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In vitro digestibility and nutrient profile of dried and ensiled ripe and unripe plantain peels

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Target Audience: Animal scientists, students, and producers.

Abstract

The experiment was conducted to determine the In-vitro digestibility and nutrient profile of dried and ensiled ripe or unripe plantain peels. The treatments were dried unripe (T_1), ensiled unripe (T_2), ensiled ripe (T_3), and dried ripe (T_4) plantain peels. The fresh peels were collected from processing points in Choba and its environs, dried, crushed and bagged. The fresh peels for silage were wilted overnight, chopped, loaded into silos, compressed and sealed. They were ensiled for 28 days. Samples of the dried and ensiled plantain peels were taken to the laboratory for nutrient composition and in vitro digestion. The results showed significant differences ($P<0.05$) in crude protein, crude fibre, ash, dry matter and nitrogen free extract contents of the treatments. Crude protein content was highest in T_3 (9.26%) and lowest in T_4 (4.29%). Iron, Zinc, and Copper differed significantly ($P<0.05$). The neutral detergent fibre, acid detergent lignin, hemicelluloses, cellulose and non-fibre carbohydrate differed significantly ($P<0.05$). The tannins differed significantly ($P<0.05$) with the highest value in T_3. The methane production, dry matter digestibility, fermentation efficiency, metabolizable energy and organic matter digestibility differed significantly ($P<0.05$). The ensiled ripe and unripe plantain peels are more suitable for feeding ruminants because their crude protein contents were higher than the recommended 7% for ruminants. It will reduce the cost of ruminant production and the environmental pollution caused by indiscriminate dumping of peels.

Keywords: Crude protein, dry matter digestibility, methane production, neutral detergent fibre and tannins.

Description of problem

Globally, there is a wide gap between the demand and supply of conventional feed for livestock (1) especially ruminants. To bridge this gap is the use of non – conventional feed resources (2) like plantain peels. Plantain (Musa paradisiaca) is a staple food in Africa especially in Central and West Africa where it is cherished owing to its variability in the stages of ripeness and in the cooking methods involved (3). In Nigeria, over 2.11 million metric tonnes of plantain is cultivated, produced and consumed (4). Plantain peels are the major by – product of plantain processing industry. It constitutes about 40% of the fruit (5), underutilized and usually thrown away as wastes (6) and as such cause environmental pollution to the society (7). Plantain peels as

reported by (8) contains 6 – 10% CP, 6 – 12% ash, 2 – 6% lipids and 11 – 39% starch whereas (9) observed that it contains about 12% CP, 16% CF and 1300kcal/kg energy on dry matter basis.

Silage is defined (10) as a material produced by controlled fermentation of crops of high moisture content and this is done only under anaerobic condition (11). Silage making offers one option, it secures feeds during seasons of high production for conservation and storage for later use in period of scarcity.

This study is therefore aimed at evaluating the proximate composition and in vitro digestibility of dried and ensiled ripe or unripe plantain peels.

Materials and methods

Location of study

The experiment was carried out in the University of Port Harcourt Research and Demonstration Farm, Choba, Obio/Akpor Local Government Area of Rivers State in the South-South zone of Nigeria. It falls within the humid rain forest zone of West Africa with long duration of rainfall (March - November) and a very short dry season precipitation occurs during September with an average of 367 mm of rain in 182 rain days with a temperature range of 25 - 28^{0}C and a very high relative humidity (above 80 % rainfall (March-November) and a very short dry season precipitation occurs during September with an average of 367 mm of rain in 182 rain days with a temperature range of 25 - 28^{0}C and a very high relative humidity (above 80 %). (12)

Plantain peels

Ripe and unripe plantain peels were collected from processing/selling points identified within and around the University of Port Harcourt campus premises. The ripe and unripe plantain peels were dried under the sun until they become crispy to touch, they were then crushed and bagged for laboratory analysis. Another batch of fresh ripe and unripe plantain peels were allowed to stay overnight, chopped and loaded into a silo, compressed and sealed to prevent air from entering the silo. This was replicated three (3) times. This ensiling process lasted for a period of 30 days, after which the containers were opened and the physical properties such as mouldiness, odour, colour changes and moistness were determined by rating the quantities using the physical characteristics rating scale as shown in Table 1.

Table 1: Physical characteristics rating scale

Scale	Mouldiness	Odour	Colour	Moisture
1	Without mould	pleasant	Light greenish brown	No moisture
2	Slightly mouldy	Fairly pleasant	Greenish brown	Slightly moist
3	Averagely mouldy	Averagely pleasant	Dark brownish green	Averagely moist
4	Highly mouldy	Slightly pungent	Brown	Heavily moist
5	Black spores	Pungent	Dark brown	Completely moist

Source: adapted from (31)

Table 2: Physical properties of the silages.

Silage properties	T_2 (EUPP)	T_3 (ERPP)
Colour	1	4
Moisture	2	3
Odour	3	1
Mouldiness	2	1

EUPP=Ensiled unripe plantain peels. ERPP= Ensiled ripe plantain peels.

Table 3: Proximate composition of samples

	Treatments				
Ingredients(%)	1 (DUPP)	2 (EUPP)	3 (ERPP)	4 (DRPP)	SEM
Dry matter	87.34[a]	86.06[b]	87.83[a]	85.21[c]	0.32
Crude protein	4.78[c]	7.86[b]	9.29[a]	4.29[d]	0.63
Fat	3.76	3.43	3.93	3.59	0.10
Crude fibre	13.48[a]	11.31[c]	13.67[a]	12.06[b]	0.31
Ash	5.11[a]	4.31[b]	5.24[a]	4.69[ab]	0.14
NFE	60.21[a]	59.13[b]	55.70[c]	60.24[a]	0.57

[abc]Means in the same column with different superscripts are significantly ($P<0.05$) different. DUPP= Dried unripe plantain peels, EUPP= Ensiled unripe plantain peels, ERPP= Ensiled ripe plantain peels, DRPP= Dried ripe plantain peels. NFE= Nitrogen free extract.

The treatments are: Dried unripe plantain peels (T_1), Ensiled unripe plantain peels (T_2), Ensiled ripe plantain peels (T_3) and Dried ripe plantain peels (T_4). Crude protein content was determined using Kjeldahl method of nitrogen determination. Ether extracts (EE) were determined using the soxhlet extractor. Crude fibre (CF) was determined using the weende's method and nitrogen free extract was determined by adding crude protein, fat, water, ash, and fibre and the sum subtracted from 100, the difference is NFE = DM– (%Moisture + %CF + %CP + % EE + %Ash. The anti-nutritional factors (saponin, tannin and phytate) and the mineral content (calcium, potassium, sodium, magnesium and phosphorus) were also analysed. The presence of Tannins was determined by adding 2ml of 5% ferric chloride to plant extract, the presence of saponin was determined by the addition of 2ml distilled water to plant extract and shaken in a graduated cylinder for 15minutes and phytate was determined by adding equal volume of chloroform to plant extract and subjecting with few drops of concentrated sulphuric acid. Sodium, potassium, calcium and magnesium were determined with an automatic atomic absorption spectrophotometer and total phosphorus was determined spectrophotometrically after incubation with molybdo-vanadate solution (13).

Rumen Liquor Collection for *in Vitro* Study

Rumen liquor was collected from goats housed at the University of Benin Teaching and Research farm, Ugbowo Campus, Benin City. The collection was via stomach tube. The liquor was collected in the early hours of the morning into a pre warmed flask prior to feeding the animals. The flask containing the rumen liquor was taken to the laboratory where

it was strained through four layers of cheese cloth. The strained liquor was mixed with a buffer solution in a ratio of 1:2. This mixture was put in a water bath and gassed with CO_2 to maintain anaerobic condition and a temperature of 39°C to keep the microorganisms alive.

Table 4. Mineral analysis of samples

	Treatments				
Minerals	**1 (DUPP)**	**2(EUPP)**	**3(ERPP)**	**4 (DRPP)**	**SEM**
% Sodium (Na)	0.17	0.14	0.18	0.15	0.01
% Potassium (K)	0.39	0.33	0.40	0.35	0.04
% Calcium (Ca)	0.12	0.09	0.13	0.11	0.02
% Phosphorus (P)	0.23	0.20	0.24	0.22	0.02
Iron (Fe) (mg/kg)	1.32^{b}	1.24^{d}	1.33^{a}	1.29^{c}	1.12
Zinc (Zn) (mg/kg)	2.54^{b}	1.83^{d}	2.66^{a}	2.25^{c}	0.97
Copper (Cu) (mg/kg)	5.20^{b}	3.10^{d}	6.30^{a}	4.30^{c}	0.36

^{abc}Means in the same column with different superscripts are significantly (P<0.05) different. DUPP= Dried unripe plantain peels, EUPP= Ensiled unripe plantain peels, ERPP= Ensiled ripe plantain peels, DRPP= Dried ripe plantain peels.

Table 5: Anti nutritional factors of the samples

	Treatments				
Anti nutritional factors (%)	**1(DUPP)**	**2(EUPP)**	**3(ERPP)**	**4(DRPP)**	**SEM**
Phytate	0.10	0.07	0.10	0.08	0.10
Oxalate	0.08	0.05	0.09	0.07	0.009
Tannin	0.0028^{b}	0.0016^{b}	0.034^{a}	0.0021^{b}	0.0043
Saponin	0.25	0.21	0.26	0.23	0.03

^{abc}Means in the same column with different superscripts are significantly (P<0.05) different. DUPP= Dried unripe plantain peels, EUPP= Ensiled unripe plantain peels, ERPP= Ensiled ripe plantain peels, DRPP= Dried ripe plantain peels.

Table 6: Fibre fraction analysis of the samples

	Treatments				
Fibre fraction (%)	**1(DUPP)**	**2(EUPP)**	**3(ERPP)**	**4(DRPP)**	**SEM**
NDF	52.67^{a}	48.35^{c}	53.16^{a}	51.88^{b}	0.57
ADF	40.79	32.92	41.25	55.44	4.28
ADL	13.87^{a}	11.18^{c}	14.28^{a}	12.69^{b}	0.37
Hemicellulose	1.19^{c}	1.58^{a}	1.19c	1.31^{b}	0.48
NFC	3.37^{b}	3.61^{a}	3.56^{a}	2.84^{c}	0.92
Cellulose	2.71^{a}	2.14^{c}	2.70^{ab}	2.61^{b}	0.71

^{abc}Means in the same column with different superscripts are significantly (P<0.05) different. DUPP= Dried unripe plantain peels, EUPP= Ensiled unripe plantain peels, ERPP= Ensiled ripe plantain peels, DRPP= Dried ripe plantain peels. NDF= Neutral detergent fibre, ADF= Acid detergent fibre, ADL= Acid detergent lignin, NFC= Non-fibre carbohydrate.

Table 7: I*n vitro* gas production characteristics for the different treatments

Treatment	9hrs (ml)	12hrs	15hrs	18hrs	21hrs	24hrs	Methane	DMD	FE	ME	OMD	SCFA
1 (DUPP)	1.33^{b}	4.67^{b}	5.33^{b}	6.00^{b}	10.67^{b}	12.00^{b}	8.00^{b}	17.02^{b}	1.43^{b}	4.12^{b}	3.09^{b}	0.23^{b}
2 (EUPP)	3.33^{ab}	7.33^{a}	9.33^{a}	11.33^{a}	16.00^{a}	17.33^{a}	10.67^{a}	25.73^{a}	1.49^{b}	5.01^{a}	3.65^{a}	0.35^{a}
3 (ERPP)	3.33^{ab}	4.67^{b}	6.67^{ab}	6.67^{b}	9.33^{b}	11.33^{b}	8.00^{b}	19.29^{b}	1.69^{ab}	4.27^{b}	3.24^{b}	0.21^{b}
4(DRPP)	5.33^{a}	6.00^{ab}	6.67^{ab}	6.67^{b}	10.00^{b}	11.33^{b}	7.33^{b}	26.08^{a}	2.44^{a}	3.99^{b}	2.99^{b}	0.21^{b}
SEM	0.56	0.41	0.58	0.69	0.89	0.91	0.50	1.33	0.16	0.14	0.87	0.02

^{abc} Means in the same column with different superscripts are significantly (P<0.05) different. DUPP: Dried unripe plantain peels, EUPP: Ensiled unripe plantain peels, ERPP: Ensiled ripe plantain peels, DRPP: Dried ripe plantain peels. DMD: Dry matter digestibility, OMD: Organic matter digestibility, FE: Fermentation efficiency. ME: Metabolizable energy. SCFA: Short chain fatty acids.

Buffer Preparation

The buffer was prepared a day before rumen liquor collection and maintained at a pH of 6.2 (14) and temperature of 39^{o}C. The buffer used consist of the following reagents: Na_2HPO_4. $12H_2O$ 1.985g/l, KH_2PO_4 1.302g/l, $MgCl_2.6H_2O$ 0.105g /l, NH_4HCO_3 1.407g /l, $NaHCO_3$5.418g /l and NaOH ,0.100g/l.

***In Vitro* Fermentation of Samples**

The *in vitro* incubation was carried out using 120 ml calibrated syringes containing the inoculums (Rumen liquor: buffer, 1:2). 200 mg of substrate was weighed into nylon bags for the incubation at 39ºC with 30 ml of inoculums. 0.1g of each sample was added prior to sealing the bags. The bags were placed inside the syringes before the inoculum was introduced into the syringes. The syringes were fitted with silicon tube and clipped before placing them in the incubator at 39°C. The syringes containing only inoculum served as the blank while the bags containing only the substrate served as the control. The time for the commencement of incubation was noted and the syringes were monitored at three-hour intervals for the next 24 hours. For each incubation time, the head-space of the syringes was measured and recorded. At 24 hours of incubation, the final readings were taken and the syringes put on ice to stop further gas production.

Determination of Post *in Vitro* Parameters (DMD, FE, SCFA, ME and OMD)

The sealed nylon bags containing the sample were taken out from the syringes, washed with water and oven dried at 100°C to constant weight and the dry matter determined expressed as the percentage of the original sample weighed to calculate dry matter digestibility (DMD) .

$$DMD\ \% = \frac{\text{Wt of sample before incubation} - \text{Wt of sample after incubation}}{\text{Wt of sample before incubation}} \times 100$$

The Fermentation Efficiency (FE) and effect of methane reduction (CH_4%) were calculated using the following formulas

$$\text{Fermentation Efficiency (FE)} = \frac{\text{Dry matter Digestibility (g/kg)}}{\text{Total Gas Volume (mL/g)}}$$

The post incubation parameters such as metabolisable energy (ME), Organic matter digestibility (OMD), Gas volume and Short chain fatty acids (SCFA) was estimated using the equation below:

ME= 2.20 + 0.136 GV + 0.057 CP + 0.00029 CF (15).

OMD = 14.88 + 0.88 GV + 0.45 CP + 0.651 XA (15).

SCFA = 0.0239 GV – 0.0601 (16), where

GV, CP, CF and XA are total gas volume, Crude protein, Crude Fibre and ash of the incubated samples respectively.

Experimental design: The study was conducted using a completely randomized design (CRD) .

Chemical analysis: Samples of the silages were analyzed for proximate composition using the general procedures of (17) while detergent fibre was determined by the procedures of (18).

Statistical Analysis: The data obtained in this study were subjected to one way analysis of variance (ANOVA). Difference between means was determined using Duncan's multiple range test (19) using the Statistical Package for Social Sciences (SPSS) software.

Results

The physical characteristics of the ripe and unripe plantain peel silages

The result on the physical quality of the ripe and unripe plantain peel silages is shown in Table 2. For the ensiled unripe plantain peel (EUPP), the colour was light greenish brown, slightly moist, averagely pleasant odour and slightly mouldy. The ensiled ripe plantain peel was brown in colour, averagely moist, had a pleasant odour and without mould.

The result on the proximate analysis of dried and ensiled ripe and unripe plantain peels is shown in Table 3. The result revealed that crude fat did not differ significantly (P>0.05) for all treatments, while the crude protein, crude fibre, ash, dry matter and nitrogen free extract differed significantly (P<0.05) for all treatments. The highest crude protein was recorded in treatment 3; the highest crude fibre was recorded in both treatment 1 and treatment 3. The highest dry matter and nitrogen free extract was recorded in T_4, T_1 and T_4 respectively.

The result on mineral analysis is shown in Table 4. The results showed that there is no significant difference (P>0.05) between Na, K, Ca, and P for all the treatments while Fe, Zn, and Cu differed significantly (P<0.05) in all the treatments.

The result on anti-nutritional factors is shown in Table 5. The result showed that there is no significant difference (P>0.05) in phytate, oxalate and saponin for all the treatments, only the tannin differed significantly (P<0.05) for all the treatments.

The result on fibre fraction analysis is shown in Table 6 below. The result showed that there is no significant difference (P>0.05) in the acid detergent fibre for all the treatments. The neutral detergent fibre, acid detergent lignin, hemicelluloses, cellulose and non-fibre carbohydrate differed significantly (P<0.05) for all the treatments.

The result on *in vitro* gas production parameters is shown in Table 7. The results showed the *in vitro* gas production at different time intervals and the methane production levels for the different treatments at post-incubation. The table shows significant difference (P<0.05) in the gas production, methane, dry matter digestibility, fermentation efficiency, metabolizable energy, organic matter digestibility and the short chain fatty acids.

Discussion

The crude protein of the ensiled ripe plantain peels (T3) was highest (9.29%), followed by that of the ensiled unripe plantain peels (T2) (7.86%) showing that they can serve as feed for ruminants because their crude protein contents are above the recommended 7% crude protein requirement for ruminants (20). The dried ripe (T_4) and unripe plantain peels (T_1) showed 4.29% and 4.78% crude protein, respectively. The ensiling process, which is known to conserve more nutrients than drying, could have resulted in higher crude protein as silages have been reported to conserve about 75% of the nutrients in the

fresh samples (11). The crude protein content of 4.29% reported for dried ripe plantain peels in this study was lower than that (7.85%) reported for the same plantain peels by (21) and that (6.69%) reported by (22) for dried ripe plantain peels. The crude protein content of 4.78% reported in this study for dried unripe plantain peels is higher than that (2.93%) reported by (22) but lower than that (7.89%) reported by (5) for dried unripe plantain peels. Ensiled ripe plantain peels and dried unripe plantain peels had the highest crude fibre contents of 13.67% and 13.48%, respectively. The crude fibre content of the dried unripe plantain peel is higher than the 2.53% reported by (22). Ensiled ripe plantain peels had the highest ash content of 5.24% and this is comparable with 5.72% reported by (5) but lowers than 17.96% reported by (21). Dried ripe plantain peels had the highest nitrogen free extract of 60.24%, which is higher than the nitrogen free extract of 38.52% reported by (21). The differences in the nutrient composition of plantain peels can be due to differences in sampling, procedures employed during analysis (23), stage of growth, soil type, maturity, environment and differences in variety (24).

Ensiled ripe plantain peels had the highest iron content of 1.33mg/kg and this is lower than that (3.2mg/kg) reported by (5). Ensiled ripe plantain peels had the highest zinc content of 2.66mg/kg which is lower than that (3.10mg/kg) reported by (22) for ripe plantain peels. (25) showed that there is significant increase of minerals as unripe banana or plantain ripens especially in calcium and phosphorus. This agreed with the result obtained for ensiled ripe plantain peels in this study.

Tannins are the main anti-nutritional factors of banana and are mostly contained in the peels. (8). The ensiled ripe plantain peels had the highest value for tannin (0.034%). This is in contrast with what was reported by (8) that ripening causes the tannins to migrate to the pulp or to be degraded by polyphenol oxidases and peroxidases in banana peels and (26) also reported that the tannin content of the peel which act against the availability of proteins in the rumen decreases with ripening as a consequence of a migration of the polyphenols from the peel towards the pulp and the phenolic oxidative degradation by polyphenol oxidases and peroxidases. Generally, all the treatments in this study had their tannin contents below the 2% tannin level reported (27) to have adverse effects on digestibility in sheep and goats.

Fibre fractions that contribute to the nutritional value of the feed are the NDF and ADL (8). The ensiled ripe plantain peel had the highest NDF value of 53.16% and this agreed with the reports of (8) who indicated that ripeness results to higher NDF and ADL fractions.

Digestibility can be estimated from *in vitro* gas production, which has the advantage of not only being less expensive but less time consuming too (28; 29). Neutral detergent fibre of the samples was high and this caused increase in gas production. Methane production is energy loss to ruminants and is one of the main greenhouse gases that contribute to global warming (30). The total gas production, methane production, DMD, ME, OMD, and the SCFA of treatment 2 (ensiled unripe plantain peel) were the highest, green plantain peels generally tend to be of higher value than at the ripe stage but coupled with the ensiling of the green peels, it increased the gas production, methane production, DMD, ME, OMD, and the SCFA of treatment 2. As reported by (8), the changes in the CHO composition of the peels are also reflected in the SCFA profiles after fermentation. SCFA are important to consider as they contribute extensively to the energy supply of the animal. Propionate proportion increased slightly with maturation, whereas

that of the butyrate decreased significantly. This reduction is likely related to starch hydrolysis during maturation, as starch is known to favour butyrate-producing microbes. With higher ME content and butyrate-production, green peels show thus a greater interest as ingredient for ruminants especially in dairy production, as butyrate is the main precursor in the synthesis of milk fat.

Conclusion and Application

This study revealed that:

1. The ensiled ripe and unripe plantain peels are more suitable as feedstuffs for ruminants because they have crude protein contents that are higher than the recommended 7% for ruminants.
2. The ensiled ripe plantain peels also proved superior to others in terms of the minerals (Fe and Zn).
3. All the treatments in this study have tannin levels below the 2% tannin level that has been reported to have adverse effects on digestibility in sheep and goats
4. The usage of plantain peels to feed ruminants will on the long run reduce the environmental pollution caused by the indiscriminate dumping of plantain peels.

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