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Physico-chemical Characteristics of Ensiled Cassava (*Manihot esculenta* Crantz) and Sweetpotato (*Ipomoea batatas* L. (Lam.)) Foliage, and Fermentation Kinetics of Cassava Silage

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This study was conducted to determine the physico-chemical characteristics of ensiled cassava (*Manihot esculenta* Crantz) and sweetpotato (*Ipomoea batatas* L. (Lam.)) foliage with or without additives molasses and rice bran. Six treatment combinations were from two crop species (cassava and sweetpotato) and three additives (without additive, 10% molasses, and 10% rice bran). The physical (color, odor, texture) and chemical characteristics (pH, total soluble sugars, Flieg point, dry matter, organic matter, ash, crude protein, NDF, ADF, hemicellulose) of the samples were evaluated following standard procedures. Fermentation kinetics of cassava foliage silage and ruminal *in situ* DM degradability of cassava foliage silage were evaluated for 3, 6, 12, 24, 48, and 72 h using cannulated cattle. Results showed that cassava foliage (CF) and sweetpotato foliage (SF) silages with molasses had the lowest pH of 3.82 and 3.80, respectively due to high TSS values of the samples. CF had the highest crude protein (19.06%) compared to SF silage (11.61%). Moreover, CF had low fiber fractions (NDF and ADF) resulting in a high effective dry matter degradability (74.73%) of the silage. Results on silage quality, nutritive value, and dry matter degradability evaluation proved the potential of cassava foliage silage with molasses as an alternative high protein feed for ruminants.

Keywords: additive, alternative feeds, degradability, silage quality, root crops

INTRODUCTION

The lack of sufficient, good quality, and cost-efficient feed resources during the lean months drives the search for new feed alternatives for ruminants. Considering the increasing population and the decreasing area for agriculture, these new feed alternatives should not compete with food crops. Hence, the utilization of crops' by-products as feed alternatives is gaining popularity. Cassava (*Manihot esculenta* Crantz) and sweetpotato (*Ipomoea batatas* L. (Lam)) are two of the country's major crops cultivated for edible storage roots utilized as food or as a source of raw materials. In 2021, the volume of cassava and sweetpotato production in the Philippines amounted to 2,559.8 and 254.5 MT, respectively (PSA 2021). After harvesting the roots, the leaves and stems of these crops are generally left to dry or burned, potentially polluting the environmental.

Ravindran (1993) reported that cassava leaves can be harvested at maturity of the roots or it can be exclusively aimed towards leaf production. He mentioned that the amount of forage available from cassava at maturity is about 30% of the root yield. On the other hand, Salces et al. (2000) reported that leaf of the foliage dry matter ranged from 60 – 66%, stem from 12 – 15%, and petiole from 20 – 28% when cassava plants were defoliated at 4 – 5 mo after planting. Sweetpotato vines can reach 1 – 7 m in length which are mostly returned to the field after harvesting, causing huge waste (Mu et al. 2022).

In the Philippines, approximately 18 T of sweetpotato vines are discarded per hectare after harvesting (Flores and Cruz 2017). Claessens et al. (2009) reported that a dual-purpose sweetpotato has a forage yield of 14.6 t/ha.

Earlier reports indicated that leaves of cassava and sweetpotato have high nutritive value and are being utilized as alternative feedstuff in other countries. While both crops can be fed fresh or ensiled, the leaves and stems can deteriorate rapidly when fed fresh due to their high moisture content.

The presence of hydrocyanic acid (HCN) in cassava limits its use as animal feed. Cassava leaves can be effectively preserved during the dry season through ensiling which lowers the HCN content (Tewe 1991; Nguyen et al. 1996). Similarly, Salces et al. (2000) found that the level of HCN in fresh cassava foliage can be reduced by wilting from 86 – 186 ppm to 80 ppm for low and medium HCN varieties, while high HCN varieties can only be reduced by ensiling. Since studies on the chemical composition and nutritive value of both cassava and sweetpotato when ensiled with additives are limited in the country, investigation on the ensiling potential of these crops combined with common additives (molasses, rice bran) under Philippine conditions is deemed necessary. The objectives of the study were (1) to determine the physical and chemical characteristics of cassava foliage and sweetpotato foliage silage of molasses and rice bran, and (2) to determine the fermentation kinetics of cassava foliage silage.

MATERIALS AND METHODS

The study conformed with the protocols reviewed and approved by the Institutional Animal Care and Use Committee of the University of the Philippines Los Baños (IACUC-UPLB), with Protocol Review number CAFS-2022-03 and Approval Reference number UPLB-2022-010. The cannulated cattle bulls were under the care of UPLB Dairy Training and Research Institute (UPLB DTRI). Trained staff of UPLB DTRI supervised the use of cannulated cattle bulls during loading and unloading of samples from the rumen.

The study was conducted from September 5, 2022 to January 12, 2023, at the UPLB Institute of Animal Science (UPLB IAS), and the UPLB DTRI.

Fodder, Fodder Preparation, and Silage Making

Cassava foliage (CF), (Lakan 1, 60 - 90 d from planting) was gathered from the UPLB Institute of Crop Science (UPLB ICropS) on 21 October 2022 at 15:00 h. Only the upper portion of the stalk with green leaves attached to it was used for the experiment. On the other hand, sweetpotato vines with leaves (Sp 32), approximately 135 d from planting, were also gathered from UPLB ICropS on 21 October 2022 at 15:00 h. Upper ground biomass of the sweetpotato plant was harvested, leaving only the storage roots behind. The vines were sorted and only the green stems and leaves, described in this study as sweetpotato foliage (SF), were used. The wilted or senesced leaves and brown stems were discarded. For both crops, the foliage was left to partially wilt (air-dried) for at least 20 h before chopping.

CF and SF samples were chopped to 1 – 2 cm in length. Samples of approximately 200 g were taken from each treatment combination to evaluate the physico-chemical composition of fresh samples. After the vines and leaves of each species were chopped, the material was added with additives such as molasses (M), and rice bran (RB). The inclusion rates of each additive used were: control (without additive); molasses (10% of CF and SF's air-dried weight); and rice bran (10% of CF and SF's air-dried weight). Pure molasses (75% DM and 83.86 °Brix) and rice bran (D2) (89% DM) were layered and mixed thoroughly following treatment combinations and inclusion rate to increase DM content of the mixture and serve as additives to improve silage fermentation.

The treated fodder were ensiled in 1 kg capacity glass jars and compacted manually. The jars were kept at the Animal Production Laboratory in Fronda Hall, UPLB IAS, for anaerobic fermentation and were opened at 21 d. Samples of approximately 400 g from each replicate were collected for physical and chemical characterization, while fermentation kinetics was determined for CF only.

Treatments and Experimental Design

The treatment factors were species (cassava and sweetpotato) and additives (without additives, molasses, rice bran) following a 2 x 3 factorial design in CRD with six treatment combinations and four replications per treatment combination. The following were the treatment combinations: T1 - CF (Cassava Foliage); T2 - CF + M (Cassava Foliage + Molasses); T3 - CF + RB (Cassava Foliage + Rice Bran); T4 - SF (Sweetpotato Foliage); T5 - SF + M (Sweetpotato Foliage + Molasses); and T6 - SF + RB (Sweetpotato Foliage + Rice Bran). The additives were added at the level of 10% (w/w) of the air-dried weight of the foliage.

Sample Collection and Analysis

The physical and chemical characteristics of silages were evaluated at 21 d. The pH was determined immediately after the silages were opened. Samples of the ensiled mixture of approximately 25 g each were mixed with 100 ml of distilled water and blended using an osterizer. The filtrates were subjected to pH testing using a portable pH meter (YSI pH10A pH/Temperature – EcoSense®

pH10A). Also, Total Soluble Sugars (TSS) were measured using a Digital Refractometer (Atago 3810 PAL-1, 0.0 - 53.0 % Brix Measurement Range). Color, texture, and odor were evaluated by five-panel members using a scoring method. The scoring matrix for color was adapted from Sudarman et al. (2016) while the rating scales for texture and odor were adapted from DTRI UPLB.

Samples after ensiling were subjected to oven-drying at 70°C for 3 d to a constant weight, then were ground using a Wiley mill to pass through 1 mm granulation. Samples were analyzed for moisture (oven-drying), and ash (ignition) content at the Animal Nutrition Analytic Services Laboratory, UPLB IAS using the procedures described by the Association of Official Analytical Chemists (1998). The crude protein was analyzed using Kjeldahl method while neutral detergent fiber (NDF) and acid detergent fiber (ADF) determination were done using the Van Soest method at the Lipa Quality Control Center Inc., Lipa City, Batangas, Philippines. The hemicellulose component was computed by subtracting ADF from NDF.

Flieg point (FP) which is an indicator of silage fermentation was calculated based on DM and pH values of the silage at the end of the fermentation period following the equation (Kilic 2006 as cited by Saricicek, 2016):

$$Flieg\ Point = 220 + (2 \times \%DM\ of\ silos\ feed - 15) - 40 \times pH$$

where FP < 20, bad silage quality; FP = 21 – 40, poor quality; FP = 41 – 60, medium quality; FP = 61 – 80, good quality; FP = 81 – 100, very good quality.

Ruminal Incubation of the Samples

The cannulated animals used were Holstein-Sahiwal bulls, about 5 yr old, and weighing from 406 – 535 kg. They were individually penned and fed with fresh and chopped Napier grass (*Pennisetum purpureum*) supplemented with concentrate feeds at 70:30 ratio based on recommended dry matter intake of 3% of the body weight. Animals were fed at 8:30, 12:00, and 4:00 h, and were given free access to clean water.

Fermentation kinetics of CF silages were evaluated using *in situ* technique. Composite samples of approximately 5 g were enclosed in Ankom forage bags (10 x 20 cm; 50 ± 10 micron porosity). The rumen pH of the animals was also determined before and after the whole incubation period to assess rumen fermentation. Each sample was incubated in duplicates in the rumen of each of the three cannulated bulls for 3, 6, 12, 24, 48, and 72 h. The gradual in-all-out method was used, i.e., the bags were placed in the rumen at designated time points and retrieved all at once. After removal from the rumen, the bags were washed with running water until minimal colored liquid appeared and were air dried for 4 h. After air-drying, the bags were oven dried to constant weight at 70°C.

Loss in weight during the washing of the samples with running water after the incubation were corrected by soaking control samples in water, then washing and drying them normally. Control bags were also incubated in the rumen during the whole incubation period to correct the changes in the weight of the bags due to soaking in rumen liquor. Similarly *in situ* bags containing test samples were soaked in water for 1 h and then washed in running water until the water becomes clear. These control bags served to correct for the changes in the weight of the samples due to soaking in water.

Rumen DM degradability of the silages was estimated by fitting the data to the exponential equation (Eq. 1) proposed by Ørskov and McDonald (1979):

$$y = a + b\,(1 - e^{-ct}) \qquad \text{(Eq. 1)}$$

where y = DM disappearance in rumen (%) at time t; a = the rapidly soluble fraction (%); b = the potentially degradable fraction (%); c = the constant rate of degradation of b (%/h).

The model parameters were estimated using the non-linear procedure, specifically the one-phase decay exponential function of GraphPad Prism 7 (GraphPad Software, Inc., San Diego, CA). Separate curves were fitted to the data points of each replicate. The effective DM degradability was calculated (Eq. 2) by assuming a rumen outflow rate of 2%/h following the recommended rate for animals at maintenance level (NRC 2001):

$$y = a + (bc/(c + k)) \qquad \text{(Eq. 2)}$$

where (a), (b), and (c) are the same as in Eq. 1, and (k) is the rumen outflow rate.

Statistical Analysis

For physico-chemical characteristics, a 2 x 3 factorial experiment (2 species - cassava, sweetpotato; 3 additives - without additive, molasses, rice bran) was laid out following a completely randomized design (CRD). For fermentation kinetics, a randomized complete block design with 3 treatments (additives - without additive, molasses, rice bran) using three cannulated bulls with weight as a blocking factor. The data gathered were subjected to analysis of variance and differences among means were tested using PROC GLM of SAS 9.1.3, with significance at $p < 0.05$. The Tukey-Kramer test was used to compare the treatment means at 95% confidence interval.

RESULTS AND DISCUSSION

Physico-chemical Characteristics of Cassava and Sweetpotato Foliage Before Ensiling

The physico-chemical characteristics of the cassava and sweetpotato foliage with or without additive before ensiling was presented in Table 1. Significant interactions were observed between species and supplemental additives for pH and CP content except for TSS. The pH of samples for ensiling ranged from 5.82 – 6.37 while the TSS, measured in Brix, ranged from 2.53 – 21.67 °Brix indicating variable amounts of soluble sugar for fermentation. It was highest (19.03 – 21.67 °Brix) for silages with molasses and lowest for sweetpotato alone (2.53). The higher TSS values of silages with molasses compared with other treatments was because of the high TSS of molasses. The highest crude protein (24.81%) was obtained from cassava foliage alone or control treatment (CF) while sweetpotato foliage + Rice Bran had the lowest CP with 9.63%, respectively. According to Ravindran and Ravindran (1988), cassava leaves contain an average of 21% crude protein, and several reports also mentioned that their value ranges from 16.7 – 39.9% (Allen 1984). A lower % CP in sweetpotato foliage was observed compared with other studies which might be due to high stem-to-leaf ratio used in the study since the stem has lower CP (10.4 – 14.1%) than leaves (26.5 – 32.5%) (Woolfe 1992; Ishida et al. 2000; An et al. 2003). Also, CF-based silages have higher pH than that of SP because it has higher CP which influences their buffering capacity to be higher leading to a more restricted fermentation (Kung et al. 2018). The average DM content of cassava and sweetpotato foliage prior to ensiling was 23.63 and 16.34 %, respectively.

Physico-chemical Characteristics of Ensiled Cassava and Sweetpotato Foliage

The physico-chemical properties of cassava and sweetpotato foliage after 21 d ensiling were presented in Table 2. The interaction between species and additives significantly influenced pH and Flieg point of the treatments. The lowest pH was observed from silages

Table 1. Physico-chemical characteristics of ensiled cassava and sweetpotato foliage with or without additives before ensiling.

Parameter	Treatment (Interaction Effects)						Treatment (Main Effects)					SEM	*p*-value		
	Cassava Foliage Silage			Sweetpotato Foliage Silage			Species		Additives				Species x Additive	Species	Additive
	Without additive	Molasses	Rice Bran	Without additive	Molasses	Rice Bran	Cassava	Sweet-potato	Without additive	Molasses	Rice Bran				
pH	6.37^{a}	6.36^{a}	5.98^{b}	6.35^{a}	5.89^{bc}	5.82^{c}	6.24^{a}	6.02^{b}	6.36^{a}	6.13^{b}	5.90^{c}	0.058	< 0.0001	< 0.0001	< 0.0001
TSS	5.20	21.67	6.77	2.53	19.03	4.33	11.21^{a}	8.63^{b}	3.87^{b}	20.35^{a}	5.55^{b}	1.840	0.9874	0.0018	< 0.0001
CP, %	24.81^{a}	16.55^{b}	16.74^{b}	12.40^{c}	13.45^{c}	9.63^{d}	19.37^{a}	11.83^{b}	18.60^{a}	15.00^{b}	13.19^{c}	1.160	< 0.0001	< 0.0001	< 0.0001

Values in the same row followed by different letters are significantly different according to Tukey's test ($p < 0.05$). Abbreviations: TSS, Total soluble sugars; CP, crude protein; *SEM*, standard error of the mean.

Table 2. Physico-chemical characteristics of ensiled cassava and sweetpotato foliage with or without additives.

Parameter	Treatment (Interaction Effects)						Treatment (Main Effects)					SEM	*p*-value		
	Cassava Foliage Silage			Sweetpotato Foliage Silage			Species		Additives				Species x Additive	Species	Additive
	Without additive	Molasses	Rice Bran	Without additive	Molasses	Rice Bran	Cassava	Sweet-potato	Without additive	Molasses	Rice Bran				
pH	5.26^{a}	3.82^{d}	5.21^{a}	4.86^{b}	3.80^{d}	4.33^{c}	4.79^{a}	4.32^{b}	5.10^{a}	3.81^{c}	4.77^{b}	0.13	<0.0001	<0.0001	<0.0001
TSS	10.08	18.60	10.11	5.34	13.73	7.44	12.93^{a}	8.97^{b}	7.90^{b}	16.16^{a}	8.78^{b}	0.92	0.0998	<0.0001	<0.0001
Flieg points/ silage quality	40.99^{e} (Medium quality)	113.38^{a} (Very good quality)	55.70^{d} (Medium quality)	39.88^{e} (Poor quality)	94.9^{b} (Very good quality)	74.13^{c} (Good quality)	70.02	69.63	40.43^{c} (Medium quality)	104.14^{a} (Very good quality)	64.91^{b} (Good quality)	5.74	<0.0001	<0.0001	0.8135
Color	yellowish green	brownish green	yellowish green	brown to black	brown to black	brown to black	-	-	-	-	-	-	-	-	-
Odor	alcohol	slightly sweet	sharp sweet	slightly alcohol	alcohol	slightly alcohol	-	-	-	-	-	-	-	-	-
Texture	good to very good	good to very good	good to very good	poor to moderate	poor to moderate	moderate	-	-	-	-	-	-	-	-	-

Values in the same row followed by different letters are significantly different according to Tukey's test ($p < 0.05$). Abbreviations: TSS, Total soluble sugars; CP, crude protein; *SEM*, standard error of the mean.

made with molasses (pH 3.8) while higher pH values were observed from silages with cassava alone (pH 5.26) and cassava with rice bran (pH 5.21). Sudarman et al. (2016) reported that the addition of molasses at 5 and 10 % significantly reduced pH of ensiled cassava foliage, while the addition of 5 and 10 % rice bran resulted in comparable pH with ensiled cassava foliage. They also stated that the pH values of cassava leaf silage with additives were lower compared with that of control groups without additives.

Significant differences observed in TSS were attributed to the main effects of crop species and additives. Silages made from cassava had the highest TSS (12.93 °Brix) compared to sweetpotato silage (8.97 °Brix). On the other hand, silages with molasses had the highest TSS value (16.16 °Brix) which was significantly higher than the silage without additives (control, 7.90 °Brix) or silage treated with rice bran (8.78 °Brix).

The color of cassava silages ranged from yellowish green to brownish green while sweetpotato silages were generally brown to black in color. Sudarman et al. (2016) also observed that cassava silages with 10% molasses or rice bran were brownish-green in color. Also, Van Saun and Heinrichs (2016) revealed that silages with excess acetic acid are generally yellowish in color while brown to black silage color indicates heating from fermentation and moisture damage.

Results of silage odor evaluation showed that cassava silage had an alcohol scent, while cassava with molasses was slightly sweet, and cassava with rice bran silage had a sharp sweet odor. On the other hand, sweetpotato alone and sweetpotato with rice bran silage manifested a slightly alcoholic scent. While sweetpotato with molasses silage had a distinct alcohol odor. The sharp and sweet smell is indicative of propionic acid fermentation, the alcohol odor suggests high ethanol content due to yeast fermentation (Van Saun and Heinrichs 2016). In terms of texture, cassava silages were generally non-slippery and slightly wet (good to very good) while sweetpotato silages exhibited slimy and wet texture (poor to moderate).

There was a significant difference between species and the addition of additives in the silage in terms of Flieg point. Kilic (2006) as cited by Saricicek (2016) mentioned that Flieg point is a measure of good silage fermentation and the higher value correlates to a good quality of the silage. Saricicek et al. (2016) also mentioned that Flieg point gives information on the quality of corn silage using pH and DM. Also reported that corn silage with DM content of 31.95% and pH 3.84 had an FP of 115 indicating a very good quality corn silage. In this study, cassava silage with added molasses had an FP (113) and a very good quality silage. Higher (> 80%) FP was observed from silages added with molasses indicating very good quality silage, followed by SF silage with rice bran (good quality), and other treatments have low (< 60%) FP which means medium to poor quality silage. Sweetpotato silage without any additive showed the lowest FP, an indication of poor quality silage having a brown to black color and slimy and wet texture. Based on the physical characteristics, SF silage showed inferior quality than CF silage and this can be attributed to the low DM content of the former (14.68%) compared to the latter (24.92%) both without additives. In addition, SF also has low TSS content compared with CF. The DM level of corn suitable for ensiling should be within the range of 30 – 40% and with enough soluble sugar to promote efficient fermentation (PNS/BAFS 2015).

The proximate and detergent fiber compositions of the silages were presented in Table 3. Ensiled cassava foliage showed higher DM ranging from 24.92 – 30.49% compared to sweetpotato foliage silages which had lower values from 14.68 – 21.21% DM. On the other hand, the addition of molasses or rice bran to cassava foliage

Table 3. Proximate and detergent fiber composition of ensiled cassava and sweetpotato foliage with or without additives.

Parameter	Treatment (Interaction Effects)						Treatment (Main Effects)					SEM	*p*-value		
	Cassava Foliage Silage			Sweetpotato Foliage Silage			Species		Additives				Species x Additive	Species	Additive
	Without additive	Molasses	Rice Bran	Without additive	Molasses	Rice Bran	Cassava	Sweet-potato	Without additive	Molasses	Rice Bran				
DM %	24.92	30.49	29.59	14.68	20.97	21.21	28.34^{a}	18.96^{b}	19.80^{b}	25.73^{a}	25.41^{a}	1.17	0.5358	< 0.0001	< 0.0001
OM %	91.19^{a}	91.24^{a}	88.99^{b}	84.53^{d}	87.42^{c}	85.08^{d}	90.47^{a}	85.68^{b}	87.86^{c}	89.33^{a}	87.04^{b}	0.65	< 0.0001	< 0.0001	< 0.0001
Ash %	8.81^{d}	8.76^{d}	11.01^{c}	15.47^{a}	12.58^{b}	14.92^{a}	9.53^{a}	14.32^{b}	12.14^{b}	10.67^{c}	12.96^{a}	0.65	< 0.0001	< 0.0001	< 0.0001
CP %	21.44	18.49	17.24	13.81	10.42	10.61	19.06^{a}	11.61^{b}	17.62^{a}	14.46^{b}	13.93^{b}	0.99	0.1981	< 0.0001	< 0.0001
NDF%	44.09^{c}	30.47^{d}	49.20^{ab}	46.28^{bc}	27.07^{d}	52.03^{a}	41.25	41.79	45.18^{b}	50.62^{a}	28.77^{c}	2.30	0.0104	< 0.0001	0.4866
ADF%	32.40	21.88	38.75	38.30	23.32	42.12	31.01^{b}	34.58^{a}	35.35^{b}	22.60^{c}	40.44^{a}	1.92	0.1723	< 0.0001	0.0019
Hemicellulose	11.69^{a}	8.59^{bc}	10.45^{ab}	7.98^{c}	3.75^{d}	9.91^{abc}	10.24^{a}	7.21^{b}	9.83^{a}	10.18^{a}	6.17^{b}	0.64	0.0033	< 0.0001	< 0.0001

Values in the same row followed by different letters are significantly different according to Tukey's test ($p < 0.05$). Abbreviations: DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; *SEM*, standard error of the mean.

increased the DM from 24.92 to about 30.49%, which was the recommended dry matter for ensiling. In the case of sweetpotato without additives, it has a low initial DM of about 19.80 and the addition of additives increased the final DM of silages to only about 25% DM, which is still below the recommended DM content. Air-drying of sweetpotato vines with leaves for about 20 h did not increase the DM to the recommended level. The addition of molasses (75% DM) and rice bran (89.0% DM) contributed to the higher DM of the mixture.

Consequently, organic matter (OM) was highest in silages made from cassava compared to sweetpotato. High OM values were observed from cassava silage (91.19%) and cassava with molasses silage (91.24%), followed by cassava with rice bran silage (88.99%). Within sweetpotato silages, silage treated with molasses contained significantly more OM (87.42%) compared with those treated with rice bran (85.08%), or control (84.53%). In contrast, the ash content of sweetpotato silages was higher compared to cassava silages. Sweetpotato alone and sweetpotato with rice bran silages contained the most ash with 15.45 and 14.92 %, respectively. Lower ash values were observed from cassava silage (8.81%) and cassava with molasses silage (8.76%). The slightly higher ash content of sweetpotato may be due to soil contamination during collection. An and Lindberg (2004) reported that sweet potato leaves ensiled with molasses had 5.8% ash content.

Cassava silage has a higher CP value (19.06%) than sweetpotato silage (11.61%). Silage without additives (control) regardless of species recorded the highest CP value (17.62%) than other silages with additives which was higher than the findings of Anaeto et al. (2013) having 15.46% CP. According to Lutwama (2016) and Marjuki et al. (2008), cassava silage has higher CP values than sweetpotato silage. Moreover, the CP values of CF silages (17 – 21%) with or without additives were comparable with the values reported by Guadayo et al. (2019) for Rain tree - *Samanea saman* (20.21%), Ipil-ipil - *Leucaena leucocephala* (18.96%) and Kakawate - *Gliricidia sepium* (19.27%); while the CP of SF silages (10 – 13%) was higher than Napier grass - *Pennisetum purpureum* (8.92%), Para grass - *Brachiaria mutica* (6.92%) and Guinea grass - *Panicum maximum* (7.23%).

The NDF, ADF, and hemicellulose fractions of the ensiled materials were important factors to be considered since their concentration and digestibility are key factors in determining the forage intake potential and energy availability (Mertens 2019). In this study, the result showed that the highest values of NDF were observed for silages with added rice bran (49.20% for CF + RB and 52.03% for SP + RB). Similarly, high ADF values were observed for silages supplemented with rice bran (38.75% for CF + RB and 42.12% for SP + RB). This could be partially explained by the high NDF (48.7%) and ADF (32.7%) contents of rice bran which was incorporated at 10% of the silage (PHILSAN 2010). While the lowest values were recorded from treatments added with molasses where NDF for CF + M and SP + M were 30.47 and 27.07 %, respectively.

There were no significant interaction effects between the species and additives for the ADF fractions. On the other hand, significant interaction effects of species and additives were obtained for the NDF fractions. This could indicate that adding molasses and urea in rice straw during silage preparation could enhance the growth of microorganisms capable of hydrolyzing both cellulose and hemicelluloses of the fiber of the ensiling material. The high NDF and ADF values for rice bran-mixed treatments were due to the high NDF and ADF content of rice bran (Rusdy 2015). Similarly, Chanjula et al. (2003) found that rice bran has the lowest ($p < 0.05$) total degradable fraction and effective degradability in beef steers compared to yellow, white, and purple sweetpotato and cassava chips.

Dry Matter Degradibility and Degradation Kinetics of Cassava Foliage Silage

The estimated dry matter (DM) degradation kinetics of the three cassava foliage silages were presented in Table 4 and Fig. 1. All three silage preparations followed the standard non-linear degradation curves wherein most of the degradable fraction disappears from the bag within the first 12 h. The highest rates of degradation for all treatments occurred within the first 3 h of incubation.

There were significant differences in the total degradable fractions (a + b) and effective degradation (ED) with silage supplemented with molasses having the highest value. Silage supplemented with rice bran showed the lowest values for all parameters measured. However, there were no significant differences in the

Table 4. Estimated dry matter degradation kinetics and effective dry matter degradability of different cassava foliage

Parameter	Additive			SEM	*P*-Value
	Control	Molasses	Rice Bran		
a, %	-13.01	-0.95	-16.31	4.90	0.4615
b, %	83.94	82.89	76.00	4.31	0.7705
a+b, %	70.93[b]	81.94[a]	59.69[c]	3.22	< 0.0001
c, %	0.18	0.22	0.24	0.02	0.6100
ED, %	62.66[b]	74.73[a]	53.70[c]	3.05	< 0.0001

Values in the same row followed by different letters are significantly different according to Tukey's test ($P < 0.05$).
a - rapidly soluble fraction; b - potentially degradable fraction; a + b - total degradable fraction; c - constant rate of degradation; ED - effective degradability; SEM, standard error of the mean.

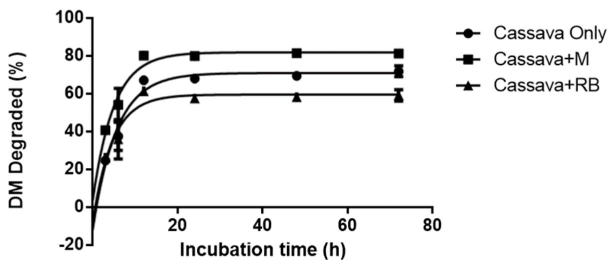

Fig. 1. Dry matter degradation curves of different cassava foliage silages with or without additives.

rapidly soluble fractions (a) among the treatments. Notwithstanding the values for the rapidly soluble fraction for all silages were all negative, this could mean that there was a lag phase. It shows that the DM degradation has an initiation period before the actual degradation begins (Orskov et al. 1980). There were also no significant differences among the treatments in terms of potentially degradable fraction (b) and the constant rate of degradation (c).

The CF + M had the highest (p < 0.001) total degradable fraction (a + b), followed by CF while CF + RB had the lowest. The calculated effective degradability (ED) value was also significantly different among the treatments with CF + M having the highest value (74.73%), followed by CF (62.66%), and then by CF + RB (53.70%). In a study by Brunnen and Givens (1987), the degradability of hay DM in sheep was significantly increased by the addition of up to 200g/kg DM molasses with the largest increase observed between 0 and l00g/kg DM molasses. This could explain why CF + M has the highest (p < 0.001) total degradable fraction (a + b) and effective degradability (ED) among the three treatments. Further, Karimi et al. (2014) stated that adding molasses and urea to the ensiling material during silage preparation could enhance the growth of microorganisms capable of hydrolyzing both cellulose and hemicelluloses of the fiber. The lower values of NDF found in this study led to higher degradability of CF.

The DM degradability has a strong negative correlation with NDF and ADF contents (Ramana et al. 2000), which is why the high NDF and ADF values of rice bran (Chanjula et al. 2003; Rusdy 2015) could also explain why CF + RB had the lowest total degradable fraction (a + b) and effective degradability (ED). In the study of Chanjula et al. (2003), rice bran had the lowest (p < 0.05) total degradable fraction and effective degradability in beef steers compared to yellow, white, and purple sweetpotato and cassava chips. Moreover, the ED values of ensiled CF silages (53 – 74%) were higher than Rain tree (34.20%), Ipil-ipil (40.60%), Kakawate (52.49%) Napier grass (50.32%), Para grass (42.94%), and Guinea grass (36.48%) (Guadayo et al. 2019). The high CP and ED values of CF silages compared with common leguminous feeds and grasses indicate the potential of CF silages as fodder for ruminants.

CONCLUSION

Based on all parameters on silage quality, nutritive value, and dry matter degradability used in this study, CF silage with molasses yielded the best results, suggesting that it could be used as an alternative high protein (18.49%) feed for ruminants. Moreover, it has desirable pH and low fiber fractions (NDF and ADF) resulting in a highly effective dry matter degradability (74%) of the silage.

RECOMMENDATION

Further studies (i.e., feeding trials) are necessary to determine the production performance of ruminants fed with ensiled cassava foliage and sweetpotato foliage. It is also recommended to utilize ensiled cassava as a component of feed and feeding systems through technology commercialization. The preservation of crop by-product like cassava foliage and sweetpotato foliage could provide farmers with alternative feed sources especially during feed scarcity.

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