which account for 10% - 25% of the live weight.

Body condition score

Table 6 shows the body condition score of Saanen does feed with four treatment levels of Napier Pak Chong grass supplemented with *Azolla microphyla.*

Table 6: *Body condition score (BCS) of Saanen does feed at four treatment levels.*

Items	Control	Treatment 1	Treatment 2	Treatment 3
Before	1.67±0.29[a]	1.50±0.50[a]	1.83±0.29[a]	1.83±0.29[a]
After	2.00±0.00[a]	2.33±0.29[a]	2.17±0.29[a]	2.17±0.29[a]

[a] *Means with common superscript is non-significantly different (p > 0.05).*

Feeding different treatments of Napier Pak Chong and *A. microphylla* demonstrated that the treatments had a similar effect on the body condition score (BCS) both before and after the study, as indicated in Table 6. There is no significant difference ($p>0.05$) in BCS between the control and the treatment at both data collection times can likely be attributed to random errors that may have occurred during the measurements. It is important to note that BCS is a subjective, semi-quantitative method of evaluating body fat and muscle. Methods for assigning a BCS have been developed for production (cattle, sheep, goats) (Burkholder, 2000). Therefore, the statistical results obtained reflect the subjective nature of the BCS assessment.

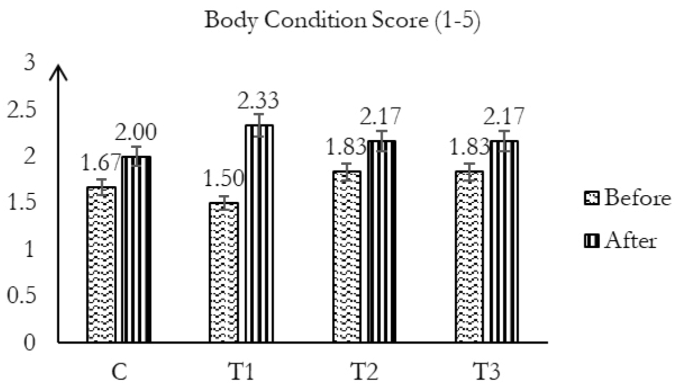

Figure 2: *Body condition score of female Saanen goat.*

Figure 2 illustrates the correlation between different treatments and the body condition score (BCS) of Saanen does before and after the study. According to the correlation analysis, Treatment 1 resulted in the highest BCS after the study, with a score of 2.33, followed by T2, T3, and C, with BCS values of 2.17, 2.17, and 2.00, respectively. This suggests that goats fed with Treatment 1 received adequate nutrition compared to those fed with the other treatments. Maintaining the goat's nutritional level to achieve an optimal body condition (neither too fat nor too thin) is crucial for ensuring the reproductive performance of does and reducing feeding costs, leading to significant cost savings.

A decline in fertility, increased susceptibility to diseases or internal parasites, decreased milk production, and higher feed costs are all potential consequences of inadequate understanding regarding the appropriate conditions for goats in various physiological states. Therefore, it is essential to maintain goats in a moderately desirable body condition. When the overall BCS of a farm or flock significantly decreases, preventive measures such as deworming, proper nutritional supplementation (in terms of energy and protein), vaccination against common diseases, and pasture management techniques like rotational grazing should be implemented. Debilitated or low BCS goats should be separated and provided with adequate additional nutrition in terms of energy and protein, along with ample access to feeds and fodders. Conversely, overly fat does should have limited access to feed (Ghosh *et al*., 2019).

Average daily gain

The average daily gain (ADG) is a widely used measurement in livestock farming that quantifies the rate at which animals gain weight during a specific timeframe, typically presented as grams or kilograms per day. ADG plays a crucial role in evaluating livestock's development and productivity, offering valuable insights into their general well-being, nutritional status, and the effectiveness of management practices.

Feeding different treatments of Napier Pak Chong and *A. microphylla* revealed that the treatments had a similar effect on the average daily gain (ADG) during the study, as indicated in Table 7. This lack of significant difference ($p>0.05$) in ADG between the control group and the treatment groups at both data collection times can likely be attributed to the similar amount of feed consumed by each goat across all groups. Although the overall ADG of the control and treatment groups was statistically equivalent, the treatment group T1 displayed a numerical advantage. Previous studies by Jyoti *et al*. (2016); Toradmal *et al.*

(2017); Dev *et al.* (2022) reported similar findings in involving kids. The average daily gain was significantly higher in the treatment group (T2) compared to the control group during the 4th, 5th, 9th, 10th, 11th, 12th, and 13th week of the experiment.

Feed conversion ratio

A lower FCR indicates higher feed efficiency, meaning less feed is needed to produce weight gain. This is desirable for livestock producers as it reduces feed costs and improves profitability. Factors that can influence FCR include the species, breed, age, genetics, health, and diet composition of the animals, as well as environmental conditions and management practices.

Table 7: *Average daily gain (ADG).*

Items	Control	Treatment 1	Treatment 2	Treatment 3
ADG	0.24 ± 0.04[a]	0.36 ± 0.07[a]	0.26 ± 0.11[a]	0.24 ± 0.04[a]

[a] *Means with common superscript is non-significantly different (p > 0.05).*

Feeding different treatments of Napier Pak Chong and *A. microphylla* revealed that the treatments had a similar effect on the average daily gain and feed conversion ratio (FCR) during the study, as indicated in Table 8. There is no significant difference ($p>0.05$) in FCR between the control group and the treatment groups at both data collection times indicating that the FCR remained constant and did not vary significantly between the groups. This suggests that, throughout the feeding period, the efficiency of converting feed into weight gain was consistent across all groups. Additionally, it can be inferred that goats that consumed more feed were able to achieve higher levels of growth, as supported by the findings of Aswanimiyuni *et al.* (2018).

Table 8: *Feed conversion ratio (FCR).*

Items	Control	Treatment 1	Treatment 2	Treatment 3
FCR	6.19 ± 0.94[a]	3.25 ± 0.64[a]	6.24 ± 3.29[a]	5.14 ± 0.78[a]

[a] *Means with common superscript are non-significantly different (p > 0.05).*

Figure 3 illustrates the correlation between different treatments and the feed conversion ratio (FCR) of Saanen does before and after the study. Based on the correlation analysis, T1 exhibited the lowest FCR with an average of 3.25 kg, followed by T3, C, and T2 with averages of 5.14 kg, 6.19 kg, and 6.23 kg, respectively. The FCR is an essential parameter used to assess animal growth performance, measuring the efficiency with which livestock convert feed into the desired output. It is defined as the mass of feed consumed divided by the output over a specific period (Carstens *et al.*, 2006). FCR is useful for evaluating the effects of diet quality, environment, and management practices (e.g., implants, ionophores) on production efficiency in growing and finishing cattle, FCR has limited value as an efficiency trait for genetic improvement, even though FCR is moderately heritable (Crews, 2005). As indicated in Table 8, goats fed with T1 demonstrated a lower FCR compared to those fed with other treatments. Animals with a low FCR are considered efficient feed users, which is preferred by farmers as it allows them to achieve higher output with less feed. Consequently, a low FCR implies reduced feed costs (Aswanimiyuni *et al.*, 2018).

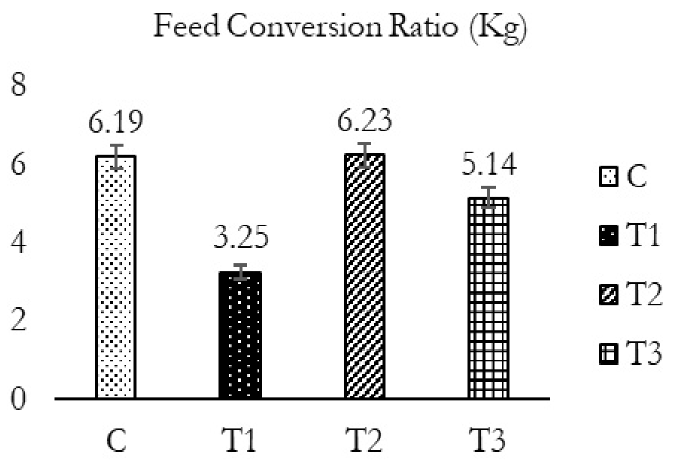

Figure 3: *Feed conversion ratio of different treatments.*

Conclusions and Recommendations

In summary, adding *A. microphylla* to Napier Pak Chong has significantly improved the growth performance of Saanen does. This enhancement is due to the higher protein content in both feed sources, which positively affected growth-related factors such as live weight, body measurements, body condition score, average daily gain (ADG), and feed conversion rate (FCR) when the does were given the supplemented diets. Using this unconventional feed source can help reduce feed costs for farmers. Treatment 1 offers a nutritional profile with 8.69% protein, 42.90% crude fiber, 68.28% carbohydrates, and 332.63 kcal of metabolizable energy, making it a strong choice for supporting the growth and health of Saanen does. Both Napier Pak Chong and *A. microphylla* are valuable crops for animal feed and forage, and their cultivation could bring significant socio-economic benefits to rural communities.

Acknowledgements

This study was funded by the Fundamental Research Grant Scheme by the Ministry of Higher Education, Malaysia (MOHE) FRGS/1/2019/WAB01/UNISZA/02//4.

Novelty Statement

This study comprehensively improves the growth performance of Saanen doe by enriching their diet with a combination of Napier Pak Chong as the basal diet and *A. microphylla* as a protein supplement. This innovative approach facilitates the identification of the most effective dietary regimen for Saanen doe in terms of delivering essential protein supplementation.

Author's Contribution

Nurul Aini Kamaruddin, Nur Qistina Afiqah Muhamad Asri and Nur Alya Adila Rosli: Designed the study.
Nur Qistina Afiqah Muhamad Asri and Nur Alya Adila Rosli: Performed the field work and collected the data.
Nurul Aini Kamaruddin and Nur Qistina Afiqah Muhamad Asri: Analyzed the data and drafted the manuscript.
All the authors read and approved the final manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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