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Assessment of Chemical Composition and *In Vitro* Rumen Fermentation of Tuber and Crop Peels

Muhammad, A.I.[1,2], Sani, N. I. M[1], Zainudin, N. N[1], Hemly, N. I. M.[1], Khairul, A.B.[1], and Samsudin, A.A.*[1]

[1]Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia.
[2]Department of Animal Science, Faculty of Agriculture, Federal University Dutse. P.M.B. 7156, Jigawa State, Nigeria.

*Corresponding author: anjas@upm.edu.my

Abstract

Tuber and root crops, rich in carbohydrates, are staple foods in Malaysia. However, their peels, often discarded, represent a potential feed resource for ruminants. This study assessed the nutritive value and *in vitro* gas production of various root and tuber crop peels as a sustainable feed ingredient for ruminant livestock. The root and tuber peels used in this experiment were potato peels (T_1), taro peels (T_2), sweet potato peels (T_3), cassava peels (T_4) and Chinese yam peels (T_5). The proximate analysis (moisture, dry matter (DM), organic matter (OM), crude protein (CP), crude fibre (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL)) was conducted on the peels samples to evaluate their nutritional profiles. The results showed that potato peels showed the highest ($P < 0.05$) moisture, CF, NDF, and ADL contents compared to other root and tuber peels. Conversely, taro peels showed the highest CP, ADF, and ADL contents. Cassava peels had the highest DM and ash contents. Significant ($P < 0.05$) differences were observed in the metabolisable energy (ME) content, estimated based on digestible dry matter (DDM) content, among the various root and tuber peels. The ME content of Chinese yam peels was higher than that of other root and tuber peels. At the 4th, 6th, 8th, 10th, 12th, 24th, and 72nd hours of incubation, there was a significant ($P < 0.05$) difference in the gas produced by different peels in the *in vitro* rumen fermentation analysis. The taro peels produced the least gas, while Chinese yam produced the highest. In conclusion, cassava and Chinese peels could improve rumen fermentation efficiency based on their DM and ME content in terms of *in vitro* gas production.

Keywords: root and tuber peels, nutrient composition, *in vitro* rumen fermentation, digestibility.

Introduction

The search for sustainable and cost-effective feed alternatives is becoming increasingly important in livestock nutrition, especially as global demand for animal products rises (Parisi et al., 2020). The increasing global demand for livestock products has placed immense pressure on conventional feed resources, driving the need for alternative feed options that are both sustainable and economically viable (Salami et al., 2019). Traditional feed ingredients, such as grains and high-quality forages, compete with human food sources, contributing to resource scarcity and heightened feed costs (Duguma & Janssens, 2021). Researchers and producers are exploring unconventional feed resources, including agricultural by-products, which can serve as potential supplements or partial replacements in animal diets (Malenica et al., 2023). These by-products, which frequently consist of crop and tuber peels that are thrown away during food processing, are a viable choice for ruminant feed since they are high in fibre, carbohydrates, and essential minerals (Salami et al., 2019).

Tuber and crop peels, though often overlooked in livestock nutrition, contain significant amounts of nutrients beneficial for ruminant animals in tropics (I et al., 2022), whose unique digestive systems enable them to utilize fibrous plant materials through microbial fermentation in the rumen (Cholewińska et al., 2020). This microbial ecosystem breaks down fibrous feeds, converting them into volatile fatty acids and microbial proteins that provide energy and essential nutrients to the host animal (Paswan et al., 2022). However, the extent of nutrient availability and digestibility of these by-products depends on their chemical composition and fermentation characteristics, which vary depending on the type of crop or tuber, soil conditions, and processing methods (Alao et al., 2017). Thus, understanding the nutritive value and fermentation profile of specific crops and tuber peels is essential for determining their potential as sustainable feed resources. The potential of crop and tuber peels as livestock feed is determined by their nutrient profile and digestibility, both of which influence their capacity to meet animals' nutritional requirements effectively (Aziz et al., 2024). Some of the readily locally available agricultural waste are the peels from tuber and root crops. The crops on focus include potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), Chinese yam (*Discorea polystachya)* and taro (*Colocasia esculenta*).

In vitro rumen fermentation techniques offer a controlled method to evaluate the digestibility and fermentation potential of these agricultural by-products (Marcos et al., 2022), allowing researchers to simulate the ruminal breakdown process. This approach enables the assessment of parameters such as gas production, pH levels, and volatile fatty acid profiles, which are critical indicators of feed quality and fermentative efficacy (Behan et al., 2024; Menke & Steingass, 1988). By measuring these parameters, we can determine not only the nutritive value but also the potential of these by-products to meet ruminant dietary requirements without compromising animal performance. Microorganisms such as bacteria and protozoa will ferment the feed, which usually consists of plant polymers into short-chain volatile fatty acids (VFA), methane and carbon dioxide (Harirchi et al., 2022).

The local ruminant industry is still far from achieving the self-sufficiency level for ruminant (cattle and sheep) production. Feeding ruminants with an adequate nutritional diet is important for achieving optimum growth. Peels from root and tuber crops that are typically thrown away as waste, like taro (*Colocasia esculenta*), Chinese yam (*Discorea polystachya*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), and potato (*Solanum tuberosum*), would be useful if they could be added to the ruminant feed. Products derived from the peels of root and tuber crops, such as potatoes and cassava, are excellent sources of feed for ruminants. Additionally, they will provide new opportunities for processing the peels, typically classified as waste, to make them into beneficial ruminant feed.

This study seeks to evaluate the nutritional composition and in vitro rumen fermentation characteristics of selected tuber and crop peels to assess their feasibility as alternative feed resources for ruminants. By identifying the nutritive potential and limitations of these by-products, we aim to contribute to the development of more sustainable and economically feasible feeding strategies, reducing reliance on traditional feed sources and enhancing the circularity of agricultural systems. The outcomes of this study may offer valuable insights into optimizing the use of agricultural residues in livestock production, supporting both environmental sustainability and the economic viability of animal farming systems. Thus, the study determined the nutritive content and *in vitro* rumen fermentation of different types of root and tuber crop peels

Materials and methods

Sample Collection and Preparation

Five different root and tuber crops, i.e., potato (*Solanum tuberosum*), taro (*Colocasia esculenta*), sweet potato (*Ipomoea batatas* (L.) Lam.), cassava (*Manihot esculenta*), and Chinese yam (*Dioscorea polystachya*) were obtained from reputable sources. All root and tuber crops were sorted, chopped, washed and peeled manually using a peeler. Five paper bags were weighed and labelled as T_1, T_2, T_3, T_4 and T_5. The proportion of peel from five root and tuber crops were inserted into each paper bag respectively and weighed. The samples were dried in a 60 °C oven for three days (Khalil, 2022). After three days, each paper bag was weighed and recorded. The loss of moisture was indicated by the weight loss of the samples. The dry matter percentage was calculated by subtracting 100% from the percentage of moisture. The dried peels were finely ground using an electrical grinder. The ground peels were collected and placed on a standard sieve (2mm size) and mechanically shaken to separate the particle size and for proximate analysis. The samples were kept in 2 OZ pill boxes (properly labelled) to prevent additional moisture or mould growth.

Substrates, treatments and experimental design

Potato, taro, sweet potato, cassava and Chinese yam were obtained from a reputable source. Proximate analysis (AOAC, 2016) and *In vitro* rumen fermentation analysis (Menke & Steingass, 1988) were conducted in the Nutrition Laboratory, Department of Animal Science, Faculty of Agriculture at University Putra Malaysia. Potato peels (T_1), taro peels (T_2), sweet potato peels (T_3), cassava peels (T_4), and Chinese yam peels (T_5) were the five treatments used in the proximate analysis, while for the *in vitro* analysis, samples T_1, T_2, T_3, T_4, T_5, and standard hay (T_6) positive control were tested. The units of measurement were the nutritive value of samples and total gas production in the trials. The experimental design is completely randomized design.

Proximate composition

The AOAC (2016) was applied to determine the proximate compositions of moisture, protein, fat, and ash content of the root and tuber peels. The Kjeldahl method was used for the determination of the crude protein as a function of nitrogen (Pearson et al., 1981). The proximate analysis samples were carried out in four replicates. The metabolizable energy (ME) was estimated for the root and tubers using the following formula:

$$ME = 0.057CP + 2.20 + 0.136V + 0.0029CF$$

Collection and preparation of rumen fluid

The in vitro experiment was conducted using the procedure of Menke & Steingass (1988**).** The rumen fluid was obtained from Kompleks Abatoir Shah Alam Jabatan Perkhidmatan Veterinar, Selangor, Malaysia. The fluid was collected into a pre-warmed thermos flask and immediately transported to the laboratory. The rumen fluid was pooled and quickly filtered through a cloth strainer into a beaker and added into the buffer mix medium in a volumetric flask while supplied with carbon dioxide (CO_2) in a 39 °C water bath. The flask was covered with aluminium foil to retain anaerobic condition. Then, the *in vitro* rumen fermentation was resumed.

Preparation of Buffered Media

The buffered media was prepared by mixing five different solutions consisting of Solution A (micromineral), Solution B (buffer), Solution C (macro mineral), Resazurin and reducing solution (Behan et al., 2024). The strained rumen liquor was added to the media in a ratio of 1:2 (v/v). The mixture was kept stirred and then placed in a water bath at 39 °C under constant CO_2 flushing.

In vitro rumen fermentation analysis

Gas production analysis

The *in vitro* rumen fermentation analysis was carried out according to Menke & Steingass (1988**).** Briefly, each sample (approximately 200 mg) was placed in a 100 mL calibrated glass syringe fitted with a rubber tube and about 30 ml rumen liquor buffer medium was added. A pre-lubricated piston was inserted into the syringe and pressed forward to remove air from the syringe through the rubber tube. The rubber tube was sealed with a plastic clip and the initial gas volume was read at the point where the end mark of the piston lies. The in vitro gas production was measured by incubating the samples for 72 hours at 39 °C in a water bath and the gas produced was recorded at 2, 4, 6, 8, 10, 12, 24 and 72 hours of incubation. The pH of the rumen fluid was taken with a Mettler-Toledo pH meter (Mettler-Toledo, Ltd England).

Statistical analysis

The data obtained from the proximate analysis and *in vitro* rumen fermentation analysis was further analysed using one-way ANOVA by a general linear model (GLM) procedure in SAS Software 9.4 Version (SAS Institute Inc., Cary, NC, USA). Tukey's Range Test was used to determine the differences between group means at $p < 0.05$ significant level.

Results and Discussion

Proximate analysis

There were notable differences in all parameters analysed according to the results of the proximate analysis of different tubers and root peels (Table 1). The moisture and DM content varied significantly ($P < 0.05$) among treatments. With potato peels (T_1) having the highest moisture content and cassava peels (T_4) having the lowest, all treatments had a moisture content above 70%. The storage and transportation of feed materials may be affected by increased moisture content (Bradford et al., 2020). Furthermore, peels with a high moisture content need to be dried for safe storage since a moisture level greater than 15% encourages the growth of microorganisms (Farahmandfar et al., 2020; Mphahlele et al., 2016).

Table 1. Dry matter, crude nutrient, and fibre fraction content of cassava tuber peel derived from three different cassava varieties

Parameters	Treatments					*P-values*
	T_1	T_2	T_3	T_4	T_5	
Moisture (%)	89.27 ± 0.00^{a}	87.27 ± 0.00^{c}	86.42 ± 0.00^{d}	72.80 ± 0.00^{e}	88.53 ± 0.00^{b}	<0.0001
DM (%)	10.73 ± 00^{e}	12.73 ± 00^{c}	13.58 ± 00^{b}	27.20 ± 00^{a}	11.47 ± 00^{d}	<0.0001
Ash (%)	13.09 ± 0.14^{d}	15.94 ± 0.29^{b}	14.85 ± 0.06^{c}	26.02 ± 0.49^{a}	14.37 ± 0.13^{c}	<0.0001
CP (%)	16.44 ± 0.80^{b}	19.72 ± 0.79^{a}	8.68 ± 0.10^{d}	9.48 ± 0.56^{d}	12.82 ± 0.08^{c}	<0.0001
CF (%)	25.73 ± 0.18^{a}	17.99 ± 0.40^{b}	11.24 ± 0.10^{c}	9.17 ± 0.66^{d}	10.59 ± 0.24^{c}	<0.0001
Fibre fraction (% DM)						
NDF (%)	68.85 ± 7.57^{ab}	47.58 ± 0.45^{c}	74.45 ± 2.02^{a}	59.88 ± 1.36^{bc}	52.66 ± 4.24^{c}	0.0045
ADF (%)	31.60 ± 0.73^{c}	65.94 ± 0.17^{a}	31.06 ± 0.53^{c}	45.65 ± 2.21^{b}	23.31 ± 0.76^{d}	<.0001
ADL (%)	81.10 ± 12.69^{a}	42.49 ± 4.12^{b}	16.07 ± 5.81^{c}	22.24 ± 4.04^{bc}	9.24 ± 1.37^{c}	0.0001
ME (MJ/kg DM)	9.17 ± 0.07^{b}	4.98 ± 0.03^{d}	9.24 ± 0.08^{b}	8.06 ± 0.17^{c}	10.83 ± 0.07^{a}	<0.0001

$^{a, b, c, d, e}$ Means with different letters within a row differed significantly ($P < 0.05$). Dry matter (DM), Crude protein (CP), Crude fibre (CF), Neutral detergent fibre (NDF), Acid detergent fibre (ADF), Acid detergent lignin (ADL) and Metabolizable energy (ME). T_1(potato peels), T_2 (taro peels), T_3 (sweet potato peels), T_4 (cassava peels) and T_5 (Chinese yam peels).

However, peels from root and tubers possess significant moisture content, which influences their handling, storage, and potential as a valuable by-product (I et al., 2022; Joshi et al., 2020; Ncobela et al., 2017). It was reported that potato peels generally contain 60-80% moisture (Awogbemi et al., 2022), while cassava peels might have a slightly lower range of 50-70% due to the fibrous nature of cassava (Ahmed Edhirej et al., 2017). The proximate analysis of the peels of several sweet cassava cultivars shows a moisture content of 69.03 to 72.00 per cent, comparable to the current findings (Otache et al., 2017). The results of the present investigation are consistent with their studies on the moisture content of root and tuber peels. In comparison to other root and tuber peels, cassava peel has a higher fibre content, which may also explain why it has the lowest moisture level.

However, the peels of cassava (T_4) had the highest DM concentration, whereas the peels of potatoes (T_1) had the lowest. One important factor in assessing the nutritional and processing value of root and tuber peels is their dry matter (DM) content (Choquechambi et al., 2019). In line with the current study, cassava peels have a higher dry matter content of about 20–30% because of their dense fibrous structure (Nizzy & Kannan, 2022), whereas potato peels have a dry matter level of 15-20%, consist up of starch and fibre (Aziz et al., 2024). Likewise, the dry matter content of sweet potato and yam peels is usually between 15 and 25 per cent. Root and tuber peels' high dry matter content can affect their nutritional value when used as feed or processed products, however, it also provides advantages for industrial applications.

The treatment groups differ significantly ($P < 0.05$) in the organic matter of the tuber and root peels. Although the OM content of cassava peels (T_4) was higher than that of sweet potato peels (T_3), no significant difference ($P > 0.05$) was found between the peels of sweet potatoes and Chinese yams or between the peels of potatoes and sweet potatoes. The OM content represents the mineral content, which is important, especially for calcium and phosphorus balance in the ruminant diet. The organic matter in the peels, which is mostly composed of carbon-based chemicals, contributes to their nutritional value and industrial potential (Hussein et al., 2021).

Among the most vital elements that ruminants require is protein, through the amino acids that are available and necessary for growth and maintenance (Afolabi et al., 2012). Proteins are the building blocks of all tissues, blood, hormones, enzymes, and immunoglobulins (Prasad et al., 2023). Thus, a lack of protein in ruminants' diet may decrease development. The protein content of the taro peels was much higher than that obtained from the cassava peels with a significant difference among all the five samples. Any feeds that are less than 1.3 % N (8 % crude protein) are considered deficient as they cannot meet the minimum ruminant ammonia levels requirements (Kubkomawa et al., 2015). Compared with other root and tuber peels, taro contains higher protein on a dry weight basis than yam, cassava or sweet potato (Temesgen, 2015). It contains high protein fractions that are rich in essential amino acids of threonine, leucine, arganine, valine and phenylalanine as well as methionine, lycine, cystine, phenylalanine and leucine are relatively abundant in the leaf than the corm. The high protein content as compared to other root and tuber crops is because of the presence of symbiotic soil bacteria in the root and rhizome part (Temesgen, 2015), which help bacteria fix atmospheric bacteria and increase nitrogen occurrence in the corm and leaf (de Andrade et al., 2023). The protein content of 202.08% obtained for taro peels in this study is higher than the total protein of 7.43% reported by (Econ & 2018). The variations may result from a variety of environmental factors, including soil quality, plant maturity, and seasonal variations. The low crude protein content found in cassava peel could be attributed to higher peel structural fibre (Oladimeji et al., 2022). The high moisture content could be the reason for the higher crude protein content of more than 100%. Thus, a large quantity of peels is needed to meet the protein needs of ruminants.

The indigestible fraction of carbohydrates is known as crude fibre, and it is primarily composed of cellulose (60–80%), lignin (4-6%), and other soluble fibre (Williams et al., 2019), which are highly correlated to the maturity of the plant. The results indicated that the crude fibre concentration and fibre fractions varied significantly across all samples. The crude fat and neutral detergent fibre contents were observed to be higher ($P < 0.05$) in potato peels (T_1) as compared to other treatments. This implies that ruminants and monogastric animals might likewise be fed cassava peel, which is derived from sweet potato peel. The fibre fraction content of neutral detergent fibre and acid detergent lignin content of potato peels followed the pattern of crude fibre, whereas taro peels differ by having higher acid detergent fibre content. The crude fibre content and fibre fractions of all root and tuber peels were optimal for ruminants in the current investigation, which supports prior findings (I et al., 2022). The rumen microbes convert cellulose and hemicellulose into volatile fatty acids (VFA), which provide ruminants with energy (Owens & Basalan, 2016), a higher fibre content, however, may restrict the animal's voluntary intake.

In comparison to other root and tuber peels, taro peels had a significantly ($P < 0.05$) different acid detergent fibre content which consist of cellulose and lignin and the least digestible part. Higher acid detergent fibre content of any feed material can negatively influence the dry matter digestible of ruminant animals (Riaz et al., 2014). In contrast to other root and tuber peels, the acid detergent lignin content of potato peel and taro peel did not ($P > 0.05$) differ substantially. The main structural component of mature plants is the high acid-detergent lignin content present in the root and tuber peels, which are primarily composed of periderm (plant protective tissue) (Scaria et al., 2024). It is mostly found in the woody tissue of forages, is highly indigestible, and can affect the amount of available energy and the digestibility of cellulose (Sun et al., 2022).

Root and tuber crops like potatoes, cassava, sweet potatoes, and yams are energy-dense foods, with their peels retaining a significant portion of this energy (Bayata, 2019). In root and tuber peels, ME content varies by species and can be influenced by fibre, starch, fat, and protein composition. The ME content of root and tuber peels reflects the chemical composition of these by-products, primarily influenced by their carbohydrate and fibre contents (Plakantonaki et al., 2023). For instance; Potato peels have a high starch content and metabolizable energy, typically ranging from 9 to 13 MJ/kg on a dry matter basis (Khan, 2016), which is within the range of the results obtained in this study. Cassava peels contain a high starch content with moderate fibre, resulting in metabolisable energy values similar to, or slightly lower than, potato peels (Jumare et al., 2024). The metabolisable energy levels of sweet potato peels, which are high in carbohydrates and bioactive substances, can range from 8 to 11 MJ/kg. Compared to potato peels, the fibre content may lower energy digestibility (Shi et al., 2024). The higher fibre and lignin content of yam peels may result in a lower ME value. However, they have a reasonable energy content (7–10 MJ/kg) (Fasina, 2014), which makes them an excellent feed alternative considering that it is not as high in energy. The metabolizable energy content of all the tuber and root peels differed ($P < 0.05$) significantly. The Chinese yam peels had higher energy values, while cassava peels were observed the least. As evidenced by Chinese yam peel, which has a higher ME content than other root and tuber peels but a lower acid detergent fibre concentration, the lower ME content may be linked to an increase in ADF (Nolan & Savage, 2009).

In vitro gas production

In vitro gas production and rate of gas production per two hours did not differ ($P > 0.05$) significantly at early hours (2h), how it does ($P < 0.05$) at the subsequent hours (4th, 6th, 8th, 10th, 12th, 24th,48th and 72nd) hours of incubation for monitoring gas production (**Table 2**). The taro peels (T_2) produced the least amount of gas and were substantially different from the other treatments in the fourth, sixth, eighth, tenth, twelve, twenty-four, forty-eight, and seventy-two hours of incubation. Degradation of the organic fraction of feed by rumen microorganisms is the main source of gas produced by feed in the rumen (Chen et al., 2024). *In vitro* gas production is an essential measure of feed digestibility (Dijkstra et al., 2005), and the level of *in vitro* gas production can directly reflect the nutritional quality of feed samples (Chen et al., 2024), which indicate the metabolism of rumen microorganisms and measure dietary digestibility (Menke et al., 1979). There is a positive correlation between the magnitude of gas production and digestibility (Lei et al., 2018). digestibility facilitated by bromelain. The amount of lignin in the rumen disrupts the breakdown of plant cell walls (Zhang et al., 2022).

Table 2. *In vitro* gas production of different root and tuber peels

Sample	Gas production (ml/200mg)								
	2h	4h	6h	8h	10h	12h	24h	48h	72h
T_1	1.57 ± 0.17^{a}	3.14 ± 0.83^{a}	5.76 ± 0.66^{a}	7.33 ± 0.76^{a}	10.30 ± 0.96^{a}	13.09 ± 1.04^{a}	19.20 ± 1.48^{a}	24.09 ± 1.24^{a}	24.79 ± 1.19^{a}
T_2	0.70 ± 0.29^{a}	2.44 ± 0.20^{b}	1.05 ± 0.35^{b}	1.40 ± 0.45^{b}	2.27 ± 0.33^{b}	3.14 ± 0.61^{a}	3.67 ± 0.77^{c}	6.29 ±1.29^{b}	5.59 ± 1.66^{b}
T_3	1.75 ± 0.20^{a}	4.89 ± 1.03^{a}	6.98 ± 0.49^{a}	8.56 ± 0.66^{a}	9.95 ± 0.77^{a}	11.35 ± 0.87^{a}	13.96 ± 1.09^{b}	23.21 ± 1.77^{a}	24.79 ± 1.92^{a}
T_4	1.40 ± 0.40^{a}	2.44 ± 0.45^{ab}	5.24 ± 0.45^{a}	8.03 ± 0.49^{a}	10.30 ± 0.34^{a}	11.87 ± 0.64^{a}	15.71 ± 0.81^{ab}	21.47 ± 1.62^{a}	22.87 ± 1.35^{a}
T_5	0.88 ± 0.34^{a}	2.27 ± 0.33^{ab}	5.24 ± 0.20^{a}	6.81 ± 0.34^{a}	9.95 ± 0.33^{a}	12.40 ± 0.44^{a}	18.85 ± 0.83^{a}	25.66 ±2.12^{a}	28.45 ± 1.94^{a}
T_6	0.88 ± 0.18^{a}	2.27 ± 0.52^{ab}	5.41 ± 0.44^{a}	6.63 ± 0.57^{a}	8.90 ± 0.44^{a}	10.47 ± 0.57^{a}	13.79 ± 0.44^{b}	20.60 ± 0.85^{a}	23.91 ± 1.15^{a}
P-values	0.0720	0.0031	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

The gas production differed significantly ($P < 0.05$) among treatments at 4th, 6th, 8th, 10th, 12th, 24th,48th and 72nd hours of incubation. There is no significant difference ($P > 0.05$) between all treatments in 2 hours of incubation. T_1 (potato peels), T_2 (taro peels), T_3 (sweet potato peels), T_4 (cassava peels), T_5 (Chinese yam peels) and T_6 (standard hay).

This may help explain why taro peels produce less gas during incubation than other root and tuber peels since they have a higher lignin concentration. It was shown that the total accumulated gas production (72 hours) for the standard hay (T_6) and other treatments did not differ ($P > 0.05$) significantly, with the exception of taro peels (T_2). In this study, the same treatments exhibited the highest 48 h cumulative gas production, suggesting that a significant portion of fermentable components in them were utilized. However, comparing *in vitro* digestibility alone should not be used to evaluate the overall quality of feed. In this experiment, the root and tuber peels had adequate substrate fermentation in the early stages, which led to an increase in gas production and an increased GP rate with time. In the later stages, the substrate reduced, and the GP production gradually levelled off. In the pre-fermentation period, the degree of feed degradation by rumen bacteria increased with time; however, in the subsequent period, the amount of degradable material gradually reduced, resulting in a slow increase in GP.

Conclusion

In conclusion, it was observed that the potato peels had higher moisture content as compare to other roots and tubers, however, the cassava and Chinese peels shown to improve rumen fermentation efficiency based on their DM and ME content in terms of *in vitro* gas production. Although taro peels have shown to have higher CP contents and least gas produced, but similar ADL content with potato.

Ruminants may consume less DM as a result, and more feed materials on a fresh weight basis may be needed to meet livestock nutrient requirements and compensate for the high moisture content of forage. The comparison of tuber and root crop peels with other feed ingredients and the potential anti-nutritional substances should be studied further.

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