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Effectiveness of Integrating Botanical Ash in an Underground Clay-Composite Storage on the Rate of Mass Loss (Decay) and Proximate Composition Profile of Stored *Colocasia Esculenta*

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Abstract
The investigation analysis of the effectiveness of using botanical ash in an underground clay-composite storage on the rate of mass loss (decay) and the proximate composition profile of stored *Colocasia esculenta* was carried out using standard methods. According to the results, the lowest percentage decrease in cocoyam weight was observed in walls integrated with iroko and palm kernel ash. This tends to suggest that Iroko tree bark (I) and palm kernel shell ranked best among the plant materials for cocoyam storage, having shown a great tendency in the level of weight retention and weight loss reduction of cocoyam. Cocoyam stored in pits with walls integrated with palm nut shell (P) ash has the highest drop in percentage crude protein when compared with a value of 21.3%, while Iroko tree bark (I) showed the least percentage decrease in crude protein content of stored cocoyam. Cocoyam stored in pits with walls integrated with Iroko tree bark (I) showed no drop (0%) in percentage ash, while Groose grass (G1) showed the highest drop of about 18.9% as compared with the control. The moisture and carbohydrate contents of stored cocoyam increased while crude protein, crude fibre, and fat progressively decreased as storage months increased. Statistical variations ($p<0.05$) existed across the different types of plants (leaves) utilized for the cocoyam storage for weight loss.
***Keywords*: Investigation, botanical ash, proximate composition, storage, mass loss, profile**

Introduction

Cocoyam (*Colocasia esculenta*) is an aroid belonging to the family Araceae and is mainly grown for its edible corms (O'Hair, 1984). They are food crops that thrive well across many agroecological zones of sub-Saharan Africa and are ranked higher nutritionally above cassava and yam in protein, minerals, vitamins, and digestible starch. The increasing production in sub-Saharan Africa largely depends on farming more land rather than increasing crop yields. This is opposed to the projections of the FAO that the 70% growth in global agricultural production needed to feed an additional 2.3 billion people by 2050 must be achieved by increasing yields and cropping intensity on existing farmlands, rather than by increasing the amount of land brought under agricultural production (FAO, 2009).

Mature aroids can be processed into different food forms to satisfy the economic needs of human nutrition. In the southeastern parts of Nigeria, cocoyam is used as a soup thickener after boiling and pounding to obtain a consistent paste (Obiechina *et al*., 1987; Onwueme, 1978). Cocoyam chips are an important product, and the young leaves can serve as an excellent vegetable (Opara, 2000). Roasted or boiled corms can also be eaten alone or with stew. Cocoyam flour can also be utilized by the food industry to produce weaning food for growing children due to the high rate of a starch digestibility and the small granule size (Onwulata *et al*., 2002) Taro flours have unique properties from small starch granules (<1.5 µm) and high mucilage (gum) content, suggesting a replacement for corn or wheat starch in weaning foods.

Cocoyams are stored in a variety of traditional low-cost structures such as shade, hut, basket, and underground pits dowsed with botanical ash and covered with palm leaves. In underground storage pits, corms are placed inside the pits and covered with leaves and soil. The major disadvantage of using this method is that the leaves will eventually decay and increase the possibility of microbial growth during storage, which will affect the shelf-life of the cocoyam by causing early deterioration of the cocoyam tuber, leading to mass loss. Traditionally, the idea of incorporating different types of plant materials (leaves) in the preservation of cocoyam during storage is to exert on the cocoyam the different botanical effects that can lower the rate of decay of cocoyam. Therefore, investigating the effectiveness of using botanical ash in the storage of cocoyam to checkmate the rate of decay and the proximate composition profile of the cocoyam becomes the aim of this study.

Materials and Methods

Experimental Location

The experiment was carried out at the National Root Crops Research Institute, Umudike, Abia State.

Sample Collection

Colocasia esculenta samples were harvested from the experimental farm of the National Root Crops Research Institute, Umuike, Abia State, situated in the south-eastern geo-political zone of Nigeria. Five different plant ashes were selected for storage. The plants include: Groose Grass *(elousine indica),* Feathery Pennisetum Grass *(pennisetum polystachion),* Palm nut shell*,* Rice husk, and Iroko tree bark. The clay soil was used for preparing the walls of the underground storage chamber.

Storage Structural Design: The pit was designed to prevent water from flowing into the pit.

I. The pit was protected from rodents and insects.
II. Air circulators were by natural convention

Design Analysis

The pits were designed to store a maximum of 2kg of cocoyam each. Thus, the volumetric requirement for the aforementioned mass of cocoyam was estimated from the equation:

$$V = \frac{m}{\rho_b}$$

Where, V = bulk volume of cocoyam; ρ_b = bulk density of cocoyam = 1.02 g/cm^3;m = mass of cocoyam = 5 kg

Taking 10% headspace for overboard and proper circulation, the design capacity for the pit becomes:

$$V_d = V + 0.1V$$

An additional 10% overboard in height was added above the ground surface to prevent flowing water from entering the pit.

Underground Chamber Development and the Analysis

In this study, the following steps were carried out: The five different plants were dried under the sun and burned to ashes. Three pits were developed for each ash with wet clay on the walls only for each plant-clay composite.

I. Stored cocoyam was analyzed for proximate composition.
II. Mass loss was estimated.

Description of the Underground Storage Chamber

A cuboid-shaped pit of the designed dimensions was dug. A composite of the burnt botanical ash and clay mixed with water was made in the ratio 1:5. The floor and walls of the pit were smothered and plastered with 5mm thick clay composite, while the overboard was laid on top with the same material. The overboard was covered with an insect hole net, and the structure was allowed to dry for seven days. For each botanical ash, three pits were made, and the average was used for data analysis. Additionally, three pits were dug without a botanical ash composite to serve as a control. Therefore, a total of 18 pits were made. To prevent rain from interfering with the structure, a bevel palm leaf roof was placed at 2m above a wooden stand, while the layout was protected with a 30 cm wall to prevent flooding.

Mass loss estimation

The mass losses were presented as a percentage of the initial weight recorded weekly throughout the experiment as follows:

$\%M_L = Mi – Mw/Mi \times 100$

Where Mi is the initial weight of cocoyam, Mw is the weekly mass of cocoyam.

Proximate composition analysis of the cocoyam

The moisture content, crude protein, fat content, crude fibre, and total ash were determined by the methods of AOAC (1984). All analysis in this section was expressed on a dry weight basis.

Carbohydrate Content

The carbohydrate content of the samples was determined by subtracting the sum percentage proximate composition of moisture, ash, crude lipid, crude protein, and crude fibre from 100.

$$\text{Carbohydrate} = 100 - (\%\,\text{moisture} + \%\,\text{ash} + \%\,\text{protein} + \%\,\text{lipid} + \%\,\text{fibre}).$$

Calorie

The energy content of the samples (kJ/100g) was determined from the proximate composition using the equation described by Kirk *et al*. (1991).

Calorie = (% available carbohydrate × 17) + (% protein × 17 + (% fat × 37)

Where = 17, 17, and 37 are conversion factors for carbohydrate, protein, and fat, respectively, for energy content calculation.

Experimental design

Complete Randomized Design (CRD) was used as the Design of the experiment. Plant ash with five levels was also considered in this research work. It was considered the treatment, and the experiment was replicated three times. The five levels of factor (plant ash) were denoted by:

- **G0** No Grass (Control)
- **G1** Groose Grass (limousine India)
- **G2** Feathery Pennisetum Grass (*Pennisetum polystachion*)
- **P** Palm nutshell
- **I** Iroko tree back
- **R** Rice husk

Statistical Technique- Analysis of Variance (ANOVA):

The mathematical model specification for the factorial design in Randomized Complete Block Design is given as follows:

$$Y_{ij} = \bar{Y}_{..} + G_i + \varepsilon_{ij}$$

Where,

Y_{ij} - Any observation for which *i* is the Ash grass, $\bar{Y}_{..}$ - is the overall mean, G_i - effect for being in the grass ash, ε_{ij} - is the error term. Where ε_{ij} ~ N $(0,\sigma^2)$ are independent and $\sum G_i = 0$

Data Transformation

The proximate property data (presented in percentages) were transformed into proportions, and the beta regression model was used to model the data. Ferrari and Cribari-Neto (2004) proposed a regression model for continuous varieties that assume values in the standard unit interval, e.g., rates, proportions, or concentration indices. Since the model is based on the assumption that the response is beta-distributed, they called their model the beta regression model.

The beta regression model is given below as follows:

$$f(y;\mu,\varphi) = \frac{\Gamma(\varphi)}{\Gamma(\mu\varphi)\Gamma((1-\mu)\varphi)} y^{\mu\varphi-1}\left(1 - y^{(1-\mu)\varphi-1}\right) \quad 0 < y < 1,$$

With $0 < \mu < 1$ and $\phi > 0$. We write $y \sim B(\mu, \phi)$.

POSTHOC, the Least Square Difference (LSD) test

The LSD was developed by Fisher to explore all possible pair-wise comparisons of means comprising a factor. In the circumstance of having significant mean differences, the LSD test will be used to determine which mean is significantly different from the others. The least significant difference between the two means is calculated by:

$$LSD = t\sqrt{\frac{2MSE}{n}}$$

Where *t* is the critical tabled value of the t-distribution with the degree of freedom associated with *MSE*, the denominator *n* is the number of scores used to calculate the means of interest, and *MSE* is the mean square error. All statistical analysis was done in an open-source R environment version 4.2.2 using the following packages: ggplot2, tidyverse, agricolae, and betareg.

Results and Discussion

Description of the Storage Structure:

A cuboid-shaped pit was selected. The inner walls of the storage chamber were made up of a 4 cm-thick clay-botanical ash composite, smothered uniformly on the walls and the base. The storage chamber is 0.06 m^3 in volume, and an overboard rectangular structure 10 cm thick was mounted on top of the storage chamber to prevent flooding. The overboard was covered with a plastic net fixed to a wooden frame.

A total of 18 underground structures were laid in an array of three, with a gap of 0.5 m separating one line from the next. All the arrays were covered with a thatched palm leaf roof mounted on a 2 m wooden stick to protect the structure from direct solar radiation and rainfall. The arrays of the underground storage chambers covered a total land area of 3 m^2. The use of a raised open thatched roof is to allow for natural ventilation of the storage structure.

Figure 5 presents the effect of different types of clay-ash composites on the weight loss of cocoyam. Mass loss is attributed to the decay of various levels of cocoyam mass from each sample compared to the initial weight. The result showed that there were significant differences in the different types of plants for weight loss. However, mass loss was absent in the first two weeks for all treatments and three weeks of storage for the Iroko back and palm kernel ash treatments. Mass losses become noticeable from the 4th week. Compared with the initial mass, the highest percentage decrease was observed in the control, with a percentage mass decrease of 55 % after 13 weeks. However, among treated pits, Goose grass (G1) and feather pennispertum (G2), rice husk (R), and untreated pits (G0) with a percentage value of 50% showed the highest weight loss. Similarly, Iroko tree back (I) and palm kernel shell (P) showed the least percentage decrease, with a percentage value of 30% when compared with the initial weight. The results of I and P could be comparable to 34.7% and 30.5% reported by (Eze *et al*., 2015) on the evaluation of indigenous technologies of fresh cocoyam storage in southeast Nigeria. The different values obtained could be attributed to the effect of different treatments and ecological factors. This has demonstrated the work of Ugwuoke *et al*. (2008) on the efficacy of botanical preservatives in cocoyam storage.

The results of four proximate components of cocoyam stored under different crop plants were summarized in Table 1. It was observed that there is a statistically significant difference ($p < 0.05$) in the level of moisture content (MC) among the cocoyam stored with different crop plants. The control showed the highest level of moisture content (MC), Ash, and Crude Protein (CP). Compared with the Control, Rice Husk (R) had the lowest percentage decrease of 0.8% (from 10.67 to 10.58). The highest percentage decrease in moisture content (MC) came from the Iroko tree back (I) with a percentage value of 8.8% (10.67 to 9.73). A similar trend was also observed in crude protein (CP) content. Palm nutshell (P) has the highest drop in percentage crude protein when compared with the Control, with a value of 21.3%. Iroko tree back (I) showed the lowest percentage decrease in crude protein content of stored cocoyam. In percentage ash content, Iroko tree bark (I) showed no drop (0%) while Goose grass (G1) showed the highest drop of about 18.9% as compared with the control. There is a significant progressive increase in moisture content (MC) in the first two months of cocoyam storage. Table 4.4: Similarly, the ash content in cocoyam also increased significantly as the storage month progressed. On the opposite trend, Crude protein, Crude fibre, and Fat progressively decreased as the month increased. The percentage decrease of Crude protein, Crude fibre, and Fat from month 0 to month 3 of storage time was 4.5% (6.775 to 6.471), 7.1% (1.471 to 3.367), and 13.0% (1.511 to 1.314), respectively. There was evidence of an increase in the Carbohydrate (CHO) content of cocoyam as the storage months progressed. There was an increase of about 0.48% (76.88 to 77.25).

Table 2 presents the effect of different underground storage systems and time on the proximate contents of cocoyam. Clay without grass (G0) and month 2 gave the highest moisture content (MC) of 10.87%, while Iroko tree back (I) and month 0 gave the lowest value with 9.52%. Dry matter content was highest in the combined effect of Iroko tree back (I) and month 0, with a value of 90.47%, while the combined effect of Clay without grass (G0) and month gave the lowest value of moisture content (MC) with 89.12%. The highest value of ash content was obtained in the Iroko tree back (I) underground storage type and month 3, with a value of 3.84%, while the control and zero months gave the highest value of crude protein (7.56%). Rice Husk (R) and Palm nutshell (P) storage types at month 0 gave the highest values of crude fibre (1.63%) and fat (1.65%), respectively. Similarly, the highest value of the effect of different underground storage systems and months of storage on carbohydrate content (CHO) in cocoyam was obtained in Feathery pennisetum grass (G2) and month 3, with a value of 77.84%

Conclusion

The lowest percentage decrease in cocoyam weight was observed in walls integrated with iroko and palm kernel ash. This tends to suggest that Iroko tree bark (I) and palm kernel shell ranked best among the plant materials for cocoyam storage, having shown a great tendency in the level of weight retention and weight loss reduction of cocoyam. The constant trend in weight reduction of cocoyam and the subsequent increase in weight loss of cocoyam as shown in Figure 5, with time (duration) of storage as relates to the control, expresses the effect of the botanical extracts (leaves) on the cocoyam during storage. Cocoyam stored in pits with walls integrated with palm nut shell (P) ash has the highest drop in percentage crude protein when compared with a value of 21.3%, while Iroko tree bark (I) showed the least percentage decrease in crude protein content of stored cocoyam. Cocoyam stored in pits with walls integrated with Iroko tree bark (I) showed no drop (0%) in percentage ash, while Groose grass (G1) showed the highest drop of about 18.9% as compared with the control. The moisture content and carbohydrates of stored cocoyam increased while crude protein, crude fibre, and fat progressively decreased as storage months increased.

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Figure 1: The botanical plant materials (A) Groose Grass (limousine India), (B) Feathery Pennisetum, (C) Rice husk, (D) Palm nutshell, (E) Iroko tree bark

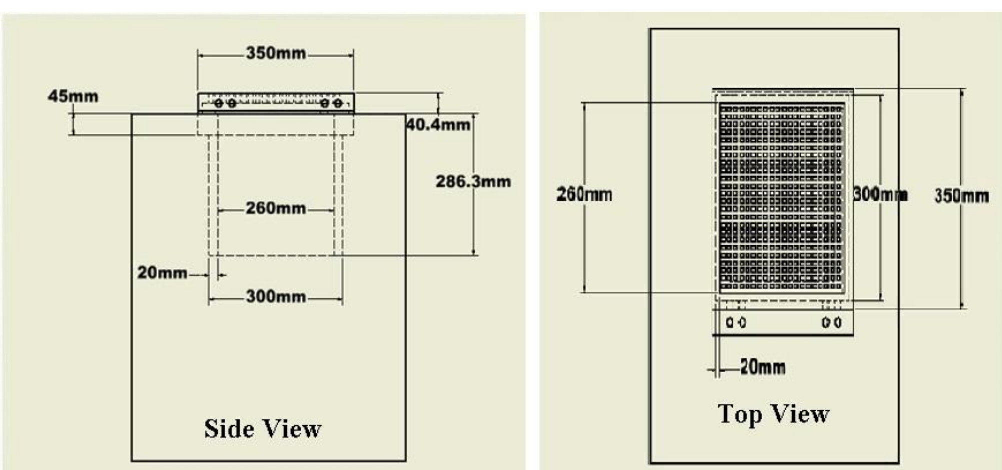

Figure 2: The side and Top views of the pit

Figure 3: Cuboid-shaped pit structure

Figure 4: Complete layout of the underground clay-composite storage chambers
Mass loss profile for different pits

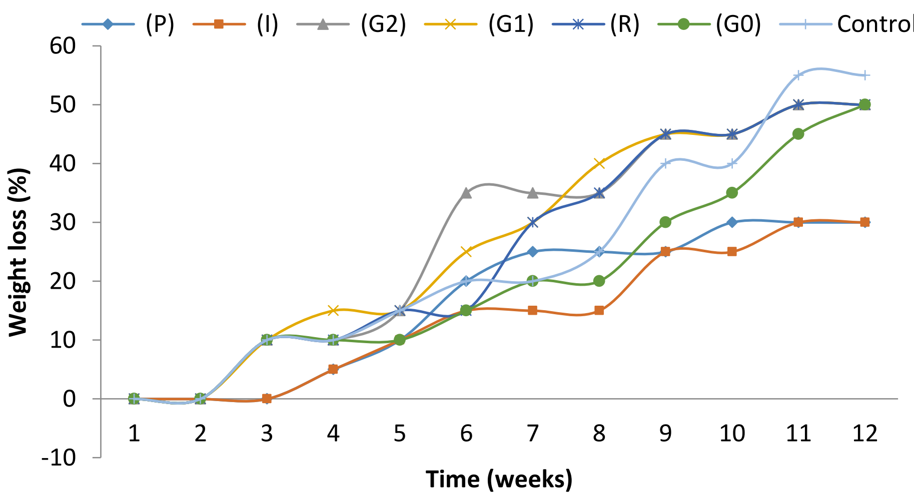

Figure 5: Effects of different treatments on the mass loss of cocoyam Proximate Composition

Table 1: Proximate Main Effect

	MC (%)		DM (%)		ASH (%)		CP (%)		CF (%)		FAT (%)		CHO (%)	
CONTROL	10.67	a	89.33	F	3.59	a	7.37	a	1.33	E	1.36	D	75.68	E
G0	10.36	d	89.64	C	3.47	b	6.25	f	1.50	B	1.39	C	77.01	C
G1	10.52	b	89.48	E	2.91	c	6.54	d	1.39	D	1.38	C	77.22	B
G2	9.85	e	90.15	B	3.25	b	6.66	c	1.34	E	1.42	B	77.62	A
I	9.73	f	90.23	A	3.59	ab	7.16	b	1.42	C	1.36	D	76.73	D
P	10.56	c	89.45	D	3.23	b	5.80	g	1.33	E	1.55	A	77.48	A
R	10.58	b	89.42	E	3.41	ab	6.48	e	1.56	A	1.26	E	76.71	D
CV (%)	**4.688**		**0.541**		**5.281**		**8.211**		**6.413**		**6.699**		**0.989**	
M0	10.28	c	89.717	B	3.14	b	6.775	a	1.471	A	1.511	A	76.88	A
M1	10.35	b	89.664	C	3.41	a	6.677	b	1.422	B	1.471	B	76.64	B
M2	10.51	a	89.489	D	3.42	a	6.513	c	1.384	C	1.251	D	76.92	A
M3	10.17	d	89.814	A	3.43	a	6.471	d	1.367	D	1.314	C	77.25	B
CV (%)	**1.379**		**0.152**		**4.1862**		**2.1477**		**3.270**		**8.954**		**0.326**	

Table 2: Proximate Interaction

		MC (%)	DM (%)	ASH (%)	CP (%)	CF (%)	FAT (%)	CHO (%)
CONTROL	Month0	10.78	89.22	3.44	7.56	1.44	1.39	75.4
G0	Month0	10.13	89.86	2.87	6.31	1.59	1.54	77.56
G1	Month0	10.64	89.33	2.95	6.77	1.46	1.53	76.48
G2	Month0	9.83	90.17	3.17	6.88	1.37	1.61	77.69
I	Month0	9.52	90.47	3.08	7.25	1.44	1.47	77.23
P	Month0	10.27	89.72	3.2	5.91	1.38	1.65	77.58
R	Month0	10.77	89.24	3.28	6.75	1.63	1.39	76.19
CNTRL	Month1	10.86	89.14	3.61	7.54	1.34	1.37	75.3
G0	Month1	10.28	89.72	3.69	6.27	1.52	1.48	76.72
G1	Month1	10.81	89.2	2.97	6.51	1.41	1.53	76.78
G2	Month1	9.87	90.13	3.32	6.71	1.36	1.54	77.21
I	Month1	9.56	90.44	3.68	7.17	1.46	1.41	76.72
P	Month1	10.38	89.67	3.26	5.84	1.32	1.63	77.42
R	Month1	10.66	89.34	3.37	6.71	1.55	1.35	76.34
CNTRL	Month2	10.83	89.17	3.69	7.22	1.29	1.33	75.64
G0	Month2	10.87	89.12	3.66	6.19	1.46	1.27	76.55
G1	Month2	10.82	89.18	2.9	6.47	1.36	1.24	77.21
G2	Month2	9.87	90.13	3.25	6.57	1.34	1.26	77.72
I	Month2	9.68	90.32	3.77	7.13	1.43	1.19	76.8
P	Month2	10.77	89.23	3.24	5.74	1.27	1.33	77.64
R	Month2	10.74	89.26	3.44	6.27	1.54	1.14	76.88
CNTRL	Month3	10.22	89.78	3.63	7.16	1.24	1.34	76.4
G0	Month3	10.17	89.84	3.68	6.22	1.44	1.27	77.24
G1	Month3	9.79	90.21	2.83	6.43	1.34	1.2	78.41
G2	Month3	9.83	90.17	3.27	6.48	1.31	1.27	77.84
I	Month3	10.17	89.68	3.84	7.08	1.36	1.37	76.18
P	Month3	10.81	89.19	3.22	5.71	1.37	1.61	77.28
R	Month3	10.17	89.83	3.54	6.21	1.52	1.14	77.42