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REGULAR ARTICLES

# Replacement of soybean meal with levels of inclusion of soya waste in the diet of growing goats

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## Abstract

An experiment was conducted to investigate the effect of replacing soybean meal with soya waste at different levels on intake, digestibility and growth in goats. Eighteen male goat kids with initial body weight (BW) of 13.0 kg were distributed equally to three dietary groups. They were fed Napier grass (*Pennisetum purpureum*) and concentrate mixture, and each goat was assigned to an individual pen. Soybean meal in the concentrate mixture was replaced with soya waste at 0% (T1), 50% (T2) and 100% (T3) levels in respective dietary groups. These diets were isocaloric and isonitrogenous. Results showed that animals fed T3 diet exhibited higher Napier grass intake than those fed T1 or T2 diet. There was no influence on total intakes of dry matter (DM), organic matter (OM), crude protein (CP), metabolic BW, per cent BW and metabolisable energy by the dietary groups. However, there was an increasing trend on intake and digestibility of neutral detergent fibre (NDF) with increasing levels of soya waste in the diets. Animals fed T3 diet showed higher intake and digestibility of NDF than those fed T1 diet. There was no influence of the dietary groups on digestibilities of DM, OM and CP. Similarly, there was no effect of them on the final BW, total BW gain, daily BW gain, feed conversion ratio and feed cost. Soya waste can replace 100% soybean meal in diets for growing goats, because no change was observed in nutrient intake, digestibility and growth performance; inclusion of soya waste enhanced the intake and digestibility of NDF.

**Keywords** Digestibility · Feed conversion ratio · Feed intake · Growth · Napier grass · Soya waste

## Introduction

Due to food-feed competition between humans and livestock, the feed price of concentrates for livestock rearing is increasing. As a result, scientists and farmers are trying to find alternative feed sources from agro-industrial manufacturing companies. To begin with, soybean meal is a widely used protein source in livestock feeding which has a comparatively higher cost than others. In fact, soybean meal can be replaced with soya waste, an agro-industrial by-product, which can be obtained as residue during the manufacturing process of tofu and soymilk from soybean. This product is also known as soy pulp, okara, soybean curd residue or ampas tahu. It is a good source of protein and fibre, which can be fed up to 2.0% of body weight (BW) as a dry matter (DM) basis by adult goats as replacement of traditional concentrate supplement (Rahman et al. 2015; 2016). The partial inclusion (30–50%) of soya waste in cattle diets has been evaluated, and no adverse effects were observed on intake, milk production and milk composition of cows (Wang et al. 2003; Thakur et al. 2015). Soya waste has high potential to be used as a cheaper source of protein for goats.

Soya waste has high nutritional values with 39.1% crude protein (CP), 77.0% total digestible nutrients, 31.9% neutral detergent fibre (NDF), 2.05 Mcal net energy per kg DM for

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lactation, 2.3% calcium and 4.6% phosphorus (Harthan and Cherney 2017). Although raw soybean contains anti-nutritional factors such as trypsin inhibitor, its concentration can be reduced by manufacturing process (i.e., soaking and grinding); thus, it can be used safely in livestock feeding.

However, the use of soya waste has a major constraint of having high moisture (about 80%), which makes it difficult to be handled and preserved. In our previous research, animals showed diarrhoea symptoms when they were fed ad libitum feeding of fresh soya waste and Napier grass (*Pennisetum purpureum*), which included 3.0% soya waste intake of their BW (Rahman et al. 2015). This was probably due to soya waste's high moisture and palatability, indicating the importance and drawback of inclusion of this product with other feed ingredients in livestock feeding. Moreover, it also showed that there was a decreasing trend in DM intake with increasing levels of soya waste in the diet, which was probably due to soya waste's moisture restricting rumen's capacity of consumption. Furthermore, goats can be safely fed with 2.0% soya waste of their BW as the only source of concentrate supplement with Napier grass ad libitum (Rahman et al. 2015). To prevent farmers from taking account of this restriction during feeding, this study was conducted with one of the methods of reducing the soya waste moisture so that animals can receive concentrated mixture as ad libitum basis without any health problems. The methods include fresh soya waste being incorporated with other dry feed ingredients or dried (sun dry or oven dry) using recent technologies to reduce its moisture.

Therefore, the objective of this experiment was to investigate the effect of substituting soybean meal with soya waste at various levels on intake, nutrient digestibility and growth performance in mixed breed goat kids.

## Materials and methods

This experiment was conducted at the Institute of Biological Sciences (ISB) mini farm, University of Malaya, located in the city of Kuala Lumpur, Malaysia. All experimental procedures were carried out with the guidelines of the Institutional Animal Care and Use, under the licence number (ISB/11/08/2014/MMR-R).

A total number of 18 weaned male goats (mixed breed) at about 90 to 120 days of age with an initial BW of 13.0 ± 2.3 kg were used in this study. They were selected from existing goats in the ISB mini farm which had been reared under identical management. Before the beginning of the trial, all the experimental animals were dewormed with Bomectin, and they were adapted to similar management as before. During the adaptation period, animals were fed Napier grass ad libitum and concentrate at 1.0% of their BW for 14 days. Afterwards, they were randomly distributed into 3 dietary groups (6 animals in each group) in a complete randomised design. All 3 diets were formulated as isocaloric and isonitrogenous, and they contained three levels of soya waste as replacement for soybean meal (Table 1). The 3 dietary groups were T1, diet without inclusion of soya waste; T2, diet with inclusion of 28% soya waste; and T3, diet with inclusion of 56% soya waste. Diets of T2 and T3 were prepared daily, while T1 was prepared every fortnight. The experimental diets were prepared to fulfil the nutrient requirements of experimental goats according to the NRC (2007). Soya waste was provided by a local dealer from a soybean processing factory once a week, and it was preserved in airtight containers. Napier grass was cut daily at about 2-month maturity from the regrowth Napier grass plots at the goat farm. After the harvest, it was chopped mechanically and offered to the experimental goats as a fresh basis.

Each goat was housed in an individual pen with access to drinking water. Napier grass and concentrate mixture were given to the goats twice a day (morning and afternoon). All the animals were fed Napier grass and respective concentrate mixture on an ad libitum basis. Feeding trial lasted 98 days for collection of data and samples. Daily feed offered and refusals were recorded to calculate feed intake, maintaining a level of 10% refusals throughout the experiment. Samples of feeds and refusals were collected weekly and preserved in a refrigerator (− 20 °C) for further analysis. Goats were weighed every fortnight prior to feeding time to calculate BW change. Body weight gain was estimated by subtracting the initial BW from the final BW.

At the end of the feeding trial, 18 goats were transferred to metabolic crates where they were adapted for 5 days followed by 7 days of collection period. Similar feeding management was carried out as stated above in the feeding trial. The offered feed, refusals and faecal excretions were measured and recorded daily. The samples (feed, refusals and faeces) were collected and preserved in a refrigerator (− 20 °C) daily. The collections were then pooled. The pooled composites of samples were thawed at room temperature, mixed properly, dried in an oven at 70 °C for 48 h, ground and passed through the sieve (1 mm). Then, it was stored in plastic bottles for further chemical analysis. The digestibility of respective nutrients was calculated.

The samples were analysed for DM (method 934.01), organic matter (OM, method 930.05), ash (method 942.05) and CP (method 981.10) according to AOAC (2000). Neutral detergent fibre was measured as mentioned by Van Soest et al. (1991) without alpha-amylase and expressed inclusive of residual ash.

All data were analysed using analysis of variance following the procedure of SPSS (version 22.0, SPSS Inc., Chicago, IL, USA) as a completely randomised design (CRD) as shown below:

$$Y_{\mathrm{ijt}} = \mu + T_i \ + \alpha_j + \beta_t + e_{\mathrm{ijt}}$$

where $Y_{ijt}$ is and dependent variable; $\mu$ is the overall mean; $T_i$ is the treatment effect $i$; $\alpha_j$ is the covariate effect (initial body

**Table 1** Chemical composition of ingredients fed by goats

| Item | Napier grass | Corn (cracked) | Wheat pollard | Soybean meal | Soya waste |
|---|---|---|---|---|---|
| Dry matter (%) | 30.6 | 89.9 | 90.5 | 89.8 | 22.9 |
| Organic matter (%) | 91.3 | 98.7 | 96.2 | 93.0 | 96.3 |
| Crude protein (%) | 7.9 | 7.5 | 14.6 | 38.2 | 23.3 |
| Neutral detergent fibre (%) | 70.1 | 12.9 | 36.2 | 15.6 | 37.4 |
| Ash (%) | 8.7 | 1.3 | 3.8 | 7.0 | 3.7 |
| Metabolisable energy (Mcal/kg dry matter)* | 1.8 | 3.2 | 2.5 | 3.3 | 2.7 |

*Obtained from secondary data (Yusoff et al. 2005)

weight) $j$; $\beta_t$ is the random effect of the measurement taken at time $t$; and $e_{ijt}$ is the residual error. For feed intake parameter, a model of repeated measurements was used for data analysis. Mean values between experimental diets were compared using Tukey test at 5% probability.

## Results

Intake and nutrient digestibility of experimental diets by goats are shown in Table 3. There was an increasing trend on Napier grass intake with increasing levels of soya waste in the diets. Animals fed with T3 diet showed significantly ($p < 0.05$) higher Napier grass intake than those fed with T1 or T2 diet, while no difference ($p > 0.05$) was observed on concentrated intake among the dietary groups. The total DM, OM and CP intakes did not vary ($p > 0.05$) among the dietary groups.

There was an increasing trend on NDF intake with increasing soya waste levels in the diets. Animals fed with T3 diet showed higher ($p < 0.05$) NDF intake (284.6 g/d) than animals fed with T1 diet (222.6 g/d), but there was no difference ($p > 0.05$) from that of animals fed with T2 diet (234.3 g/d), whereas animals fed with T1 and T2 diets did not differ significantly ($p > 0.05$) from each other. Dry matter intake per 100 kg BW of experimental goats ranged from 3.0 to 3.5 kg, but the variation between the dietary groups was found non-significant ($p > 0.05$). Similarly, metabolisable energy (ME) intake was similar in all dietary groups, and it ranged from 1.8 to 2.2 Mcal/goat/d. The digestibilities of DM, OM and CP of animals fed with T2 diet were non-significantly ($p > 0.05$) higher in comparison with that of animals fed with T1 and T3 diets. In contrast, the NDF digestibility of T1 diet was significantly ($p < 0.05$) lower than that of T2 and T3 diets. However, no difference was observed on NDF digestibility between the animals fed with T2 and T3 diets.

Performance of goats fed with experimental diets with inclusion of various levels of soya waste is shown in Table 4. Increasing the inclusion levels of soya waste to the goat's diet did not lead to any increase in the final BW, total BW gain, average BW gain, feed conversion or feed cost. Although the least cost of feed required per unit gain was found in animals fed with T3 diet followed by T2 and T1 diets, the differences were found non-significant ($p > 0.05$) among the dietary groups.

## Discussion

The OM, CP and ME values were relatively close among dietary groups. However, diets containing soya waste showed higher percentage of NDF and lower percentage of ash due to high content of NDF and low content of ash in soya waste, respectively. The ME contents among the dietary groups were more than the ME requirement (1.66 Mkal/day) of the experimental growing goats in this study, assuming an average daily gain of 100 g/day according to the IGR system (Cannas and Pulina 2008).

There was an increasing trend on Napier grass intake with increasing levels of soya waste in the dietary groups, suggesting that inclusion of other feed ingredients with soya waste in the diet may have caused a decline in the trend of concentrate intake. However, Napier grass intake of animals fed with T2 diet was similar to that of T1 diet, implying that inclusion of soya waste up to 50% in the dietary groups does not influence Napier grass intake. These findings are in line with the results of Rahman et al. (2015) who stated that goats showed diarrhoea symptoms when they were fed soya waste as ad libitum basis. They mentioned that it may have been linked with the different moisture contents among treatment diets, since soya waste contained significant amounts of moisture. High moisture may lead to a reduced intake which can support the findings of the current study. In this study, there was a decreasing trend in total intakes of DM, OM and CP with increasing levels of inclusion of soya waste. It may also be related to the high moisture content of the soya waste, thus restricting the rumen's capacity to take more feed.

Increasing levels of inclusion of soya waste in the dietary groups did not have a significant effect on the total intakes of

DM, OM, CP, ME, DM intake in per cent BW and DM intake per $kgW^{0.75}$. This is explained by the similarity of OM, CP and ME contents among the dietary groups (Table 2) since the diets were prepared to be isocaloric and isonitrogenous. These results also indicated that all the diets supplied to the experimental animals with the essential nutrients were adequate for maintenance and growth. In our previous studies, goats fed soya waste (up to 2.0% DM of BW) and Napier grass ad libitum did not show any negative effects on animal performance (Rahman et al. 2015; 2016). The DM intake in per cent BW in this study did not differ among the dietary groups, indicating that goats consumed adequate amounts of DM (3.0% or more of their BW), which is the recommended daily DM intake of goats raised in the tropics (Devendra and McLeroy 1982). The values found for the DM, CP and ME intakes of the dietary groups were close to the recommendations of the NRC (2007), which recommends daily DM (3.3–3.7% of BW), CP (94.6 g) and ME (1.6 Mcal) intakes for daily weight gain of 100 g/d for goats weighing about 20 kg, respectively. The values found (65.1–74.8 g) for the daily feed intake per kg of metabolic BW of the dietary groups were also similar with the values (56.8–82.4 g) of growing sheep as reported by McDonald et al. (2010) Table 3.

It was hypothesised that the promotion in the NDF content of the dietary groups with the increasing levels of the soya waste would exhibit reduction in the DM intake; however, the statistical analysis showed that there was no effect on DM, OM and CP intakes. This can be attributed due to the NDF values in this study, which were still below the maximum limit as reported by Mertens (1997) who reported that NDF values above 60% present a negative correlation on DM intake. Van Soest (1994) reported that the NDF intake usually varies from 0.8 to 1.2% of BW which corroborates in the current experiment: 0.96% in the diet without containing soya waste, 1.10% in the diet containing 28% soya waste and 1.26% in the diet containing 56% soya waste. If the energy concentration of the diet is low, however, this limit can be exceeded. The NDF intake in this study increased with increasing levels of soya waste in the dietary groups, which can be explained by the higher NDF contents in both of the soya waste and Napier grass compared with other feed stuffs (Table 1).

Even though soya waste was high in NDF content, it resulted in better digestibility of DM, OM and CP. The NDF content in the diet is negatively correlated with DM intake due to slower fermentation in the rumen, which was also observed in this study through a decreasing trend of DM intake with increasing level of soya waste in the diets. In spite of that, fibre that is more digestible might enhance feed intake as it disappears from the rumen, making space for another feed sooner (Robinson and McQueen 1997). The findings of this experiment suggested that soya waste has a positive effect on fibre digestion as fibre concentration in the diet is increased by inclusion of soya waste.

There were no differences in the final BW, daily BW gain, feed conversion ratio (FCR) and feed cost among the dietary groups (Table 4). This finding may possibly be attributed to the fact that there was no effect of dietary groups on the total DM intake by the experimental goats. Thus, the diets containing soya waste resulted in a similar performance to those fed with a control diet containing only soybean meal, which indicated that soya waste can be used as a source of alternative protein source to the goats. A similar finding was stated by Harthan and Cherney (2017) who stated that the evaluated diets did not affect the daily BW gain of the lambs when evaluating the effect of inclusion of okara (soya waste) on diet. This result can be attributed to the non-significant effect of the diets on the DM intake, which is the nutritional factor with the major influence on BW gain. Harjanti et al. (2012) reported that soya waste has nutritional and functional properties that helped in increase of BW which may explain the similarity

**Table 2** Feed ingredients and chemical composition of concentrate mixture

| Feed ingredients | Substitution levels by soya waste (%, dry matter) | | |
|---|---|---|---|
| | 0 (T1) | 50 (T2) | 100 (T3) |
| Corn (cracked) | 42 | 46 | 44 |
| Wheat pollard | 38 | 16 | 0 |
| Soybean meal | 20 | 10 | 0 |
| Soya waste | 0 | 28 | 56 |
| Total | 100 | 100 | 100 |
| Chemical composition (%, dry matter) | | | |
| Organic matter | 96.6 | 97.1 | 97.4 |
| Crude protein | 16.3 | 16.1 | 16.4 |
| Neutral detergent fibre | 22.3 | 23.7 | 26.6 |
| Ash | 3.4 | 2.9 | 2.6 |
| Metabolisable energy (Mcal/kg dry matter)* | 3.0 | 3.0 | 2.9 |

*Calculated from secondary data (Yusoff et al. 2005)

**Table 3** Intake and nutrient digestibility by goats according to the inclusion levels of soya waste in the concentrate mixture

| Parameters | Substitution levels by soya waste (%, dry matter) (Mean ± standard deviation) | | | *p* value |
|---|---|---|---|---|
| | 0 (T1) | 50 (T2) | 100 (T3) | |
| Intake (g/day) | | | | |
| Napier grass | $95.2^{b} \pm 60.3$ | $126.7^{b} \pm 60.0$ | $233.8^{a} \pm 54.9$ | 0.000 |
| Concentrate | 665.1 ± 283.2 | 613.3 ± 109.1 | 454.2 ± 209.9 | 0.053 |
| Total dry matter | 760.3 ± 305.3 | 740.0 ± 141.5 | 688.0 ± 198.1 | 0.722 |
| Total organic matter | 729.7 ± 293.6 | 711.0 ± 135.0 | 655.7 ± 193.2 | 0.689 |
| Total crude protein | 116.1 ± 47.7 | 109.0 ± 19.7 | 92.8 ± 33.1 | 0.270 |
| Total neutral detergent fibre | $214.9^{b} \pm 84.9$ | $234.3^{ab} \pm 56.5$ | $284.6^{a} \pm 56.0$ | 0.043 |
| DM intake (g/kg $W^{0.75}$/day) | 73.5 ± 17.8 | 74.8 ± 12.8 | 65.1 ± 13.5 | 0.237 |
| DM intake (% body weight) | 3.5 ± 0.9 | 3.5 ± 0.4 | 3.0 ± 0.5 | 0.483 |
| Metabolisable energy intake (Mcal/day) | 2.2 ± 0.9 | 2.1 ± 0.4 | 1.8 ± 0.6 | 0.175 |
| Digestibility (%) | | | | |
| Dry matter | 78.2 ± 5.1 | 85.0 ± 5.0 | 80.6 ± 4.8 | 0.198 |
| Organic matter | 79.3 ± 5.1 | 85.8 ± 4.7 | 81.0 ± 5.0 | 0.211 |
| Crude protein | 79.9 ± 4.1 | 84.3 ± 6.0 | 79.8 ± 4.3 | 0.372 |
| Neutral detergent fibre | $53.7^{b} \pm 14.7$ | $73.9^{a} \pm 7.8$ | $73.3^{a} \pm 6.3$ | 0.034 |

[ab] Means with different superscripts in the same row differ at $p < 0.05$

between goats fed the control and treatment diets in terms of total BW gain. Thakur et al. (2015) reported that there were no adverse effects on feed intake, average daily gain, milk yield and milk composition when animals were fed soya waste as supplement. This indicates the importance of this by-product in animal feeding. Although the experimental animals appeared to be healthy throughout the study, further study is essential to find out the soya waste's effect on physiological health status of the animals.

The weight gains of all the experimental goats in this study were comparatively lower (73.2–93.7 g/d) than their potential growth (100 g/d), which may have resulted due to being mixed breed and poor feeding management of goat kids after birth as well as during pregnancy period of their mother doe. In our previous study, Boer goat kids with 3 months of age showed good growth performance (138.2–174.7 g/d) when their mother does were managed under proper feeding during pregnancy period (Rahman et al. 2015). It indicates that if proper management is provided during pregnancy and after birth along with plane of nutrition, growing animals can exploit their full potential under these experimental diets.

There were no differences in production performance or cost between the diets containing soybean meal and soya waste in this study. In fact, other studies showed that soya waste diet results in lower cost than diet-containing soybean meal because soya waste can be obtained freely as industrial residues unlike soybean meal which needs to be purchased; having said that, this study showed similar cost between the diets due to soya waste being purchased. Furthermore, soya waste is suitable for ruminants but not poultry because of its

**Table 4** Growth performance, feed conversion and feed cost of goats according to the inclusion levels of soya waste in the concentrate mixture

| Parameters | Substitution levels by soya waste (%, dry matter) (Mean ± standard deviation) | | | *p* value |
|---|---|---|---|---|
| | 0 (T1) | 50 (T2) | 100 (T3) | |
| Initial BW (kg) | 12.9 ± 2.9 | 13.2 ± 2.2 | 13.0 ± 2.6 | 0.989 |
| Final BW (kg) | 22.3 ± 7.2 | 21.3 ± 3.1 | 23.4 ± 6.3 | 0.874 |
| Total BW gain (kg) | 9.4 ± 5.7 | 8.1 ± 1.4 | 10.4 ± 4.5 | 0.757 |
| Average BW gain (g/day) | 84.5 ± 51.1 | 73.2 ± 12.5 | 93.7 ± 40.5 | 0.757 |
| Feed conversion (DMI/BW gain) | 10.9 ± 3.5 | 10.2 ± 0.6 | 8.1 ± 2.7 | 0.303 |
| Feed cost (RM) for 111 days | 74.6 ± 28.5 | 66.4 ± 12.9 | 60.2 ± 16.0 | 0.227 |
| Feed cost (RM)/kg BW gain | 9.2 ± 3.0 | 8.2 ± 0.5 | 6.4 ± 2.2 | 0.218 |

*BW*, body weight; *DMI*, dry matter intake. The costs of 1 kg of fresh feeds were Napier grass = Malaysian Ringgit (RM) 0.18, corn = RM 0.70, wheat pollard = RM 0.61, soybean meal = RM 1.59, soya waste = RM 0.20

high NDF (37.4%); thus, it will help to reduce the competition of purchasing soybean meal between ruminant and poultry producers and may lead to lower soybean meal price. Moreover, massive production of soya waste from the manufacturing industries creates disposal problems, such as dumping in landfills which contaminates the environment by, for instance, nitrogen leaching because of soya waste's susceptibility to putrefaction (Li et al. 2013). Using soya waste as a protein and fibre sources in ruminants would be mutually advantageous to both livestock farmers (source of protein and fibre for animal consumption) and soya waste producers (eliminates disposal problems). In addition, high moisture content (77.1%) of soya waste makes it difficult to be preserved and handled as animal feed; however, the mixing of soya waste with other feed ingredients used in this study reduces the moisture. As a result, this can minimise the problems faced by livestock farmers.

## Conclusions

Replacement of soybean meal with soya waste in the diets does not alter the intake, digestibility, FCR and growth performance of the animals. Moreover, the intake and digestibility of NDF increase with increasing levels of soya waste in the diets. Replacement of soybean meal with soya waste would be beneficial to farmers and manufacturers because it would provide a source of protein and fibre for animal consumption and also eliminate the disposal problems faced by producers. Therefore, in areas where there is availability of soya waste, this by-product can be used to replace 100% soybean meal in diets for growing goats. Future research can be done to investigate the drying of soya waste for use as an animal feed, as well as soya waste's effect on animal's physiological health.

**Authors' contributions** Mohammad Mijanur Rahman, Ramli Bin Abdullah and Ryo Akashi designed the experiment, Mohammad Mijanur Rahman and Ramli Bin Abdullah carried out the analysis, Khairiyah Binti Mat, Maryana Mohamad Nor and Genki Ishigaki assisted with data analysis, Mohammad Mijanur Rahman and Ryo Akashi arranged the scientific content, and Khairiyah Binti Mat, Mohammad Mijanur Rahman and Maryana Mohamad Nor drafted the manuscript. All authors contributed editorial suggestions and supported the final manuscript draft.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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