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Physicochemical composition of different parts of cassava (*Manihot esculenta* Crantz) plant

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Abstract

Cassava (*Manihot esculenta* Crantz) is one of the main sources of carbohydrate and it is a useful plant in Malaysia. Its root is used to produce various foods such as cassava chips, while the other parts are potentially to produce feeds and other useful products. However, details observation in the proximate composition of each part of the cassava plant is important in utilizing it as an animal feed, especially for the ruminants. Hence, this research was conducted to evaluate the proximate composition of each part in the cassava plant and characterized its functional groups using Fourier-transform infrared spectroscopy (FTIR) and the thermal properties using thermogravimetric analyzer (TGA). The results obtained showed that the portions of fresh cassava plants namely flesh, stem, peel, discarded tuber and the leaf were recorded at 50.06%, 31.01%, 10.63%, 6.92% and 1.49% (w/w), respectively. Proximate analysis showed that the leaf has potential as animal feed as it contains significant high in crude protein (28.02±0.10%), crude fat (5.63± 0.12%) and the gross energy value of 4824.3 g/cal. Even though the leaf has a higher cyanide content (0.02 mg/kg) than other parts, it is still in acceptable range as an ingredient in animal feed. For animal feed that focuses on high protein and gross energy, the leaf has potential in feed ingredients. Meanwhile, cassava flesh also has potential as an animal feed since it has low crude fiber (2.11±0.03%) but high in carbohydrate (92.66±1.88%) and gross energy content (4223.9 cal/g). FTIR spectra showed that there were different functional groups present in the samples. From the TGA data, it showed that the major components in samples were cellulose which started to decompose rapidly at maximum degradation rate temperature of 315-400°C, especially for flesh and discarded tuber. Different parts of cassava plants are expected to help the agriculture industry in producing alternative animal feed at the same time minimizing the impact of waste generated in the environment.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is consumed across the world as one of the main sources of carbohydrates and as a staple food (Edhirej *et al.,* 2017). The ability of cassava plants to grow on lands with low water supply, fertilizers and agrochemical inputs allows easier, cost-effective cultivation and management of this plant. Hence, it is one of the main crops produced in many countries including Malaysia. The annually harvested cassava in Malaysia is approximately 44,229.05 metric tonnes (Department of Agriculture Peninsular Malaysia, 2017).

High cassava production unfortunately also leads to high waste generation. Some wastes are produced during the post-harvest activity, where leaves and stems were discarded or burnt, constituting 50% of the production. Industrial cassava processing is primarily carried out to separate the flesh from the skin, which also produces an abundant solid waste (Widiarto *et al.,* 2019). These peels are considered waste and are generally discarded and permitted to rot. With hand peeling, the peels can make up 20-35% of the tuber's weight (Ekundayo, 1980; Ubalua, 2007).

Without proper handling, these generated wastes may affect the environment negatively. One of the efforts to utilize this generated waste is by giving them to the villagers to use as a ruminant feed. However, without a proper processing technique, the ruminant may die due to cyanide poisoning from the cassava plant. Besides,

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most of the parts are also naturally low in protein content which deemed insufficient to cater to the ruminant diet. Hence, further explorations on the physicochemical composition of the cassava plant parts are required to link the findings with any suitable processes or treatments for a successful ruminant or other animals' feed production.

Based on the literature, cassava leaf consists of protein and starch and these nutrients are the building blocks for the growth of the cell and its development (Thomas, 2006). The stem of the plant plays the function of transport organ as it transfers the produced food to the different plant parts and the woody stem is useful for next planting. While tuber consists mainly of starch grains and is a secured source of carbohydrate in developing countries (Otache *et al.,* 2017). The tuber's outer layer is composed mostly of dead cork cells which are called periderm and the layer located beneath the periderm is called cortex as shown in Figure 1.
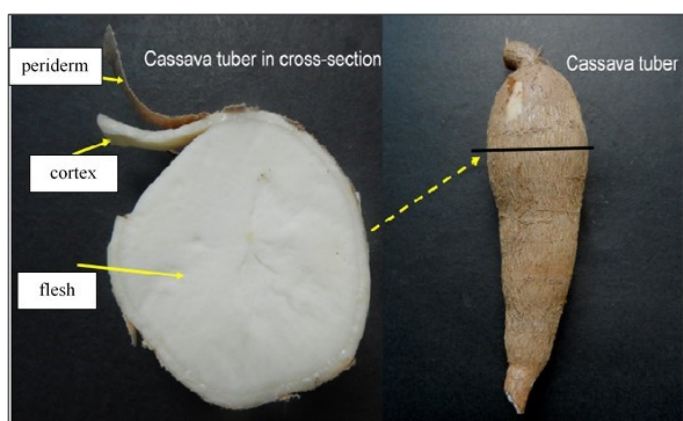

Figure 1. Cross-sectional of cassava tuber (Yao *et al.,* 2014)

All of the information from the literature is important as references to spark other research avenues. However, some are lacking in linking this information with the potential applications of the cassava plant parts, particularly for animal feed production. It is wise if the characterization of the cassava plant can be done by focusing on its intended applications. The results are important to identify the potential usage of every cassava plant parts. Furthermore, this can lead to a new strategy of complete utilization of cassava waste and so in the future, there will be little residue left that could pose a pollution problem.

According to Adetunji *et al.* (2015), cassava flesh and leaf have been used as one of the ingredients for animal feed, focusing on ruminant due to it is rich in digestible carbohydrates, mainly in starch and protein. However, other parts are generated from the cassava plant as a waste which may have potential as an animal feed ingredient. An early study of cassava plant as a potential animal feed is a need. Thus, the aim of this is to

determine the characteristics of physicochemical, FTIR and TGA of each part of the cassava plant.

2. Materials and methods

2.1 Sample preparation

In this research, ten cassava plants were collected from the local planter, Banting, Malaysia after freshly harvested. Then, the plants were cut and separated into each part namely the flesh, tender stem, cortex, periderm, discarded tuber, and leaf as shown in Figure 2. The samples were washed with tap water repeatedly to remove soil. Then, the samples were peeled, sliced, and oven-dried at 60°C for 24 hrs. All the samples were ground into powder and screen sieved at 2 mm and were stored at -4°C for further analysis. Each sample was weighed and reported as a percentage of the proportion part of a cassava plant.

Figure 2. (a) flesh (b) discarded tuber (c) leaf (d) stem (e) cortex and (f) periderm

2.2 Physicochemical composition

2.2.1 Proximate composition analysis of samples

The moisture content, crude protein, fat, ash and crude fiber were determined by following AOAC (1990) methods. Every determination of composition value performed in duplicates. Carbohydrate content was determined by using the difference method. This method involves adding the total values of crude protein, fat, crude fiber, moisture, and ash constituents of the sample and subtracted it from 100.

2.2.2 Gross energy

A Parr 1341 Oxygen Bomb Calorimeter was used to determine the gross energy of dried samples. The samples were burned in a container that was closed and measured the heat generated from it.

2.2.3 Determination of cyanide using picrate paper

Cyanide levels of the samples were determined using a picrate in solution method (Moriasi *et al.,* 2017). In 5 mL of distilled water, 3 g of each part of the samples were dissolved. Samples were boiled and 0.04 mL of each sample was mixed with two mL of alkaline picrate solution (dissolved by 2.56 g of moist picric acid and 5 g of sodium carbonate in 100 mL of distilled water) and 1.96 mL distilled water. Then, the mixture was incubated in a 37°C water bath for 15 mins. Then 15 µL of concentrated sulphuric acid was added to the blend. The mixtures against distilled water were read

spectrophotometrically at 535 nm. The sample cyanide absorption was extrapolated from a standard curve prepared by diluting potassium cyanide in the water at 0.00 to 1.35 µg/mL. The amount of cyanide in samples was calculated using equation:

$$\text{Total cyanide} \left(\frac{mg}{Kg}\right) = \frac{\frac{ug}{mL} \text{ of cyanide from the KCN calibration curve} \times \text{final volume of filtered extract}}{\text{weight of sample extracted (Kg)}}$$

2.3 Fourier Transform Infrared (FTIR) spectroscopy

Functional groups of samples were determined using Spectrum 100 FT-IR spectrometer, Perkin Elmer, United States. The absorption bands were registered in the wavenumbers of 4000 cm^{-1} to 600 cm^{-1}.

2.4 Thermogravimetric Analyzer (TGA)

The pyrolysis of 10 mg of samples was carried out in a TGA (Mettler Toledo, Model TGA/SDTA851^e, United States). The samples have been put and weighted in an alumina ceramic crucible. The TGA was heated up to 600°C under the purge of nitrogen gas at a constant heating rate of 10°C/min.

2.5 Statistical analysis

Using Minitab, version 17.0, the data were subjected to analysis of variance (ANOVA). Results are described as deviations of the means±standard deviation. ANOVA has been used to compare the means. Using the Tukey test, the information was discovered to be significant at $p<0.05$.

3. Results and discussion

3.1 The proportion of the cassava plant

Local cassava plant was divided into different parts as presented in Table 1. From the cassava wastes, the stems were the largest portion (31% w/w). Other proportions namely the peel, discarded tuber and leaf were 5.14%, 3.35% and 0.72% (w/w) respectively. While flesh, the only part needed during the process, represented 50.1% of the total weight proportion of the plant. These findings indicated that almost half of the cassava plant proportion has consisted of the discarded

parts that are considered as production wastes. This is in agreement with Ketnawa *et al.* (2012) on their studies with another plant which also had 50% (w/w) of pineapple wastes. These waste parts should be utilized to

Table 1. Proportion of local cassava parts

Cassava parts	kg	(w/w)%
Flesh	24.2	50.1
Stem	14.9	31
Peel	5.1	10.6
Discarded tuber	3.4	6.9
Leaf	0.7	1.5
Total	48.3	100

provide more profit to the producer while avoiding environmental issues.

3.2 Physicochemical composition

The data showed that the moisture content of cassava parts (dry weight basis) as observed in Table 2 ranged from 1.23-6.11% and was significantly different from each other ($p<0.05$). The leaf has the highest moisture content (6.22±0.06%) than other parts of the plant, while the least is stem (1.23±0.00%). Siti Sarah and Aishah (2016) found that the local cassava leaf has quite similar moisture content (7.4%). Sarkiyayi and Agar (2010) reported that the flesh has 0.82% moisture, which is lower than in this study. However, the moisture content in peel is higher compared to the result of Otache *et al.* (2017). Low moisture content (<10%) of all the cassava parts may bring some convenience to the producer as these parts can be kept at a longer time before their utilization for other applications, including for animal feed production (Eleazu and Eleazu, 2012).

Crude fiber represents that portion of carbohydrate that is not digestible by the body and it mainly consists of largely of cellulose (60-80%), lignin (4-6%) and other soluble fiber (Eleazu and Eleazu, 2012; Zainuddin *et al.,* 2014). Based on the findings, all samples showed significant differences in the crude fiber contents $p<0.05$. Crude fiber contents were highest in the stem (39.51±0.05%) and the flesh was the least (2.11±0.03%). According to Charles *et al.* (2005) crude fiber for flesh is within a range of 1.5 to 3.5%. Crude fiber content is

Table 2. Physicochemical composition of cassava plant

Cassava Parts	Moisture content (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Ash (%)	Carbohydrate (%)	Gross energy (cal/g)	HCN equivalent (mg/kg)
Flesh	2.83±0.02^c	1.75±0.01^d	0.64±0.05^d	2.11±0.03^f	1.24±0.05^e	92.66± 1.88^a	4223.9±4.9^c	0.01±0.00^a
Discarded tuber	4.03±0.02^d	3.54±0.04^c	0.75±0.05^{cd}	5.31±0.11^e	2.94±0.00^d	83.39±0.43^b	3645±0.1^e	0.01±0.00^a
Stem	1.23±0.00^a	5.24±0.19^b	1.37±0.05^{bc}	39.51±0.05^a	6.43±0.18b^c	42.99±1.52^e	4168.4±38.4^c	7.03 x 10^{-4}±0.00^a
Leaf	6.11±0.06^f	28.02±0.10^a	5.63± 0.12^a	21.41±0.00^c	7.28±0.39^b	31.55±1.09^f	4824.3±10.6^a	0.02±0.00^b
Cortex	1.40±0.01^b	0.023±0.03^e	1.56±0.06^b	12.41± 0.12^d	5.58±0.28^c	78.94±0.05^c	4069.2±26.8^d	0.01±0.00^a
Periderm	5.03±0.02^e	4.08±0.16^c	1.14±0.37^b	24.49±0.11^b	14.59± 0.07^a	50.71±0.20^d	4666.5 ±0.3^b	6.50x10^{-3}±0.00^a

Values are mean of duplicate determination expressed on dry weight basis±standard deviation. Different alphabet superscript indicates significantly different at $p<0.05$ between samples

commonly used as a measure of nutritive for feeds and generally, about 15% of crude fiber content is required in the ruminant feed (Luthfi *et al.,* 2018).

Crude fat is important to the structure and biological functions and also, it gives high energy to the body (Eleazu and Eleazu, 2012). Crude fat contents in cassava leaf (5.63%) is significantly higher than other parts, while cortex, periderm and stem did not show a significantly different ($p<0.05$) with each other. The values of the carbohydrates content of the cassava parts ranged from 31.55±1.09 % (leaf) to 92.66±1.88% (flesh). The result shows a significant difference ($p<0.05$) between each part of the plant. Flesh would be a good source of energy. Gross energy values presented based on the dry matter indicate their potential as food or as feed for the ruminants. From Table 2, the leaf has the highest gross energy content (4824.3±10.6 cal/g) and the least was discarded tuber (3645±0.1 cal/g). This result may be explained by the fact that the leaf has the highest crude fat and protein. This suggests that after harvesting of the tubers, cassava leaf wastes could use as animal feed because of its high protein, fat, and energy gross contents.

Due to concern about the cyanide content after cassava plants being dried, the limitation of recommended cyanide level in food is 10 mg HCN equivalent/kg dry weight which means cassava cannot be eaten raw. As expected, the leaf has the highest cyanide content, which is six times higher than the flesh (Achidi *et al.,* 2008) and is significantly higher than the other parts of the plants ($p<0.05$). However, all samples were below the cyanide content limit, which is 50mg/ kg of fresh forms (Delange *et al.,* 1982). This indicates the efficiency of the processing method during sample preparation. According to Apata and Babalola (2012), cassava leaf has relatively the same properties compared

to maize (high protein) and would be an alternative livestock feed.

3.3 FTIR analysis

FTIR analysis was conducted to compare the functional groups that present in the samples as shown in Figure 3, whereas the interpretation of main peaks is given in Table 3. The FTIR spectra of all samples displayed wide bands in the range of 3500-3200 cm^{-1} indicating O-H stretching absorption bends such as alcohol and carboxylic acid groups usually in cellulose while in 2000-1500 cm^{-1} region is for C=O stretching was found in hemicellulose (Yang *et al.,* 2007). The sharp absorption peak in lignin and hemicellulose molecules for C = O stretching (1730-1740 cm^{-1}). The absorption peak at ~1443 cm^{-1} represents C-C stretching vibration in aromatics. C-H bending vibration at ~1369 cm^{-1} may reflect of ionic carboxylic groups indicate the C-O stretching of COOH. ~1200 cm^{-1} peaks are associated with C-O stretching of hemicellulose and lignin.

The highest absorbance of OH and C-O display in all samples' spectra, but not visible for flesh. These functional groups exist for the compound with cellulose. All samples contained hemicellulose, but not flesh because the absorbance of C=O compounds is invisible at 1765-1715 cm^{-1}. For the lignin band, a big difference was found in the fingerprint region (1830-730 cm^{-1}), which indicates that lignin is rich with C-O-C stretching (methoxy compound) and C=O (aromatic ring). All samples appeared at a strong peak in this region but not for the flesh. According to Ketiku and Oyenuga (1972), hemicellulose formed only 1% of the flesh. The stem has the highest percentage of lignin since it is the main structure in the cell wall. The presence of cellulose can also be expected from the signal at ~900 cm^{-1} due to the
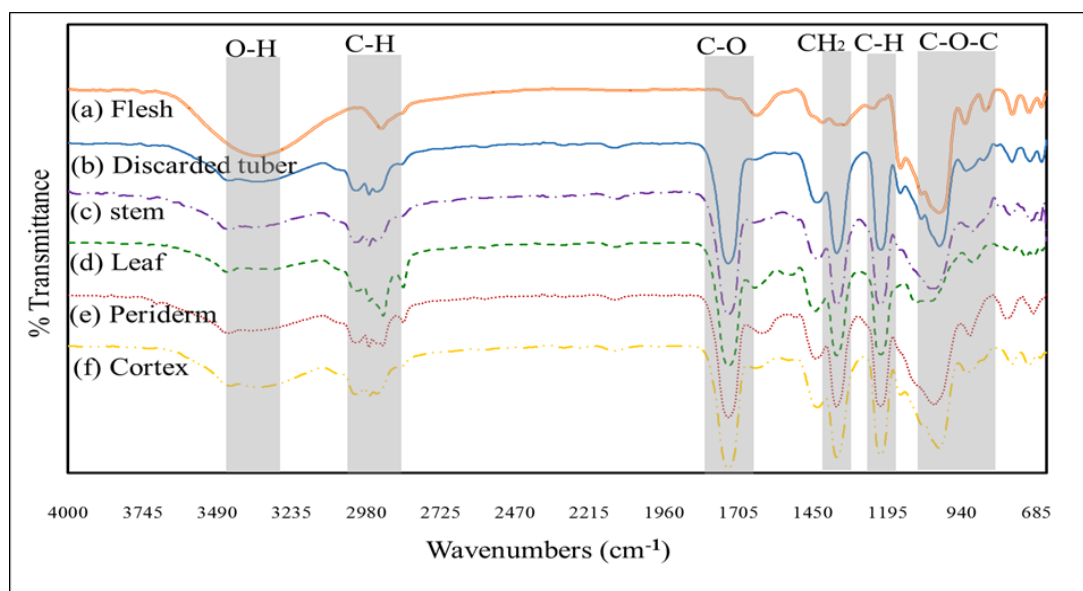
Figure 3. FTIR spectra of flesh, discarded tuber, stem, leaf, periderm and cortex

Table 3. The main functional groups identified by FTIR analysis of stem, leaf, discarded tuber, cortex, periderm and flesh

Stem (cm^{-1})	Leaf (cm^{-1})	Discarded tuber (cm^{-1})	Cortex (cm^{-1})	Periderm (cm^{-1})	Flesh (cm^{-1})	Band assignment	Functional groups
3447, 3015(s)	3451, 3011(s)	3342, 3015 (s)	3343, 3015 (s)	3448, 3015 (s)	3344 (s)	O-H stretching	Acid, methanol
2970 (m)	2922 2852 (m)	2970, 2943 (m)	2969 (m)	2970, 2923 (m)	2929 (m)	C-H$_n$ stretching	Alkyl, aliphatic, aromatic
1740 (s)	1739 (s)	1740(s)	1740(s)	1740(s)	-	C=O stretching	acetyl or carboxylic acid groups
1652 m)	1650(m)	-	-	1626 (m)	1643(m)	C=C	Benzene stretching ring
1434(w)	1443(w)	1436(w)	1435(w)	1440 (w)	1417(w)	C-C stretching	Aromatics
1369(w)	1369(w)	1368(w)	1368(w)	1369(w)	1344(w)	C-H bending	Lipids, protein, lignin
1218 (s)	1217(s)	1217(s)	1219(s)	1217(s)	1245(m)	C-O	Phenol, Aryl-alkyl ether linkage
-	-	1151(s)	1149(s)	-	1150(s)	C-O-C stretching	Pyranose ring skeletal
1034(m)	1095(m)	1017(m)	1018(m)	1034(m)	-	C-O association	C-O-H (ethanol)
900, 773,702 (m)	901, 768,721 (m)	925, 768,707 (m)	923, 769,712 (m)	913, 784 (m)	929, 767, 771 (m)	C-O-C ring vibration	Aromatic hydrogen

s: strong, m: middle, w: weak

existence of β-glycosidic networks between glucose units. These findings were consistent with Yang *et al.* (2007) study on FTIR analysis of hemicellulose, cellulose and lignin as shown in Table 3.

3.4 Thermogravimetric Analysis (TGA)

Thermal decomposition which involves weight changes to lighter form at a different temperature range due to its material composition (Wahyuningtyas *et al.,* 2017). According to Yang *et al.* (2007), pyrolysis of lignocellulosic materials consists of hemicellulose, cellulose and lignin start to degrade at the temperature range of 220-315°C, 315-400°C and 100-900°C, respectively. Hemicellulose is rich in branches and consists of various saccharides that are volatile and releases gases such as carbon monoxide, carbon dioxide and other hydrocarbons. Cellulose is high in thermal stability because its structure consists of a glucose long polymer without branches. While for lignin, its structure full of aromatic rings without branches thus lead to a wide degradation temperature (Zainuddin *et al.,* 2014).

TGA and Differential thermogravimetric (DTG) of cassava flesh, discarded tuber, stem, leaf, periderm and cortex are illustrated in Figure 4. The step one of mass loss occurred at below 200°C due to the evaporation of water and light volatile matters with total loss of less than 11% of the tested samples (Gai *et al.,* 2013). Different samples show different steps in TGA and DTG which means there is the existence of different components that decompose at a certain range of temperature.

In step two is the process of hemicellulose pyrolysis at the maximum degradation rate temperature of 304-350°C for all samples. According to Yang *et al.* (2007),

hemicellulose starts to decompose at 315-400°C. DTG curves show the maximum mass loss rate of the samples. The maximum rate of flesh decomposition was highest (-0.002 wt. %/°C) compare to other samples because of its volatile matter, while the periderm has the lowest mass loss rate (<-0.0005 wt.%/°C). The residue left for discarded tuber and flesh at 600°C is lower (18.41% and 18.72%, respectively) as compared to other samples due to the rapid decomposition of hemicellulose
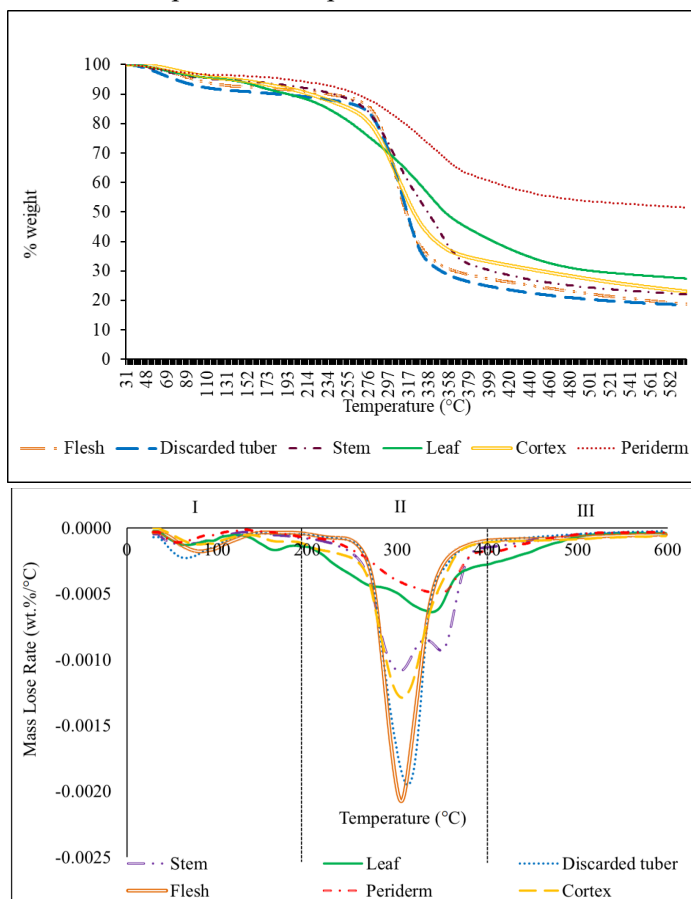

Figure 4. TGA-DTG curves of cassava flesh, discarded tuber, stem, leaf, periderm and cortex

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Table 4. TG thermal properties of samples

Sample	Step	T_{range} TG (°C)	T_{peak} DTG (°C)	Loss of mass (%)
Stem	I	30.33-105.00	65	5.37
	II	142.00- 328.83	304.67	40.6
	III	330.00-599.833	350	32.03
Leaf	I	50.00-129.33	65.33	5.02
	II	129.33.00-190.00	161.67	4.62
	III	190.00-282.00	279.33	16.23
	IV	282.00-403.33	339.83	34.07
	V	403.00-599.833	450	12.65
Discarded tuber	I	40.00-205.50	70	10.66
	II	210-599.833	310	70.93
Cortex	I	41.00-128.50	85.33	4.72
	II	140.00-220.00	181	5.92
	III	222.00-599.83	308.5	66.34
Periderm	I	42.00-90.00	58	2.79
	II	100.00-208.67	160	2.9
	III	212.00-407.33	350.5	34.67
	IV	409.00-599.33	420	8.16
Flesh	I	42.00-194.17	80	8.49
	II	200.00-599.83	305	72.79

(Wahyuningtyas et al., 2017).

Step three is the stage of decomposition of cellulose started at DTG of 339.83- 450°C. Table 4 shows that the leaf and the periderm have cellulose content degraded at this temperature range. The percentage of solid residual after pyrolysis at a maximum temperature of 600°C for discarded tuber, flesh, stem, cortex, leaf, and periderm are 18.41, 18.72, 22.00, 23.01, 27.41 and 51.53 wt %, respectively. The thermal analysis data of the samples extracted from the curves are summarized in Table 4.

4. Conclusion

The findings of this study showed that the stem was the largest wastes portion (w/w) % of cassava plants followed by the peel, discarded tuber and leaf. While for the proximate composition of the cassava plant, the leaf has significant protein content and high in energy gross than other parts of the plant. This indicates that the leaf can be incorporated into ruminant feed ingredients. Different parts of cassava other than the leaf, the flesh also have potential as ingredients in ruminant feed. The characterization of cassava plant parts was confirmed using FTIR and TGA that they are made of cellulose, hemicellulose and lignin. Clinical studies are recommended to determine at what level the physicochemical content of cassava plant is toxic to animal and ascertain the side effects if any.

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