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Bromatological Analysis and Digestibility of Rubber Seed Hulls Treated with Various Plant Ash Extract in Rabbits Ration

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Abstract

In recent decades, researchers have turned to phytobiotics and agricultural by-products in response to the nuisance caused by antibiotics and the frequent rise in raw material prices, in order to guarantee safety and profitability of consumers and intensive livestock farming respectively. This study was carried out to determine bromatological analysis and digestibility of rubber seed hulls treated with various plant ash extract in rabbits ration. At the beginning of the trial, the dry leaves of banana-plantain and bean-tops harvested from vicinity of the University of Dschang Research Farm (UDRF), the ashes will be obtained after calcination of plantain leaf and bean-tops. The extracts will be obtained after soaking ash for 48 hours at different concentrations (7.5; 10; 12.5 kg per 100 L of water). The hulls will be soaked for 12 hours in these ash extracts, then sundried, ground and incorporated into feed intake. Forty adult rabbits of local breed, 6 to 7 months old and weighing 2500 g on average were used for digestibility test and were divided into 8 batches of 5 animals each, receiving the following rations: CNH (Control-N-Hulls), CUH (Control 20 % Untreated-Hulls), $B_{7.5}$, B_{10}, $B_{12.5}$, $H_{7.5}$, H_{10} and $H_{12.5}$ (containing 20 % hulls treated with different ash concentration extracts). Data collected were subjected in a two-ways analysis of variance according to the test method. The results showed that with the exception of NDF, all other parameters were significantly ($P < 0.05$) affected by extracts of banana-plantain leaf ash and bean-tops on the bromatological composition of rubber hulls. Concerning feed intake, animals fed the CNH ration had significantly ($P < 0.05$) higher crude protein and crude fibre levels compared with the CUH ration and the other treatments. Banana leaves ash-plantain extracts induced comparable effects to those of bean-tops extracts whatever the dose and treatment considered, with the exception of crude protein at 10 and 12.5%, with a higher tendency for the bean-tops treatments. The apparent digestibility of animals fed with CNH diet produced significantly ($P < 0.05$) higher values than those fed the CUH diet for all parameters except organic matter. There was a significant ($P < 0.05$) linear increase in digestibility values with increasing ration rates, whatever the type of treatment. From the above, therefore it can be concluded that treating rubber seed hulls with banana-plantain leaves and bean-tops ash extracts improved digestibility in rabbits.

Keywords

Ashes, Bromatological Composition, Digestibility, Extracts, *Hevea*, Rabbit, Rubber Tree Hulls

1. Introduction

With a view to securing more income and covering the protein need of populations, animal industry, especially rabbits is constantly seeking the best performance [1]. To achieve this, feed which represents 60%~70% of production costs, remains the principal lever for success in intensive breeding [2] [3]. In herbivorous monogastrics such as rabbits, feed can be made up essentially of forage [4]. However, this feeding method is generally reserved for small-scale farm, due to the difficulties associated with fodder conservation, fermentation and the presence of mycotoxines produced by moulds [5]. In order to ensure a balanced gut microbiota while promoting the development of digestive tract, with a positive consequent improvement in production performance, animals must be fed a balanced diet, both qualitatively and quantitatively, with a fiber content of 14%~16% [6] [7]. However, the low avaibility of good sources of cellulose other than fodder, main source of fiber in herbivorous animals, is still a hindrance to the implementation of large-scale cunicolous livestock farming. The valorization of agricultural by-products such as rice straw, cocoa hulls, Hevea seed hulls in feed is an absolute priority [8].

The rubber tree, Hevea brasiliensis, is a member of the Euphobiaceae family. Generally cultivated for its latex, which is then transformed into rubber, it originated in Brazil and has been introduced throughout the world. In Cameroon, there are almost 55,000 ha of rubber trees spread over several towns (Edéa, Souza, Ebolowa, Kribi, Eséka, Dibombari, Memen, kumbo, tombot, tiko, limbé and Kienké) with an average production of 150 kg of seeds per hectare per year [9], or 8250 tonnes of seeds produced per year, of which only 10% are used for nursery purposes. These seeds contain 25% moisture, 40% kernels and 35% shell [10], or around 2887.5 tonnes of hulls produced. In recent years, rubber tree seeds have been the subject of several studies, and authors agree that rubber seed hulls or their meal can be used as a source of protein in animal feed [11] [12]. The use of these almonds, although on a small scale, produces a significant quantity of hulls, which will increase as its use becomes more widespread. Unfortunately, almost all the hulls produced are abandoned. However, this hull could be a significant source of cellulose for herbivorous monogastric animals. Hulls contain 66.4% hemicellulose, 25.8% cellulose and 0.1% ash, and are used to produce bio-oil [13] and biochar [14]. Their use in animal feed is hampered by the rigidity of its wall, which could greatly reduce its ingestion and digestibility [15]. Several methods have been developed to improve the digestive utilization of such components, including treatment with alkalis ($NaOH$, $Ca(OH)_2$, NH_3). The latter are effective, because they weaken the existing bonds between the various cell wall components and improve feed digestibility [16]. But their high price has led researchers to consider other alternatives. One such alternative is ash, which is cheaper and available in almost every household in Cameroon. Ash is a residue obtained after the combustion of various organic materials [17], such as wood, paper and crop residues (bean tops, banana leaves). In a book published in [18], it shows that the digestibility of straw increases with increasing NaOH concentration, obtaining a digestibility of 46% for untreated straw as well as for straw treated with 2% NaOH, and a digestibility of 71% for straw treated with 12% NaOH. They obtained a digestibility of 46% of organic matter for untreated straw, 68% for straw treated for 3 hours, 71% for straw treated for 12 hours and 73% for straw treated for 3 days. [19] showed that treatment of rice straw with bean ash and banana leaves extract at concentrations of 50 g and 100 g per liter of water for 12 h increased *in-vitro* dry matter digestibility in small ruminants. On the other hand, at a concentration of 150 g per liter of water, these parameters declined. In view of this previous work, the effectiveness of alkaline treatment depends on: the nature of the compound to be treated, the duration of treatment, the concentration of the alkaline solution and the treatment temperature. Thus, the treatment of rubber tree hulls with ash extracts could improve the digestibility of the feed in which these hulls are incorporated. It is to verify this hypothesis that the present work was initiated, with the general aim of contributing to the improvement of knowledge on harvest residue treatment methods and improving animal productivity through their valorization in animal feed. Specifically, it aims to evaluate:

1) Effect of different sources and concentrations on mineralogical composition of ash extracts and rubber hulls before and after soaking;

2) Effect of source and ash extract concentration on the bromatological composition of rubber seed hulls;

3) Effect of source and ash extract concentration on feed intake and apparent digestibility of nutrients.

2. Material and Methods

2.1. Study Area

This study was carried out at the Teaching and Research Farm (TRF) of the University of Dschang, located at 05˚26′ North latitude, 10˚26′ East longitude and at an altitude of 1420 m. The prevailing climate is equatorial, characterized by two seasons. A rainy season lasted from March to November and a dry season covers the rest of the year. Rainfall varies between 1500 and 2000 mm per year. The average temperature is around 21˚C, the average annual insolation is 1837 hours and the average relative humidity is 76.8%.

2.2. Experimental Rabbits

Forty adult rabbits of local breed, 6 to 7 months old and weighing 2500 g on average were used in this study for a period of 15 days including 10 days of adaptation and 5 days of data collection. They were randomly assigned following a completely randomized design to 8 treatments replicated 5 times with 1 rabbit each. Water and feed were provided *ad libitum* to the rabbits.

2.3. Plant Material and Experimental Rations

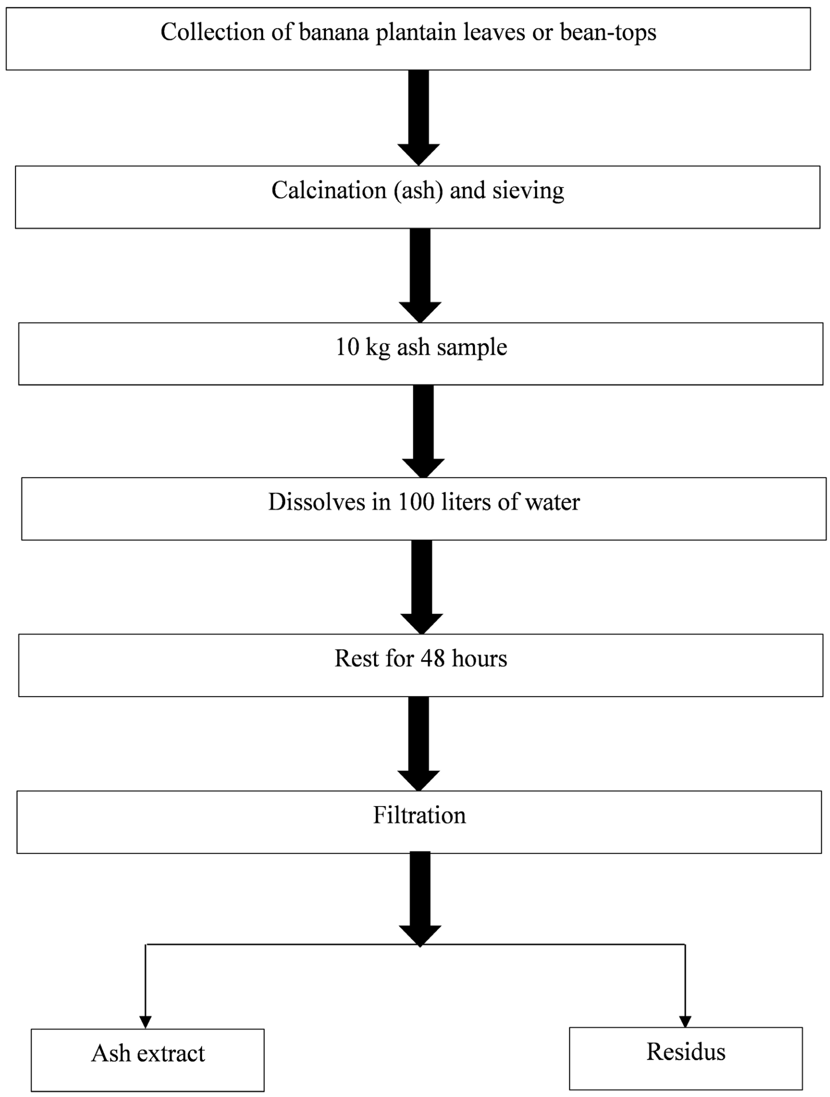

Figure 1. Steps for preparing ash extracts.

Fresh rubber seed bark were harvested from the rubber tree plantations of Societe Camerounaise de palmeraies (SOCAPALM) in Moungo Department, Littoral Region. They were shelled and subjected to various treatments. The processed hulls were then sun-dried to a constant weight, ground using a mill, stored in hermetically sealed bags, until their use in experimental rations. Powder samples were analyzed according to AOAC (2000) methods, to determine their bromatological composition (ADF, NDF, crude cellulose, crude protein, lipid, dry matter, organic matter and ash).

Ash extracts were prepared as described by Rahhman *et al.* (2009). Dry leaves of banana plantain (*Musa paradisiaca vargiant French*) were harvested from FAR plots, along with red kidney bean (*Phaseolus vulgaris*) tops. They were incinerated to obtain ash. Solutions were prepared by dissolving for 48 hours. 7.5, 10 and 12.5 kg of ash previously sieved in 100 L of water or 7.5, 10 and 12.5 (weight/volume)%. These solutions were filtered through a piece of cloth with a double layer of cotton to obtain the ash extracts. experimental rations consisted of CNH (Control-No-Hulls), CUH: (Control ration with 20% untreated-hulls), $B_{7.5}$, B_{10}, $B_{12.5}$, $H_{7.5}$, H_{10} and $H_{12.5}$ (containing 20% hulls treated with different ash concentration extracts). The steps for preparing ash extract with a concentration of 10 kg per 100 liters of water are shown in the following diagram (Figure 1, Table 1).

Table 1. Composition of experimental rations.

Ingrédients (%)	Rations							
	CUH	CNH	$B_{7.5}$	B_{10}	$B_{12.5}$	$H_{7.5}$	H_{10}	$H1_{2.5}$
Yellow corn	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00
Wheat bran	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Hevea shells	**20.00**	**0.00**	**20.00**	**20.00**	**20.00**	**20.00**	**20.00**	**20.00**
Trypsacum laxum	0.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00
Cotton cakes	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Soyabean meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Palm kernel cake	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
Fish meal	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Oeyster	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Palm oil	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Premix 0.5 %	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Bromatological characteristics of experimental rations								
Crude protein (% MS)	14.57	15.10	14.57	14.44	14.40	14.37	14.43	14.46
Digestible energy	2316.75	2350.15	2306.86	2306.66	2309.45	2306.26	2306.66	2313.21
Crude Fiber (% MS)	13.71	13.72	13.02	13.75	13.70	13.76	13.77	13.69

Note: CMAV 0.5% meat: Mineral, nitrogen and vitamin complex: Crude protein = 40%, Lysine = 3.3%, Methionine = 2.40%, Calcium = 8%, Phosphorus = 2.05%, Metabolisable energy = 2078 Kcal/kg.

2.4. Hevea Shell Processing

The hulls obtained were divided into 7 batches, a first batch which underwent no treatment and 6 other batches which were soaked for 12 hours in an ash extract solution of concentration 7.5, 10 and 12.5 kg per 100 liters of water, or 3 batches for ash extracts from bean tops and 3 others for those from banana plantain leaf. The treated hulls were dried and ground, and the powder obtained was analyzed for bromatological composition. The following diagram illustrates the hull processing stages (Figure 2).

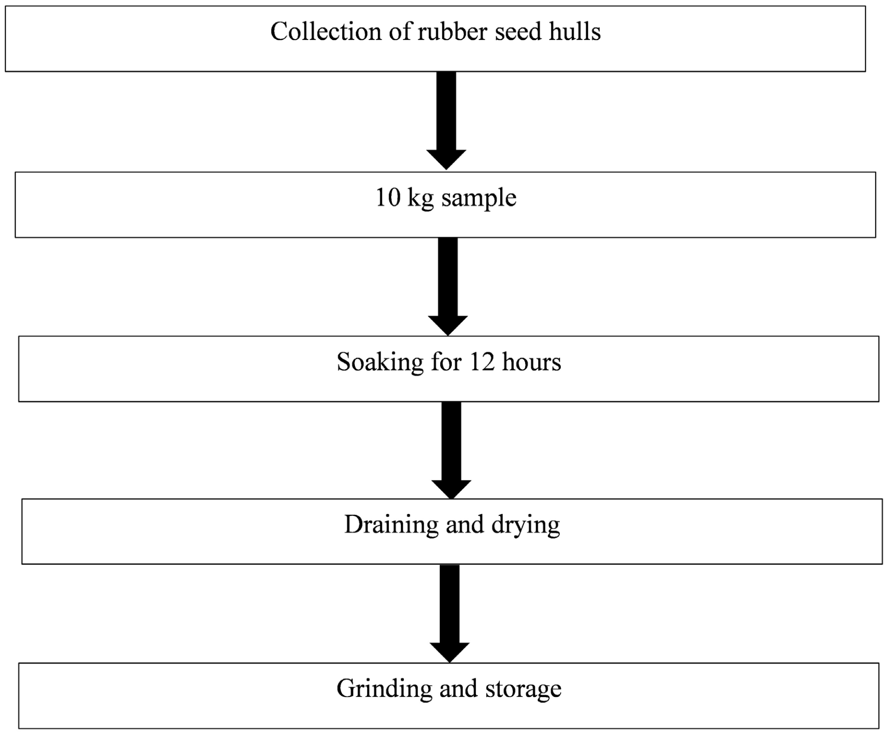

Figure 2. Steps for processing Hevea seed hulls.

2.5. Housing and Prophylaxis

The animals were housed in batteries of wire cages made of galvanized metal, measuring 97 cm long, 46 cm wide and 26 cm high, and placed in a hard-built building topped a third by wire mesh. The building was well ventilated, with natural lighting. Each cage was equipped with a feeder and a drinking trough. The digestibility device consisted of a cage lined with mosquito netting to collect faeces, topped with plastic to trap urine, which flowed directly into a bottle containing sulphuric acid.

An anti-stress was given in drinking water during the first 3 days after the rabbits' arrival and after each handing. An anti-coccidian [Vetacox®] and vitamins [AMINTOTAL®] were given through drinking water on 3 consecutive days each week. The animals were dewormed by subcutaneous injection of Ivermectin® at 0.2 ml/kg body weight.

2.6. Parameters Studied and Data Collected

2.6.1. Digestibility Test

The trial was conducted in two periods:

1) A period of adaptation of the animals to the digestibility cage and the experimental rations lasting 10 days.

2) A five-day digestibility period. During this period, rations were weighed and served in the morning between 8 and 9 am. Water was provided *ad libitum* and renewed daily. Each morning, the refusals and faeces of each animal were collected and weighed using a FS-400 digital balance with a sensitivity of 1 g and a maximum capacity of 7.000 g.

25 g of faeces collected from each subject were oven dried at 60˚C to a constant weight for bromatological analysis to determine dry matter (DM), organic matter (OM), crude fiber (CF) by the Scheerer method, crude protein by the Kjedhal method [20], and neutral detergent fibre (NDF) by the method of [21]. The apparent digestive utilization coefficients (CUDa) of nitrogen, NDF, OM and CF of the experimental rations were calculated according to the formula:

$$CUDa = \frac{Qty\,ingereted\left(g\right) - Qty\,excreted\left(g\right)}{Qty\,ingereted\left(g\right)} \times 100$$

The dried faeces were then weighed again, ground with a moulinex and used to determine the bromatological composition. Similarly, the urine produced by each animal was collected by means of containers connected to the digestibility device, into hich 10% concentrated sulfuric acid (H_2SO_4) was previously introduced according to the average volume of urine produced by each animal during the adaptation period (2.5 ml of concentrated sulfuric acid for 100 ml of urine), in order to stabilize the urinary nitrogen. The urine collected was measured every morning in a 500 ml graduated cylinder, and 10 ml was syringed into test tubes and used for the determination of urinary nitrogen in nutrition laboratory.

For the duration of the trial, the animals in the various batches were given unlimited quantities of drinking water and one of the experimental rations CNH, CUH, $B_{7.5}$, $B_{10,}$ $B_{12.5}$, $H_{7.5}$, H_{10} and $H_{12.5}$. The experimental rations are as follows:

CNH: control-No-Hulls

CUH: control ration with 20% untreated-hulls

$B_{7.5}$: Ration with 20% of hulls treated with plantain leaves ash extracts at a concentration of 7.5 kg per 100 liters of water

B_{10}: Ration with 20% of hulls treated with plantain leaves ash extracts at a concentration of 10 kg per 100 liters of water

$B_{12.5}$: Ration with 20% of hulls treated with plantain leaves ash extracts at a concentration of 12.5 kg per 100 liters of water

$H_{7.5}$: Ration with 20% of hulls treated with bean tops ash extracts at a concentration of 7.5 kg per 100 liters of water

H_{10}: Ration with 20% of hulls treated with bean tops ash extracts at a concentration of 10 kg per 100 liters of water

$H_{12.5}$: Ration with 20% of hulls treated with bean tops ash extracts at a concentration of 12.5 kg per 100 liters of water

2.6.2. Feed Intake (FI)

The feed was previously weighed and distributed daily to the animals. At the end of each week, refusals were collected and weighed. Feed consumption was calculated as the difference between the quantities served and the refusals collected in each of the experimental units.

$$FI = quantities\ served - refusals\ collected$$

2.7. Choice of Concentrations Used

They concentrations used in the present study were based on previous studies and the results obtained by these authors.

[19] Effects of treatment with ash extracts of banana-plantain leaf and bean-tops on rice straw digestibility in small ruminants.

Effects of Treatment of Cocoa Pod Husks with Aqueous Ash Extract of Bean Haulms on Growth Performance and Haemato-Biochemical Parameters of Rabbits.

2.8. Statistical Analysis

All data collected were submitted to two-way analysis of variance (ANOVA). In case of a significant differences between treatments groups, Duncan's multiple range test was used to separate mean at the 5% significance difference. The statistical software SPSS 20.0 (Statistical Package for Social Science) was used for the analyses.

In this trial, the device was the 2 × 3 factoiel (2 types of ash extracts and 3 incorporation rates).

$$X_{ijk} = \mu + \alpha_i + \beta_i + e_{ijk}$$

X_{ij} = Observation on animal k having received treatment *ij*

μ = Overall mean of the observation

α_i = Effect of the type of ash extract i, i varying from 1 to 2

β_i = Effect of the rate of incorporation of incorporation rates *j*, *j* varying from 1 to 3

e_{ij} = Residual error due to animal k having received treatment *i*

3. Results

3.1. Mineral Composition of Ash Extracts from Banana-Plantain Leaves and Bean-Tops before and after Soaking Rubber Hulls

Table 2 summarises the Mineral composition of ash extracts from banana-plantain leaves and bean-tops before and after soaking rubber hulls. The table shows that, the mineral concentration of extract solutions decreased after soaking, whatever the nature and concentration of the extract in question. The pH of the various ash extract solutions also fell after treatment of the rubber seed hulls.

Table 2. Mineral composition of ash extracts from banana-plantain leaf and bean-tops before and after soaking rubber hulls.

Minerals and pH-meter	Extract types	Mineralogical composition of ash extracts (mg/100 g DM)						Mineralogical composition of hulls (mg/100 g DM)				Percentage increase		
		AE 7.5		AE 10		AE 12.5		CUH	TH7.5	TH10	TH12.5	7.5	10	12.5
		BT	AT	BT	AT	BT	AT							
Ca	Bean-top	2731	2626	2774	2332	2860	2729	224	321	340	371	43.3	51.7	65.625
	Banana-leaf	2778	2575	2858	1556	2890	2458	224	371.84	468	477.12	66	108.9	113
K	Bean-top	1788	1670	2358	2123	2482	1780	7	14.32	14.14	14.6	104.7	102	108.6
	Banana-leaf	1780	1020	2250	1675	2360	1495	7	14.7	14.98	15.82	110	114	126
Mg	Bean-top	635	516	805	580	879	637	471.1	493.24	495.59	499.36	4.7	5.2	6
	Banana-leaf	625	595	809	530	810	589	471.1	497.01	498.42	500.3	5.5	5.8	6.2
Na	Bean-top	260	234	282	250	289	255	9.8	11.43	11.58	11.8	16.7	18.2	20.5
	Banana-leaf	259	250	268	255	280	234	9.8	11.49	11.76	12.02	17.3	20	22.7
pH	Bean-top	11.5	10.8	12.2	11	12.6	11.5							
	Banana-leaf	11.9	9.7	12.4	10.2	12.5	10.5							

3.2. Effects of Extracts of Banana-Plantain Leaf Ash and Bean Tops on the Bromatological Composition of Rubber Hulls

Table 3 summarises the effects of extracts of banana-plantain leaf and bean tops ash on the bromatological composition of rubber hulls. The table shows that, with the exception of NDF, all other parameters were significantly ($P < 0.05$) affected. On the other hand, there was a significant increase and decrease respectively in organic matter and ash with untreated rubber hulls, compared with the other treatments, which nevertheless remained comparable. In addition, there was a significant decrease in the lipid value of banana-plantain leaf and bean tops ash treatments compared to untreated rubber hulls. The opposite trend was observed with bean ash treatments. The lipid value induced by the bean-tops ash treatment was comparable than that induced by the banana-plantain leaf ash, and their values decrease with increasing concentrations. A linear and significant decrease in ADF was observed with the banana-plantain leaf ash treatment, in contrast to the bean top ash treatment, which evolved in a sawtooth pattern.

Table 3. Effects of extracts of banana-plantain leaf ash and bean-tops on the bromatological composition of rubber hulls.

Bromatological composition	CUH	Ash extract	Treated hulls (TH)			
			TH 7.5	TH 10	TH 12.5	P
DM	91.31±0.27^{b}	Bean-top	91.52 ± 0.02^{bA}	90.23 ± 0.12^{cB}	89.84 ± 0.11^{d}	*0.00*
	91.31±0.27^{b}	Banana-leaf	90.13 ± 0.04^{cB}	92.41 ± 0.14^{aA}	90.13 ± 0.03^{c}	
		P	*0.00*	*0.00*	*0.14*	
OM	99.01±0.12^{a}	Bean-top	98.15 ± 0.12^{bA}	97.89 ± 0.01^{b}	98.00 ± 0.42^{b}	*0.01*
	99.01±0.12^{a}	Banana-leaf	97.84 ± 0.17^{bB}	97.85 ± 0.02^{b}	97.61 ± 0.39^{b}	

Continued

		P	*0.01*	*0.15*	*0.43*	
	0.99±0.12^{b}	Bean-top	1.85 ± 0.12^{aB}	2.11 ± 0.01^{a}	2.00 ± 0.42^{a}	
Ash	0.99±0.12^{b}	Banana-leaf	2.16 ± 0.17^{aA}	2.15 ± 0.03^{a}	2.39 ± 0.39^{a}	*0.01*
		P	*0.00*	*0.15*	*0.43*	
	2.38±0.01^{a}	Bean-top	1.38 ± 0.02^{dB}	1.70 ± 0.04^{c}	1.84 ± 0.01^{bA}	
CP	2.38±0.01^{a}	Banana-leaf	2.36 ± 0.02^{aA}	1.73 ± 0.02^{b}	1.52 ± 0.02^{cB}	*0.00*
		P	*0.01*	*0.43*	*0.01*	
	82.82±0.24	Bean-top	82.48 ± 0.02^{A}	80.47 ± 0.12^{A}	78.57 ± 0.10	
NDF	82.82±0.24	Banana-leaf	82.20 ± 0.14^{B}	80.43 ± 4.99^{B}	79.25 ± 0.03	*0.29*
		P	*0.00*	*0.00*	*0.05*	
	66.15±0.19^{b}	Bean-top	66.32 ± 0.01^{aB}	60.73 ± 0.09^{cB}	61.73 ± 0.08^{bA}	
ADF	66.15±0.19^{b}	Banana-leaf	66.49 ± 0.11^{aA}	60.83 ± 0.03^{bA}	59.02 ± 0.02^{cB}	*0.00*
		P	*0.00*	*0.00*	*0.00*	
	36.62±0.11^{d}	Bean-top	37.67 ± 0.05^{cA}	38.62 ± 0.05^{bA}	40.91 ± 0.01^{aA}	
CF	36.62±0.11^{d}	Banana-leaf	37.39 ± 0.01^{cB}	37.83 ± 0.01^{bB}	339.59 ± 0.06^{aB}	*0.00*
		P	*0.00*	*0.00*	*0.00*	
	0.73±0.00^{a}	Bean-top	0.49 ± 0.00^{bB}	0.48 ± 0.00^{cB}	0.38 ± 0.00^{dB}	
Lipids	0.73±0.00^{a}	Banana-leaf	0.71 ± 0.00^{bA}	0.65 ± 0.00^{cA}	0.59 ± 0.00^{dA}	*0.00*
		P	*0.00*	*0.00*	*0.00*	

Note: a, b, c, d: on the same line, values with the same letter do not differ significantly (P > 0.05). CUH = Control-Untreated-Hulls, TH 7.5 = Treated Hulls with extracts of banana-plantain ash/bean-tops (7.5%), TH 10 = Treated Hulls with extracts of banana-plantain ash/bean-tops (10%), TH 12.5 = Treated Hulls with extracts of banana-plantain ash/bean-tops (12.5%), DM : Dry Matter, OM: Organic Matter, NDF: Neutral Detergent Fibre, ADF : Acid Detergent Fibre, CF: Crude Fiber, CP: Crude Protein, P: Probability, A, B: on the same column, values with the same letter do not differ significantly (P > 0.05).

3.3. Effects of Treating Rubber Seed Hulls with Extracts of Banana-Plantain Leaf Ash and Bean Tops on Feed Intake in Rabbits

The effects of treating rubber seed hulls with extracts of banana-plantain leaf ash and bean-tops on feed intake in rabbits are reconciled in (Table 4). It can be seen from this table that all the treatments were significantly affected (P < 0.05) with the exception of dry matter. However, animals fed the Control-No-Hulls ration had significantly (P < 0.05) higher crude protein and crude fibre levels compared with the Control with 20 % Untreated-Hulls ration and the other treatments. The opposite effect was observed in these same animals, which induced significantly (P < 0.05) lower levels of OM, NDF and ADF. Furthermore, banana leaf ash-plantain extracts induced comparable effects to those of bean-tops extracts whatever the dose and treatment considered, with the exception of crude protein at 10 and 12.5%, with a higher tendency for the bean-tops treatments.

Table 4. Effects of treating rubber seed hulls with extracts of banana-plantain leaf ash and bean tops on feed intake in rabbits.

Ingestion (g/day)	Control rations		Ash extract	Rations (%)			P
	CNH	CUH		$R_{1\ ECH/ECB}$	$R_{2\ ECH/ECB}$	$R_{3\ ECH/ECB}$	
DM	141.53 ± 0.32	142.14 ± 0.11	Bean-top	142.84 ± 0.90	141.81 ± 0.60	141.08 ± 0.39	*0.06*
	141.53 ± 0.32	142.14 ± 0.11	Banana-leaf	142.54 ± 0.70	142.55 ± 0.80	141.68 ± 0.40	
			P	*0.06*	*0.46*	*0.87*	
OM	137.86 ± 0.26^{c}	143.91 ± 1.12^{ab}	Bean-top	143.72 ± 0.50^{b}	144.54 ± 0.20^{a}	143.89 ± 0.70^{b}	*0.00*
	137.86 ± 0.26^{c}	143.91 ± 1.12^{ab}	Banana-leaf	143.57 ± 0.30^{ab}	144.27 ± 0.40^{a}	142.89 ± 0.50^{b}	
			P	*0.05*	*0.59*	*0.91*	
CP	22.43 ± 0.37^{a}	21.97 ± 0.17^{b}	Bean-top	21.60 ± 0.10^{c}	21.65 ± 0.07^{c}	21.69 ± 0.50^{cA}	*0.00*
	22.43 ± 0.37^{a}	21.97 ± 0.17^{b}	Banana-leaf	21.86 ± 0.08^{c}	21.45 ± 0.09^{d}	21.60 ± 0.60^{dB}	
			P	*0.37*	*0.73*	*0.00*	
NDF	52.69 ± 0.86^{c}	57.52 ± 0.45^{a}	Bean-top	57.60 ± 0.05^{a}	57.02 ± 0.04^{aB}	56.45 ± 0.47^{b}	*0.00*
	52.69 ± 0.86^{c}	57.52 ± 0.45^{a}	Banana-leaf	57.54 ± 0.03^{a}	57.92 ± 0.06^{aA}	56.66 ± 0.45^{b}	
			P	*0.35*	*0.04*	*0.45*	
ADF	25.22 ± 0.41^{c}	33.77 ± 0.26^{a}	Bean-top	33.93 ± 0.10^{a}	32.25 ± 0.15^{b}	32.55 ± 0.00^{b}	*0.00*
	25.22 ± 0.41^{c}	33.77 ± 0.26^{a}	Banana-leaf	33.99 ± 0.12^{a}	32.01 ± 0.11^{b}	32.24 ± 0.00^{b}	
			P	*0.35*	*0.97*	*1.00*	
CF	22.38 ± 0.33^{a}	20.61 ± 0.16^{b}	Bean-top	20.63 ± 0.25^{bA}	20.94 ± 0.59^{b}	20.34 ± 0.40^{bB}	*0.00*
	22.38 ± 0.33^{a}	20.61 ± 0.16^{b}	Banana-leaf	20.58 ± 0.19^{bB}	20.63 ± 0.21^{b}	20.78 ± 0.30^{aB}	
			P	*0.00*	*0.08*	*0.00*	

Note: $^{a, b, c, d}$ on the same line, values with the same letter do not differ significantly (P > 0.05). CNH = Control-No-Hulls, CUH = Control with 20% Untreated-Hulls, $R_{1\ ECH/ECB}$ = Ration with 20% hulls treated with ash extract of banana-plantain leaf/bean-top (7.5 %), $R_{2\ ECH/ECB}$ = Ration with 20% hulls treated with ash extract of banana-plantain leaf/bean-top (10%), $R_{3\ ECH/ECB}$ = Ration with 20% hulls treated with ash extract of banana-plantain leaf/bean-top (12.5%), DM: Dry Matter, OM: Organic Matter, NDF : Neutral Detergent Fibre, ADF: Acid Detergent Fibre, CF: Crude Fiber, CP: Crude Protein, P: Probability, A, B: on the same column, values with the same letter do not differ significantly (P > 0.05).

3.4. Effects of Treating Rubber Seed Hulls with Extracts of Banana-Plantain Leaf Ash and Bean Tops on the Apparent Digestibility of DM, OM, PB, NDF, ADF and CF in Rabbits

Table 5 shows the effects of treating rubber seed hulls with extracts of banana-plantain leaf ash and bean-tops on the apparent digestibility of DM, OM, CP, NDF, ADF and CF in rabbits. In general, the table shows that animals fed with Control-No-Hulls diet produced significantly (P < 0.05) higher values than those fed the Control with 20% Untreated-Hulls diet for all parameters except organic matter. Furthermore, the animals fed the Control-No-Hulls ration induced significantly (P < 0.05) higher CP and NDF values compared with the ash treatments, whatever the type and rate considered. On the other hand, these values were significantly (P < 0.05) lower when compared with the Control with 20% Untreated-

Hulls ration. In addition, there was a significant ($P < 0.05$) linear increase in digestibility values with increasing ration rates, whatever the type of treatment.

Table 5. Effects of treating rubber tree hulls with extracts of banana-plantain leaves ash and bean tops on the apparent digestibility of DM, OM, CP, NDF, ADF and CF in rabbits.

Ingestion (g/day)	Control rations		Ash extract	Rations (%)			*P*
	CNH	CUH		$R_{1\ ECH/ECB}$	$R_{2\ ECH/ECB}$	$R_{3\ ECH/ECB}$	
DM	64.64 ± 3.37^{a}	62.42 ± 3.44^{b}	Bean-top	64.17 ± 4.43^{aA}	64.27 ± 3.48^{a}	64.51 ± 4.92^{a}	*0.00*
	64.64 ± 3.37^{a}	62.42 ± 3.44^{b}	Banana-leaf	60.89 ± 1.95^{cB}	64.22 ± 4.08^{a}	63.85 ± 2.29^{ab}	
			P	*0.04*	*0.46*	*0.34*	
OM	64.64 ± 3.41^{b}	67.49 ± 2.15^{a}	Bean-top	64.17 ± 3.26^{b}	64.27 ± 2.57^{b}	64.93 ± 2.43^{b}	*0.00*
	64.64 ± 3.41^{b}	67.49 ± 2.15^{a}	Banana-leaf	60.89 ± 1.51^{d}	64.22 ± 2.99^{b}	63.85 ± 2.38^{c}	
			P	*0.05*	*0.59*	*0.91*	
CP	84.75 ± 1.31^{a}	61.88 ± 4.13^{e}	Bean-top	63.39 ± 6.26^{d}	65.71 ± 7.18^{c}	68.43 ± 4.30^{b}	*0.00*
	84.75 ± 1.31^{a}	61.88 ± 4.13^{c}	Banana-leaf	60.94 ± 4.37^{d}	67.33 ± 4.16^{b}	66.73 ± 1.66^{c}	
			P	*0.22*	*0.08*	*0.21*	
NDF	63.49 ± 4.31^{a}	50.11 ± 3.97^{e}	Bean-top	51.96 ± 3.96^{d}	52.07 ± 4.84^{cB}	61.73 ± 3.72^{b}	*0.00*
	63.49 ± 4.31^{a}	50.11 ± 3.97^{e}	Banana-leaf	51.07 ± 0.55^{d}	53.87 ± 2.15^{cA}	56.74 ± 7.69^{b}	
			P	*0.35*	*0.04*	*0.45*	
ADF	32.19 ± 2.50^{c}	28.64 ± 6.18^{d}	Bean-top	28.75 ± 3.70^{d}	33.02 ± 6.26^{b}	35.18 ± 11.18^{a}	*0.00*
	32.19 ± 2.50^{c}	28.64 ± 6.18^{d}	Banana-leaf	29.03 ± 8.23^{d}	33.23 ± 7.74^{b}	34.45 ± 8.17^{a}	
			P	*0.35*	*0.98*	*0.47*	
CF	49.27 ± 3.77^{c}	39.53 ± 5.07^{d}	Bean-top	49.26 ± 9.06^{c}	52.61 ± 1.89^{b}	63.99 ± 13.45^{a}	*0.00*
	49.27 ± 3.77^{c}	39.53 ± 5.07^{d}	Banana-leaf	48.98 ± 4.63^{c}	50.61 ± 0.84^{b}	52.11 ± 1.89^{a}	
			P	*0.48*	*0.08*	*0.10*	

Note: $^{a, b, c, d, e}$ on the same line, values with the same letter do not differ significantly ($P > 0.05$). CNH = Control-No-Hulls, CUH = Control with 20% Untreated-Hulls, $R_{1\ ECH/ECB}$ = Ration with 20% hulls treated with ash extract of banana-plantain leaf/bean-top (7.5%), $R_{2\ ECH/ECB}$ = Ration with 20 % hulls treated with ash extract of banana-plantain leaf/bean-top (10%), $R_{3\ ECH/ECB}$ = Ration with 20 % hulls treated with ash extract of banana-plantain leaf/bean-top (12.5%), DM : Dry Matter, OM: Organic Matter, NDF : Neutral Detergent Fibre, ADF : Acid Detergent Fibre, CF: Crude Fiber, CP: Crude Protein, P: Probability, A, B: on the same column, values with the same letter do not differ significantly ($P > 0.05$).

4. Discussion

The concentration of minerals in extract solutions decreased after soaking, regardless of the source and concentration of the extract in question. The drop in these elements in the extracts could be explained by the fact that they were absorbed by the rubber hulls during processing. These results are in agreement with those reported by [22], who also obtained a drop in the concentration of K, Ca and Mg after soaking rice straw in ash extract solutions. The pH of the various ash extract solutions also fell after treatment of the rubber seed hulls, irrespective of the source or concentration; this fall could be linked to the absorption of the minerals responsible for the alkalinity of these extract solutions by the rubber hulls after soaking in the ash extracts. This result is also similar to those obtained by [22]. On the other hand, the mineral content in the rubber hulls increased regardless of the extract concentration. This increase would confirm that minerals are absorbed by the Hevea hulls in the ash extract solutions after soaking. These results are in line with those obtained by [22] who showed an increase in Na, K, Mg and Ca content in rice straw treated with ash extracts.

Irrespective of the treatment considered, bromatological analysis of rubber seed hulls treated with banana-plantain leaf ash and bean tops extracts showed that organic matter, crude protein, ADF and lipid levels dropped significantly compared with those of untreated hulls, as did NDF, although this was not significant. In addition, there was a significant increase in crude fiber and ash in the hulls treated with ash extracts compared with the untreated hulls. This decrease in NDF and ADF, a direct consequence of the increase in crude fiber, could be explained by the fact that the alkalising power of the ash would have broken the ester bonds existing between the different constituents of the cell wall. These results are similar to those of [23] who reported that the treatment of cocoa pods with extracts of bean ash and banana leaves reduced the NDF and ADF content and increased that of crude cellulose. Similarly, [24] obtained a reduction in NDF and ADF for cocoa pods treated with hot water. The significant decrease in crude protein and lipid could be explained by the hydrolysis action that occurred, leading to a partial loss of these components. This result corroborates those of [19] who reported a decrease in digestible nitrogenous matter when rice straw was treated with extracts of bean ash or banana leaves.

The incorporation of rubber seed hulls treated with extracts of bean ash and banana-plantain leaves in the rabbits' feed showed that the dry matter ingested was not significantly affected regardless of the treatment. On the other hand, there was a significant decrease in the feed intake of OM, NDF and ADF in animals receiving the positive control ration (without hulls) compared with animals receiving treated or untreated hulls. This could be due to the difference in fiber source between the positive control ration ($R0^+$) containing no hulls but trypsacum and the other rations containing rubber hulls. In addition, the slightly higher energy content of the latter compared with the other rations could also explain this result. A significant drop in dietary feed intake of NDF and ADF was also observed in animals receiving treated hulls compared with those receiving untreated hulls. These results corroborate those of [23], which noted a reduction in NDF intake in animals fed cocoa pods treated with ash extracts.

Irrespective of the ash source and rate, the apparent digestibility of DM, PB, CB, NDF and ADF increased significantly in animals fed the treated hulls compared with those fed the ration with untreated hulls ($R0^-$). This could be due to the action of the ash extracts which, thanks to their alkalising power, weakened the rubber tree shell wall by hydrolysing the lignocellulosic bonds, thus making the nutrients present in the shell more available. This result is in agreement with those of [19] [23] [25] who respectively reported that, when *Chloris gayana*, rice straw and cocoa pods were treated with banana leaves ash extract and/or bean husk extract, the digestive utilization coefficient of crude protein of the NDF of the ration not containing the rubber hulls was significantly higher than that of the rations containing the hulls treated or not. This could also be explained by the low intake of NDF, which would have slowed down the digestive transit speed, resulting in better protein digestibility. Animals fed rations containing rubber tree hulls treated with bean leaves ash extracts produced higher values of CF, ADF, NDF, CP and MO digestibility compared with those fed rubber tree hulls treated with banana-plantain leaves ash extracts. This could be explained by the fact that bean ash extract is more basic than banana-plantain leaf ash extract. This high basicity could be due to the greater fragility of the hulls. These results are respectively in agreement and contradiction with those of [19] [23] who obtained a better digestibility with banana leaves ash extract by treating rice straw with it compared to rice straw treated with bean leaf extract. This could be due to the animal or plant species used in the various studies.

5. Conclusion

By treating rubber seed hulls with various plant ash extracts in rabbit rations, we found that bean ash extract at a 12.5% concentration can be used more effectively to improve feed digestibility. It was found that bean ash extract at a concentration of 12.5% can be used more effectively to improve the digestibility of feed containing rubber seed hulls in rabbits.

6. Ethical Considerations

The experimental protocol used in this study was approved by the scientific committee of the Department of Animal Science, Faculty of Agronomy and Agricultural Sciences, University of Dschang. The animals were treated in accordance with internationally accepted standard ethical guidelines for the use and care of laboratory animals described in the guidelines of the Norwegian National Committee on Research Ethics in Science and Technology [26].

Ethical assessments related to the use of animals in research are very diverse. It is generally believed that it may be necessary to use laboratory animals in some cases to create improvements for people, animals or the environment. At the same time, the general view [26] is that animals have a moral status and that our treatment of them should be subject to ethical considerations. These views are reflected in the following positions:

1) Animals have intrinsic value (real value) that should be respected;

2) Animals are sentient creatures capable of feeling pain, and the interests of animals must therefore be taken into account;

3) Our treatment of animals, including the use of animals in research, is an expression of our attitudes and influences us as moral actors.

Conflicts of Interests

The authors declare no conflict of interest.

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