Jackfruit leaves can totally replace traditional grass in the diet of lactating dairy goats

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ABSTRACT
This study aimed to evaluate the effect of replacing jackfruit leaves (JL) for Para grass (PG) on intake, digestibility, nitrogen balance, ruminal fermentation, milk yield and composition in lactating goats. Four crossbred Saanen lactating goats in mid-lactation and milking 1676 ± 112 g/day were used in a 4 × 4 Latin square design. A basal diet consisted of concentrate and PG (C:F 40:60). Treatments were dietary replacement of JL for PG at ratios of 0, 50, 75 and 100% corresponding to JL0, JL50, JL75 and JL100 diets, respectively. Feeding JL increased linearly (P < 0.01) DM intake, but decreased linearly (P < 0.05) nutrient digestibility. A linear increase in fecal N (P < 0.01) and N retention (P = 0.04), but a linear decrease in urinary N (P = 0.03) was detected when increased the JL in the diets. Total VFA concentration increased quadratically (P = 0.04), and the highest value was observed in JL75 compared with JL0 (85.9 vs. 72.8 mM). Milk production increased linearly (P = 0.03), but no change was observed in milk composition and blood urea nitrogen (BUN). Overall, combined data suggest that the substitution of JL for PG in lactating goat diets is effective in the improvement of nutrient intake, N retention, ruminal VFA concentration and milk yield without affecting milk composition and BUN.

Introduction
Livestock production systems demand high energy inputs, land, chemicals and water – all of which are becoming increasingly scarce (Preston, 2009); thus change and innovation is required in many livestock production systems if they are to meet in a sustainable manner for the present and future demands of animal products. Sustainable animal diet is a concept based on three-P dimensions including the planet, people and profit (Makkar and Ankers, 2014). Distel et al. (2020) suggested the replacement of simple traditional forage by complementary forage species that enable ruminants to select a diet in benefit of their nutrition and health, while reducing the negative environmental impacts caused by agricultural systems. Therefore, an approach promoting to improve the efficient use of feed local resources is very necessary. In this regard, jackfruit leaves (JL) can be used as an alternative forage source for traditional grasses in ruminant production, particularly dairy goats. Jackfruit trees (Artocarpus heterophyllus) thrive in tropical or subtropical climates, such as in India, Bangladesh, Thailand, Indonesia and Vietnam. These tree leaves are characterized by their high content of dry matter (33.2–38.3%), good source of crude protein (12.9–16.6%) and low contents of neutral detergent fiber (34.9–52.6%) (Mui et al., 2002, Thanh et al., 2021) in tropical and subtropical countries, compared to more common traditional forage crops for ruminant feed, such as Para grass (PG, Brachiaria mutica) containing 17.7% DM, 11.8% CP and 61.3% NDF (Thanh et al., 2021), Napier grass containing 12.9–18.8% DM, 9.58–10.4% CP and 62.9–66.6% NDF (Maleko et al., 2019) and Guinea grass containing 23.3–28.8% DM, 8.96–12.2% CP and 65.7–67.0% NDF (Oliveira et al., 2020). Moreover, JL also has a high content of phenolic compounds, e.g. condensed tannins (17.9%) according to Malik et al. (2017).

Goats can feed more types of grass and foliage compared with other ruminant species (Shaheen et al., 2020). Van et al. (2005) concluded that a goat diet containing many kinds of foliage resulted in a higher intake compared to feeding foliage alone. Jackfruit leaves had been used to replace the concentrate in dairy goats (Mui et al., 2002) and growing kids (Van et al., 2005). Recently, Thanh et al. (2021) reported that replacement of the JL for PG in the diet increased the feed intake and weight gain of growing meat goats, remarkably. To our knowledge, data on feeding JL in lactating goats are very scarce, and no reports have been published on the replacement of the traditional forage by JL – which is readily available in a large number of tropical and subtropical countries, at a very low cost as a viable alternative for goat feeds.

The objective of this study was to evaluate the effects of replacing JL for PG on intake, digestibility, nitrogen (N) balance, ruminal fermentation, as well as milk yield and composition in lactating dairy goats. The hypothesis was that an increase in the rate of JL in the diet would improve milk yield by increasing intake and ruminal fermentation. We also hypothesized that the total-tract nutrient digestibility and N excretion via urine would decrease, but N excretion via feces would increase with increasing JL in the diets.

ARTICLE HISTORY
Received 28 July 2021
Accepted 25 January 2022

KEYWORDS
Dairy goats; digestibility; jackfruit leaves; milk yield; ruminal fermentation
Materials and methods

Study site

The studies were conducted in Vietnam at Can Tho University Farm (Hoa An campus), Phung Hiep district, Hau Giang province, 40 km south-west of Can Tho city, a center of Mekong Delta in Vietnam. The experimental site is between the coordinates 9°47' N latitude and 105°28' E longitude, and at an elevation of 2 m below sea level. The area receives about 1800 mm of rainfall per year. The climate is tropical monsoon, with a wet season between May and November and a dry season from December to April. The mean daily temperature ranges from 20°C to 35°C.

Animal, experimental design and diet

All procedures were performed according to the ethical standards in the Helsinki Declaration of 1975, as revised in 2000, as well as the national law. Four 2nd parity crossbred Saanen lactating goats (♀ Saanen × ♂ Bach Thao) in mid-lactation, 35.5 ± 1.29 kg body weight, and milking 1,676 ± 112 g/day were kept in individual metabolic cages (1.2 m×0.6 m×1.2 m, LxWxH) and had free access to fresh water. Animals were milked twice a day at 07:00 h and 17:00 h.

Treatments were evaluated in a 4x4 Latin square design. A basal diet consisted of pelleted concentrate and PG was formulated at a ratio of 40:60 (C:F). Treatments were developed by the dietary replacement of JL for PG at ratios of 0, 50, 75 and 100% (DM basis) in the diets corresponding to JLO, JL50, JL75 and JL100 diets, respectively. Because PG is a traditional forage while JL had been reported as a favorite feed of goats (Van et al., 2005), goats could consume both PG and JL in the diet easily; thus each experimental period lasted for 14 days (7 days for adaptation and 7 days for sampling) instead of 21 days as recommended by McDonald et al. (2010). Diets were offered in equal amounts twice daily at 07:30 h and 17:30 h after milking, where concentrate was fed to animals prior to feeding ad libitum PG. Diets (Table 1) were formulated to meet the nutrient requirements of lactating dairy goats (NRC, 2007). The concentrate used in the experiment was mixed and pelleted from ingredients bought at the local market.

The foliage of jackfruit was pruned from 3 to 5 years old trees ensuring that some branches were left for continuous growth. After lopping, leaves were separated from branches, and fresh JL were then offered to the animals. Para grass at 30–40 days of age was cut daily from the field and chopped before feeding. Both JL and PG were collected from the areas around the Can Tho University Farm.

Sampling and measurements

From d8 to d12, data on feed offered and refused as well as total fecal, urine, and milk output were recorded daily for each goat during a 5-d period. Feces were collected in wire-screen baskets placed under the floor of the cages, and urine was collected through a funnel into plastic buckets containing 50 mL of 10% (v/v) H2SO4. The acidification to keep the final pH of urine below 3 was necessary to prevent the loss of volatile ammonium and microbial degradation. After recording the weight, 10% proportions of 24 h feces and urine were collected over 5 consecutive days, stored at −20°C, and pooled for chemical analysis. Milk from both morning and afternoon milking were sampled, cool stored and analysed for milk composition. On d13, blood samples were collected before the morning meal for analysis of blood urea nitrogen (BUN) concentration. Briefly, blood was withdrawn from the jugular vein into evacuated tubes containing lithium heparin, immediately placed on ice, and centrifuged at 4500 × g for 5 min. On d14, rumen fluid samples were collected at 0, 3 and 6 h post morning feeding using a 100-mL syringe and pH was immediately determined using a digital pH meter. The subsample was then filtrated through a clean double layer cotton cloth, and the liquid fraction was acidified with 1M H2SO4 (9:1 v/v), centrifuged at 10,000×g for 15 min and stored at −20°C for the analyses of volatile fatty acids (VFA) and NH3-N concentrations. Body weight at the beginning and end of the experimental period was also recorded.

Chemical analysis

Feed, feed refusal, and feces samples were first dried in a forced-air oven at 60°C for 48 h and then ground to pass a 1-mm screen (Cutting Mill SM 100, Retsch, Haan, Germany) before analysis. Chemical analyses of the diet, refusals, and feces were determined according to the standard methods of AOAC (1991) for dry matter (DM, method 934.01), total mineral (Ash, method 942.05), crude protein (CP, method 988.05) and ether extract (FF, method 920.39). Content of the organic matter (OM) was calculated at the 100 – Ah content (% of DM). Soluble CP (SCP) was determined by Whitelaw and Preston (1963) method. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analysed following the methods of Van Soest et al. (1991). The non-fiber carbohydrate (NFC) content of feeds was calculated according to the equation of NRC (2001) based on chemical analysis: NFC = 100 – NDF – CP – EE – ash . The gross energy (GE) content of the feed samples was analysed by

Table 1. Chemical composition (% DM unless otherwise noted) of feed and diets.

| Item       | Feed                  | Diet                  |
|------------|-----------------------|-----------------------|
|            | Conc<sup>a</sup>     | PG                    | JL                   | JLO                  | JL50                  | JL75                  | JL100                  |
| DM         | 88.9                  | 18.0                  | 38.5                 | 46.3                 | 52.5                  | 55.6                  | 58.6                   |
| OM         | 91.4                  | 88.1                  | 82.7                 | 89.4                 | 87.8                  | 87.0                  | 86.2                   |
| Ash        | 8.60                  | 11.9                  | 17.3                 | 10.6                 | 12.2                  | 13.0                  | 13.8                   |
| CP         | 21.1                  | 11.7                  | 12.4                 | 15.4                 | 15.7                  | 15.8                  | 15.9                   |
| SCP        | 14.3                  | 4.92                  | 3.41                 | 8.66                 | 8.21                  | 7.98                  | 7.75                   |
| SCP/CP, %  | 67.6                  | 42.2                  | 27.5                 | 52.3                 | 47.9                  | 45.7                  | 43.5                   |
| EE         | 4.03                  | 1.57                  | 2.52                 | 2.56                 | 2.84                  | 2.98                  | 3.12                   |
| NDF        | 38.1                  | 60.0                  | 35.1                 | 51.2                 | 43.8                  | 40.0                  | 36.3                   |
| ADF        | 16.0                  | 32.5                  | 29.1                 | 25.9                 | 24.9                  | 24.4                  | 23.9                   |
| ADL        | 11.3                  | 7.90                  | 19.4                 | 9.24                 | 12.7                  | 14.4                  | 14.6                   |
| NFC        | 28.2                  | 14.8                  | 32.7                 | 20.2                 | 25.7                  | 25.2                  | 20.9                   |
| GE, McCal/kg DM | 3.91               | 3.94                  | 3.93                 | 3.93                 | 3.92                  | 3.92                  | 3.92                   |
| Total tannins | 0.53               | 3.61                  | 3.62                 | 2.38                 | 5.09                  | 6.44                  | 7.80                   |

<sup>a</sup>Conc = Concentrate (as 100% DM): 32.3% soybean meal, 29.3% ground corn, 35% rice bran, 0.9% limestone, 0.6% DCP, 0.5% NaCl, and 1.4% premix of mineral and vitamin. Mineral and vitamin mix: provided per kg of premix including 450,000 IU vitamin A, 70,000 IU vitamin D3, 1,800 mg vitamin E, 320 g Ca, 57 g P, 32.5 g Mg, 11 g Na, 4.5 g Zn, 4.9 g Mn, 1 g Fe, 1 g Cu, 55 mg Se, and 40 mg biotin.

<sup>b</sup>JL0, JL50, JL75, JL100: jackfruit leaves replaced for Para grass at ratios of 0, 50, 75 and 100% in the diets, respectively.
combustion in an adiabatic bomb calorimeter (C6000, IKA, Wilmington, NC, USA). The determination of tannins in the feeds was done by titrimetric method following the method of AOAC (2016). The concentration of BUN in plasma samples was determined using a biochemical analyzer (XL 200, Erba, India). Ruminal pH was determined by a pH meter (H15222, Hana Instruments, US). Ruminal NH₃-N concentration was analysed using Kjeldahl methods (AOAC, 1991). Milk compositions including fat, protein, lactose, solid not fat and total solid were analysed by an automatic milk analyzer (MilkoScan Mars, Foss, Denmark). The milk samples were warmed at 40°C in a shaking incubator (ISS-4075R, JeioTech, Korea) prior to the analysis of milk composition.

Concentrations of individual VFA were analysed using a Thermo Trace 1310 GC system (Thermo Scientific, Waltham, MA, USA) equipped with a flame ionization detector. The inlet and detector temperature were maintained at 220°C. Aliquots (1 μL) were injected with a split ratio of 10:1 into a 30 m × 0.25 mm × 0.25 μm NuSil fused-silica capillary column (Cat. No: 24107, Supelco, Sigma-Aldrich, St. Louis, MO, USA) with nitrogen carrier gas set to a flow rate of 1 mL/min and an initial oven temperature of 80°C. The oven temperature was held constant at the initial temperature for 1 min, and thereafter, increased at 20°C/min to a temperature of 180°C and held for 1 min; increased at 10°C/min to a final temperature of 200°C; and a final run time of 14 min (Bharanidharan et al., 2018). Individual VFA peaks were identified based on their retention times, compared with external standards including acetic, propionic, butyric, valeric, iso-butyric and iso-valeric acids (Sigma-Aldrich, USA).

**Statistical analysis**

Statistical tests were performed using the SAS University Edition 2019 (SAS Institute Inc., Cary, NC, USA). Data were statistically analysed using the General Linear Model procedure. The statistical model was 

\[ Y_{ijklm} = \mu + A_i + D_j + P_k + e_{ijklm}, \]

where \( Y_{ijklm} \) is the dependent variable, \( A_i \) is the effect of animal (\( i = 1–4 \)), \( D_j \) is the effect of diet (\( j = 1–4 \)), \( P_k \) is the effect of a period (\( k = 1–4 \)), and \( e_{ijklm} \) is the residual effect. Data on ruminal fermentation patterns were analysed using a mixed model with repeated measures (hours). The statistical model used was 

\[ Y_{ijklm} = \mu + A_i + P_j + D_k + T_l + (D \times T)_{kl} + e_{ijklm}, \]

where \( Y_{ijklm} \) is the dependent variable, \( \mu \) is the overall of mean, \( A_i \) is the random effect of animal, \( P_j \) is the fixed effect of period, \( D_k \) is the fixed effect of diet, \( T_l \) is the fixed effect of time (hour), \( (D \times T)_{kl} \) is the fixed effect of interaction between diet and time, and \( e_{ijklm} \) is the random residual error. Significant differences among diet means were statistically compared using the Tukey test. Differences were declared significant at \( P < 0.05 \), and the tendency was declared at 0.05 ≤ \( P < 0.1 \).

**Results**

**Composition of feeds and diets**

The content of CP was low for both PG (11.7%) and JL (12.4%); thus about 52–56% of the dietary CP was supplied by the concentrate (Table 1). Jackfruit leaves had the lowest SCP/CP (27.5%) while this was 42.2% and 67.6% in PG and concentrate, respectively. In comparison with PG, JL had lower NDF content (35.1% vs 60.0%) but higher ADL content (19.4% vs 7.90%). The NFC content in JL was 2.21-fold higher than that in PG (32.7% vs 14.8%). Total tannins were 12.6% in JL, remarkably higher than those in concentrate and PG (0.53% vs 3.61%). As a consequence of different compositions between 2 forages, the replacement of JL for PG in the diets increased ADL, NFC and total tannins, but decreased SCP and NDF without changing CP and GE contents.

**Intake**

The replacement of JL for PG in the diets increased linearly (\( P < 0.01 \)) DM intake (DMI), accounting for 23.4, 32.2 and 43.7% increase in JL50, JL75 and JL100 compared with JL0 (Table 2). Total DMI expressed as % of body weight (BW) was increased linearly (\( P < 0.01 \)) in goats fed 50–100% JL (+0.95%BW to 1.75%BW) compared with those fed by only PG. Dairy goats fed JL diets increased the CP intake by 58.5–105 g/d relative to those fed by only the PG diet. The intakes of ADL and NFC in JL100 increased (\( P < 0.01 \)) by 152% and 118%, respectively, relative to JL0.

**Total-tract digestibility and nitrogen balance**

Increasing dietary JL caused a linear reduction (\( P < 0.05 \)) in apparent total-tract digestibility of the DM, OM, CP and NDF (Table 3). Goats fed JL100 decreased remarkably (\( P < 0.01 \)) the digestibility of CP (58.8% vs 78.2%) and NDF (38.6% vs 59.2%) compared with those fed by only PG. Feeding increased amounts of JL in the diets caused a linear decrease (\( P = 0.03 \)) in urinary N, but linear increase (\( P < 0.01 \)) in fecal N, and the extent of the increase was greater for the JL100 diet (22.2 g/d) compared with JL50 and JL0 (13.7 vs 8.11 g/d). Nitrogen retention showed a linear effect (\( P = 0.04 \)) and greater values were observed for the JL-diets (12.6–14.4 g/d) compared with the PG-diet (8.60 g/d).

**Rumen fermentation patterns**

Interactions between diet and sampling time (h) for rumen fermentation characteristics were not significant. Therefore, only averages of the ruminal fermentation products at different sampling times are presented in Table 4. The total VFA concentration was not affected by JL50 and JL100 diets (77.5 mM vs 77.4 mM), but increased (85.9 mM) in the JL75 diet (quadratic effect; \( P = 0.04 \)). The molar proportion of acetate increased (\( P = 0.04 \)), whereas that of propionate decreased (\( P = 0.02 \)) in JL75 compared with JL0 and JL50. As a consequence, the acetate:propionate ratio was higher (\( P = 0.02 \)) in JL75 than those in JL0 and JL50.

**Milk yield and composition**

Milk production was improved in JL75 (+192 g/d) compared with JL0 but was unaffected by feeding JL50 and JL100 (linear effect; \( P = 0.03 \); Table 5). The replacement of JL for PG
in the diets had no effect on the milk composition and blood urea nitrogen of lactating goats.

Discussion

Intake

The DMI of goats in the present study met the standard of NRC (2007); lactating goats in mid-lactation consume a DMI of 3.9% body weight. That increased nutrient intake in goats fed JL diets in this study was similar to the result in the study of Thanh et al. (2021), where growing meat goats fed 50–100% JL that were replaced for PG in the diet. Malik et al. (2017) found no change in the DMI of sheep fed JL replaced for wheat bran because the NDF content was quite the same between the two diets in their study. However, Mui et al. (2002) reported a linear reduction of the DMI in dairy goats fed, increasing JL replaced for concentrate. The main reason for this discrepancy was the evident fact that in the experiment of Mui et al. (2002), JL was substituted for the concentrate and not for forage with a higher NDF concentration, as in the present experiment. That reduced the ratio between the NDF and NFC from 2.53 to 1.17 passing from diets JL0 to JL100, which led to increased DMI with the latter diet, as it was considered as an expected effect of the JL100 treatment. Moreover, jackfruit leaves are highly palatable (Kibria et al., 1994), and thus, goats consumed a higher amount of JL-contained diets.

Table 2. Feed and nutrient intakes (g DM/d unless otherwise noted).

| Item          | JL0   | JL50  | JL75  | JL100 | SEM  | P-value | Contrast |
|---------------|-------|-------|-------|-------|------|---------|----------|
| Concentrate   | 618b  | 749a  | 787a  | 830a  | 43.4 | <0.01   | <0.01    |
| Para grass    | 871a  | 507b  | 274b  | 0c    | 107  | <0.01   | <0.01    |
| Jackfruit leaves | 0    | 581h  | 907ah | 1310a | 166  | <0.01   | <0.05    |
| Total DM      | 1,489b| 1,837a| 1,969a| 2,140a| 126  | <0.01   | <0.01    |
| DM, % BW      | 3.92a | 4.88a | 5.21a | 5.68a | 0.33 | <0.01   | <0.01    |
| OM            | 132b  | 1614a | 1709a | 1840a | 106  | <0.01   | <0.01    |
| Ash           | 157c  | 226b  | 259b  | 300a  | 22.2 | <0.01   | <0.01    |
| CP            | 233b  | 291b  | 314a  | 338a  | 19.9 | <0.01   | <0.01    |
| EE            | 38.5a | 52.6b | 58.7ab| 66.1a | 4.03 | <0.01   | <0.01    |
| NDF           | 757   | 791   | 780   | 773   | 55.0 | 0.85    | 0.77     |
| ADF           | 382b  | 454ab | 480a  | 514a  | 32.4 | <0.01   | <0.01    |
| ADL           | 138b  | 237b  | 286ab | 348a  | 27.1 | <0.01   | <0.01    |
| NFC           | 303c  | 476b  | 559ab | 662a  | 46.4 | <0.01   | <0.01    |

1JL0, JL50, JL75, JL100: jackfruit leaves replaced for Para grass at ratios of 0, 50, 75 and 100% in the diets, respectively.  
2Linear (L) and quadratic (Q) effects of diets.  
*–**Means within a row with different superscripts are significantly different (P < 0.05).

Table 3. Total-tract digestibility and nitrogen balance.

| Item          | JL0   | JL50  | JL75  | JL100 | SEM  | P-value | Contrast |
|---------------|-------|-------|-------|-------|------|---------|----------|
| Digestibility, % |       |       |       |       |      |         |          |
| DM            | 66.4a | 61.7ab| 57.9b | 58.8b | 3.07 | 0.03    | <0.01    |
| OM            | 68.6  | 65.1  | 62.0  | 62.8  | 2.72 | 0.05    | <0.01    |
| CP            | 78.2a | 70.2b | 61.6a | 58.8a | 3.22 | <0.01   | <0.01    |
| NDF           | 59.2a | 48.1b | 40.6a | 38.6a | 4.19 | <0.01   | <0.01    |
| Nitrogen balance, g/d |       |       |       |       |      |         |          |
| Intake        | 37.2b | 46.6a | 50.3a | 54.0a | 3.18 | <0.01   | <0.01    |
| Feces         | 8.11c | 13.7ab | 19.7ab| 22.2a | 2.70 | <0.01   | <0.01    |
| Urine         | 11.5  | 10.6  | 9.72  | 8.59  | 1.49 | 0.13    | 0.03     |
| Milk          | 9.02  | 8.09  | 8.29  | 8.76  | 0.85 | 0.45    | 0.77     |
| Retention     | 8.60  | 14.2  | 12.6  | 14.4  | 2.84 | 0.09    | 0.04     |

1JL0, JL50, JL75, JL100: jackfruit leaves replaced for Para grass at ratios of 0, 50, 75 and 100% in the diets, respectively.  
2Linear (L) and quadratic (Q) effects of diets.  
*–**Means within a row with different superscripts are significantly different (P < 0.05).
diets, and this is beneficial environmentally. In fact, urinary N is mainly in the form of urea, which is more rapidly hydrolyzed to ammonia and nitrated to nitrate, whereas fecal N is largely in the organic form, which is less volatile. Therefore, decreased N excretion via urine could reduce nitrous oxide and ammonia emissions into the atmosphere. The greater fecal N excretion with increasing rates of JL in this study was in agreement with previous studies, where meat goats fed JL (Thanh et al., 2021) and dairy cows fed Acacia mearnsii tannins (Grainger et al., 2009).

**Ruminal fermentation patterns**

The higher ruminal VFA concentration in JL diets was in agreement with the study of Pal et al. (2015) who reported that JL was among one of the tree leaves that produced a high concentration of total VFA in sheep. Thanh et al. (2021) found no effect on ruminal VFA concentration of growing meat goats when JL was used to replace PG from 50–100% in the diet. However, Roca-Fernández et al. (2020) reported that feeding condensed tannins at 3.80–7.56% in the diets strongly reduced ruminal VFA concentration. The greater total VFA concentration found in the current study was a result of the higher concentration and ingestion of NFC registered at a higher level of JL. Jayanegara et al. (2011) found that the content of total tannins in leaves had a positive correlation with bacterial populations. Alongside higher nutrient ingestion, a greater number of ruminal microbes could increase nutrient fermentability in the rumen, and thus, increase VFA products.

**Milk yield and composition**

Very few studies have been carried out to understand the effect of JL on the milk yield and composition of dairy goats, and this was the first study to determine the response of milk production and composition in lactating goats fed JL replaced for traditional grass. The milk yield of goats in the current study was higher than those in the report of Mui et al. (2002); dairy goats produced 1242–1751 g milk/day. This might be due to the greater dietary CP contents (15.7–16.1%) in this study compared with 11.5–12.4% CP in their experiment. That greater dietary NFC concentration and ingestion obtained with JL diets could be the main reason to improve milk production of the goats in these diets. Devendra (1991) reported that a high nutrient intake is a very important factor in ensuring the release of sufficient nutrients for maintenance and production in goats because they are able to adjust milk yield according to feed intake. The increased milk production in goats fed JL diets could also be a result of higher by-pass protein in these diets. A study on dairy cattle in tropical climates reported that feeding diets rich in by-pass protein increased milk yield by 22.9% (Thanh and Suksombat, 2015). No shift of milk composition in this study revealed that JL could be used at an unlimited level

| Table 4. Ruminal fermentation patterns. |
|---------------------------------------|
| Item | JL0 | JL50 | JL75 | JL100 | SEM | P-value | Contrast |
| pH | 6.73 | 6.72 | 6.67 | 6.62 | 0.07 | 0.48 | L Q |
| NH3-N, mg/dL | 21.8 | 23.0 | 24.6 | 23.1 | 3.35 | 0.87 | 0.62 | 0.59 |
| VFA, mM | 72.8ab | 77.5b | 85.9a | 77.4b | 3.54 | 0.03 | 0.08 | 0.04 |
| VFA proportion, % | | | | | | |
| Acetate | 59.1b | 58.0b | 61.8a | 59.9ab | 1.15 | 0.04 | 0.12 | 0.63 |
| Propionate | 21.1a | 20.5ab | 19.2b | 20.0b | 0.46 | 0.02 | 0.01 | 0.06 |
| Butyrate | 11.9 | 12.1 | 12.6 | 12.1 | 0.41 | 0.43 | 0.42 | 0.27 |
| Valerate | 2.42 | 2.42 | 2.15 | 2.44 | 0.11 | 0.09 | 0.59 | 0.10 |
| Iso-butyrate | 1.80 | 2.70 | 1.66 | 1.92 | 0.44 | 0.15 | 0.64 | 0.32 |
| Iso-valerate | 3.66 | 4.27 | 2.56 | 3.62 | 0.64 | 0.12 | 0.38 | 0.62 |
| A/P | 2.80b | 2.84b | 3.29b | 3.03ab | 0.13 | 0.02 | 0.03 | 0.15 |
| 1JL0, JL50, JL75, JL100: jackfruit leaves replaced for Para grass at ratios of 0, 50, 75 and 100% in the diets, respectively. |
| 2Linear (L) and quadratic (Q) effects of diets. |
| a,bMeans within a row with different superscripts are significantly different (P < 0.05). |

| Table 5. Milk yield and composition. |
|--------------------------------------|
| Item | JL0 | JL50 | JL75 | JL100 | SEM | P-value | Contrast |
| Milk yield, g/d | 1800 | 1917 | 1992 | 1966 | 46.6 | 0.09 | L Q |
| Component, % | | | | | | |
| Fat | 3.69 | 3.62 | 3.63 | 3.71 | 0.16 | 0.97 | 0.93 | 0.66 |
| Protein | 2.92 | 2.88 | 2.78 | 2.92 | 0.05 | 0.24 | 0.64 | 0.13 |
| Lactose | 4.46 | 4.38 | 4.45 | 4.46 | 0.05 | 0.68 | 0.76 | 0.44 |
| Total solids | 11.5 | 11.4 | 11.3 | 11.5 | 0.23 | 0.89 | 0.94 | 0.50 |
| Solid not fat | 8.01 | 7.95 | 7.87 | 8.01 | 0.09 | 0.70 | 0.84 | 0.33 |
| BUN, mmol/L | 8.07 | 8.80 | 7.47 | 7.10 | 0.65 | 0.55 | 0.24 | 0.63 |
| Initial live weight, kg | 38.1 | 37.1 | 36.8 | 37.3 | 1.32 | 0.58 | 0.41 | 0.29 |
| Final live weight, kg | 37.5 | 38.6 | 38.8 | 38.2 | 1.12 | 0.43 | 0.37 | 0.28 |
| 1JL0, JL50, JL75, JL100: jackfruit leaves replaced for Para grass at ratios of 0, 50, 75 and 100% in the diets, respectively. |
| 2Linear (L) and quadratic (Q) effects of diets. |
| a,bMeans within a row with different superscripts are significantly different (P < 0.05). |
instead of PG in the diet of lactating goats without changing the normal metabolism of milk components. Plasma urea concentration reflected the rumen NH\textsubscript{3}-N level and the unchanged BUN concentration was a result of a similar NH\textsubscript{3}-N concentration in the rumen of goats. Thanh et al. (2021) reported that the BUN concentration decreased linearly when increasing the replacement of JL in growing meat goats fed for PG, in diets containing 30% concentrate. Furthermore, the JL-fed goats in that study showed a lower concentration of BUN (4.03–6.53 mmol/L) than those (7.10–8.80 mmol/L) in the current study. For this reason, a higher proportion of concentrate (40%) was used in our study.

**Conclusion**

An increase in the replacement of JL for PG in the diet of lactating goats increased the intake of feeds and nutrients but decreased the digestibility of all nutrients. The JL diets increased the N retention, ruminal VFA concentration and milk yield, but did not change the milk composition. Feeding JL increased N excretion via feces but decreased N excretion via urine is good for the environment. Based on the findings of this study, it is concluded that the JL can totally replace PG in the diet of lactating goats, and continuous lactation feeding trials with longer periods should be conducted to elucidate the possible use of JL on milk production and gut health of the dairy goats.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

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