Evaluation of indigenous technologies of fresh cocoyam (*Colocasia esculenta* (L.) Schott) Storage in Southeastern Nigeria

Eze S. C.1*, Ugwuoke K. I.1, Ogbonna P. E.1, Onah R. N.1, Onyeonagu C. C.1 and Onyekere C. C.2

1Department of Crop Science, University of Nigeria, Nsukka, Nigeria.
2Department of Plant Science and Biotechnology, University of Nigeria, Nsukka, Enugu State, Nigeria.

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Cocoyam (*Colocasia esculenta*) also referred to as taro is an herbaceous root crop and its non availability throughout the year has implicated lack of good storage methods. Survey and storage experiments were therefore, conducted at the Department of Crop Science, University of Nigeria, Nsukka to establish the scientific basis for adopting the indigenous technologies by the farmers and indentify the best among the technologies. The experiments were carried out in two phases. Phase (1) involved collection of farm level information on the existing fresh cocoyam preservation practices from the farmers through questionnaire interview while phase (2) involved the storage of cocoyam using some of the technologies based on their frequency of application by the communities. The storage experiment was laid out as 3 x 2 x 4 factorial in completely randomized design (CRD) and replicated four times. The storage techniques (treatments) were Pit + *Casia alata* + soil, Pit + *Jatropha curcas* leaf extracts + soil and no extract control. Twenty-four pits of each 0.7 m deep and 0.33 x 0.33 m² were dug at the experimental field under plantain and banana shades. Out of the 720 farmers sampled, 34.7% used Pit + *C. alata* leaf + soil to store their cocoyams while only 11% represent those who did not add botanicals. Weight loss from cocoyams treated with *C. alata* leaf extracts inside storage pits was significantly ($P \leq 0.05$) lower than those treated with *J. curcas* and no treatment control. Similarly, treatment of cocoyams with both *J. curcas* and *C. alata* significantly ($P \leq 0.05$) reduced rot incidence compared to no treatment control but there was no significant effects of these botanicals sprout weight. Among the leaves used for storage of cocoyam in the study area, *J. curcas* and *C. alata* leaf extracts outstandingly reduced post-harvest losses of cocoyam suggesting that these botanicals possess some anti fungal or anti bacterial properties that reduced rots in the stored cocoyam.

Key words: Cocoyam, botanical extracts, pit, shade, storage.

INTRODUCTION

Cocoyam (*Colocasia esculenta* (L) Schott) also referred to as taro (Dutta, 1990) is a herbaceous root crop, measuring about 0.5 to 2 m tall and belongs to the family of Araceae. It has underground round starchy corm which
produces at its apex a whorl of large leaves with long robust petioles. The leaves are heart shaped and the corms which vary greatly in size are surrounded by a number of secondary corms (cormels). The root system is superficial and fibrous.

Cocoyam is believed to have originated from India and other parts of South East Asia (FAO, 1988). The countries popular with the cultivation of cocoyam are Hawaii, Japan, Ghana and Nigeria. Nigeria is the world’s largest producer of cocoyam. The annual production figure for Nigeria is about 5 million metric tonnes which accounts for about 37% of total world output of cocoyam (FAO, 2007).

Cocoyam is cultivated mainly for the edible corms, the leaves, petioles and flowers are used in soup preparation (Eze and Maduewesi, 1990). The researchers noted that it is nutritionally superior to other roots and tubers in terms of digestibility, crude protein and mineral (Ca, Mg and P) contents. Cocoyam possesses the smallest starch grain size relative to other root and tuber (FAO, 2007) and makes it suitable for several food products especially as food for potentially allergic infants (gluten allergy), persons with gastrointestinal disorders, diabetic patients etc. Increasing awareness and concern for environmental quality makes cocoyam starch granules superior to other sources of starch as agro-industrial material for the production of biodegradable plastics (FAO, 2007).

Chukwu and Nwosu (2008) noted that lack of good storage methods limit the availability of cocoyam all through the year. A preliminary survey that preceded this study showed that farmers commonly stored their cocoyam corms and cormels on raised platforms where they may remain in good condition for up to 3-4 months. Other storage techniques include packing on spots and dusted with wood ash, or leaving on heaps/ridges unharvested for 2 to 3 months but sprouting should not be allowed.

Under these conditions, high rate of rots could have been recorded. Cocoyam like other roots and tuber crops are liable to postharvest losses through a number of factors such as rots, sprouting, and respiration among others. Rots have been associated with microorganisms such as Botryodiplodia theobromae Pat, Fusarium moniliforme Var, Penicillium oxalicum Currie and Thom, Aspergillus niger, Rhizoctonia spp etc. (Okigbo and Ikedigwu, 2000). Some botanical extracts like Jatropha curcas, Zingiber officinale, Azadiratha indica, Xylopia aethiopica have been reported to have anti-microbial properties (Eze et al., 2006) and also effective in control of rots in yams. Therefore, there is need to investigate the use of botanicals and pit treatments for cocoyam storage.

The objective of this study therefore, was to evaluate indigenous technologies of cocoyam storage in Southeastern Nigeria in order to establish the scientific basis for adoption by farmers in the study area and to develop new technology to improve on what they have.

MATERIALS AND METHODS

The experiments were carried out in two phases:

Phase (1) involved collection of farm level information on the existing technologies of cocoyam preservation from the farmers through purposive questionnaire interview. Six local government areas in Enugu state were randomly selected for this study. They are the present Uzo-Uwani, Igbi-Etti, Udenu, Igbo-Eze North, Igbo-Eze South and Nsukka local government areas. The selection was based on the practical evidence that these areas are centres of cocoyam production in Enugu state of Nigeria. Random samples of 120 farmers were selected from each of the six cocoyam production zones giving a total of 720 respondents. Some of the farmers interviewed were not well educated so the questions were read out to them and the answers were filled by the interviewer. Other sources of information on indigenous technologies of cocoyam storage were collected from literature and books.

Phase (2) of the experiment involved the storage of cocoyam (Colocasia esculenta (L) Schott) using some of the technologies based on their frequency of application by the communities. Selection of the investigated technologies was primarily to establish the scientific basis for adoption of such technologies in a wider horizon. The storage study was conducted in the storage field of the Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka (Latitude 06°25’N, Longitude 07°24’E, Altitude 447.26 M above sea level). The storage field was under a plantation of banana and plantain mixture. The plantain and banana crops supply shade that cools the cocoyam storage environment. The experiment was carried out between the months of December 2011 and April, 2012.

Source of cocoyam and botanical extracts

Freshly harvested corms and cormels of cocoyam locally called “Ede Ofe” cultivar were collected from the experimental farm of the Department of Crop Science, University of Nigeria, Nsukka. The sound and clean cocoyams were cured under the sun for four days, and thereafter taken to the storage field where they were evaluated and graded visually to separate the wounded, rotted and disease or pest infested ones from the healthy ones. The healthy ones were separated into corms and cormels. The corms and cormels were put into bulks of 30 pieces each.

Preparation of botanical extracts

Based on survey information, the farmers in the study area put fresh leaves of some plants/botanicals on top of the cocoyams inside the pits before the pit is covered with soil. For purposes of convenience and in order to quantify the amount of these botanicals required for storing cocoyam in relation to the weight, the leaves of these botanicals were dried and prepared into powder. The fresh and mature leaves of the most frequently used botanicals of Jatropha curcas and Casia alata were harvested from the nearby village (Owerre-eseorba); a village beside the UNN campus. The fresh leaves of J. curcas and C. alata were washed clean with tap water, rinsed with sterile distilled water and dried under shade for 7 days. The dried leaves were ground into fine powder using Thomas Wiley’s Laboratory Mill Model 4 in the Physiology Laboratory of the Department of Crop Science UNN.

Storage experiment

The experiment was laid out as 3 x 2 x 4 factorial in completely randomized design (CRD) and replicated four times. The treatments
Table 1. Percentage distribution of farmers and indigenous technologies of cocoyam storage in southeastern Nigeria.

<table>
<thead>
<tr>
<th>Indigenous technologies</th>
<th>Number of farmers</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit + wood ash + soil</td>
<td>70</td>
<td>9.7</td>
</tr>
<tr>
<td>Pit + C. alata leaf + soil</td>
<td>250</td>
<td>34.7</td>
</tr>
<tr>
<td>Pit + plantain leaf + soil</td>
<td>60</td>
<td>8.3</td>
</tr>
<tr>
<td>Pit + J. curcas + soil</td>
<td>220</td>
<td>30.5</td>
</tr>
<tr>
<td>Shade + plantain leaf</td>
<td>40</td>
<td>5.5</td>
</tr>
<tr>
<td>Pit + soil alone (control)</td>
<td>80</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>720</td>
<td>100.0</td>
</tr>
</tbody>
</table>

were three storage techniques and two cocoyam storage organs replicated four times. The storage techniques were Pit + C. alata + soil, Pit + J. curcas leaf extracts + soil and no extract control. Twenty-four pits of each 0.7 m deep and 0.33 x 0.33 m² were dug at the experimental field under plantain and banana shades. Three hundred grammes of each of the botanical extracts were divided into two for each pit. The first 150 g of the botanical extracts were spread at the bottom of the pits to form beddings for the cocoyam while the other 150 g were sprinkled on top of the cocoyams. Each corm or cormel bulk containing 30 pieces was weighed and put at random into the designed pits. The pits were covered with the top soils (sandyloam) in a random manner. The cocoyams were stored for four months (December to April).

Measurements

At the end of storage the following parameters were collected using the formulae thus: Determination of post-harvest losses of cocoyam corms and cormels

\[
\text{% Weight loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100
\]

\[
\text{% physical cocoyam loss} = \frac{\text{Initial number of cocoyam} - \text{cocoyam after storage}}{\text{Initial number of cocoyam}} \times 100
\]

\[
\text{% sprout relative weight} = \frac{\text{Total weight of cocoyam} - \text{Weight of sprout}}{\text{Total weight of cocoyam}} \times 100
\]

\[
\text{% cocoyam rot} = \frac{\text{Total cocoyam rots}}{\text{Total cocoyam stored}} \times 100
\]

Statistical analysis

The data collected were subjected to Analysis of Variance (ANOVA) according to the procedure for CRD using the Statistical Analysis System (SAS) package (SAS, 1999). Mean separation was done by least significant difference (LSD).

RESULTS

Different technologies of cocoyam storage in southeastern Nigeria and percentage of farmers that practice them are shown in Table 1. Out of the 720 farmers sampled, 34.7% used Pit + C. alata leaf + soil to store their cocoyams while only 11% represent those who did not add botanicals in the pit for their cocoyam storage. However, the percentage storage in pits without addition of botanicals was higher than storage in shades covered with plantain leaves. Weight loss from cocoyams treated with C. alata leaf extracts inside storage pits were significantly (P ≤ 0.05) lower than those treated with J. curcas and no treatment control (Table 2). Similarly, treatment of cocoyams with both J. curcas and C. alata significantly (P ≤ 0.05) reduced rot incidence compared to no treatment control but there was no significant difference on the effects of C. alata and J. curcas on sprout relative weight. Application of botanical extracts of J. curcas to cocoyams stored in the pit significantly (P ≤ 0.05) reduced weight loss, percent cocoyam rot and percent physical loss/total damage compared to cocoyams in the pit where no botanical was added. Again, the extracts of C. alata significantly reduced weight loss, percent rot and percent physical loss compared with no extract in the pit storage. Sprout relative weight was significantly (P ≤ 0.05) lower with no extract pit storage compared to the cocoyams where extracts of J. curcas and C. alata were applied. The type of storage organ is important in the storability of cocoyams. Weight loss was significantly lower in stored corms than in the cormels (Table 3). Sprout relative weight varied between cormel and corm but the differences were not significant.

The combined effects of the storage treatments and storage organs on the physical characteristics of the stored cocoyams are shown in Table 4. The interaction effects of the two botanicals, J. curcas and C. alata and the two storage organs, corms and cormels significantly (P ≤ 0.05) reduced weight loss, rot incidence and total damage compared to the combined effects of no extracts (pit + soil alone) and the storage organs. Similarly, combined effects of Pit + C. alata + soil and the corms or cormels significantly (P ≤ 0.05) showed lower weight loss of cocoyam and lower sprout relative weight than the interaction effect of Pit + J. curcas + soil and corms or cormels. Correlation analysis revealed that sprout relative
Table 2. The effects of storage treatments on the physical characteristics of cocoyam in storage.

<table>
<thead>
<tr>
<th>Storage treatments</th>
<th>Physical characteristics of cocoyam in storage</th>
<th>Sprout weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight loss (kg)</td>
<td>Rot incidence (%)</td>
</tr>
<tr>
<td>Pit + soil alone</td>
<td>33.3</td>
<td>35.6</td>
</tr>
<tr>
<td>Pit + J. curcas + soil</td>
<td>29.8</td>
<td>25.8</td>
</tr>
<tr>
<td>Pit + C. alata + soil</td>
<td>28.7</td>
<td>24.9</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>2.72</td>
<td>1.47</td>
</tr>
</tbody>
</table>

Table 3. The effects of storage organs on the postharvest physical characteristics of cocoyams.

<table>
<thead>
<tr>
<th>Storage organ</th>
<th>Physical characteristics of corms and cormels in storage</th>
<th>Sprout weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight loss (kg)</td>
<td>Rot incidence (%)</td>
</tr>
<tr>
<td>Cormel</td>
<td>17.65</td>
<td>25.10</td>
</tr>
<tr>
<td>Corm</td>
<td>15.10</td>
<td>26.67</td>
</tr>
<tr>
<td>LSD0.05</td>
<td>0.95</td>
<td>0.87</td>
</tr>
</tbody>
</table>

ns = Not significant.

Table 4. The interaction effects of storage treatments and storage organs on the physical characteristics of cocoyam in storage.

<table>
<thead>
<tr>
<th>Storage treatments</th>
<th>Storage organ</th>
<th>Physical characteristics of cocoyam in storage</th>
<th>Sprout weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Weight loss (kg)</td>
<td>Rot incidence (%)</td>
</tr>
<tr>
<td>Pit + soil alone</td>
<td>Cormel</td>
<td>32.31</td>
<td>33.5</td>
</tr>
<tr>
<td>Pit + soil alone</td>
<td>Corm</td>
<td>31.60</td>
<td>35.33</td>
</tr>
<tr>
<td>Pit + J. curcas + soil</td>
<td>Cormel</td>
<td>19.65</td>
<td>24.0</td>
</tr>
<tr>
<td>Pit + J. curcas + soil</td>
<td>Corm</td>
<td>16.90</td>
<td>24.95</td>
</tr>
<tr>
<td>Pit + C. alata + soil</td>
<td>Cormel</td>
<td>15.75</td>
<td>24.79</td>
</tr>
<tr>
<td>Pit + C. alata + soil</td>
<td>Corm</td>
<td>15.70</td>
<td>24.78</td>
</tr>
<tr>
<td>LSD0.05</td>
<td></td>
<td>2.50</td>
<td>3.70</td>
</tr>
</tbody>
</table>

Table 5. Correlation analysis for weight loss, sprout weight, total damage and rot of cocoyam in storage.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Weight loss</th>
<th>Sprout relative weight</th>
<th>Total damage</th>
<th>Rot incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rot incidence</td>
<td>0.0754</td>
<td>0.8152**</td>
<td>0.930***</td>
<td>-0.7865*</td>
</tr>
<tr>
<td>Weight loss</td>
<td>0.6557*</td>
<td>0.8976**</td>
<td>0.2458ns</td>
<td></td>
</tr>
<tr>
<td>Sprout relative weight</td>
<td>0.930***</td>
<td>0.2458ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total damage</td>
<td>-0.3456ns</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** Significant at P ≤ 0.0001 ** Significant at P ≤ 0.001 *significant at  P ≤ 0.05 ns = not significant.

weight was highly and positively related with rot incidence (r = 0.82) (Table 5). Total cocoyam damage was also highly and positively related to rot incidence and sprout relative weight.

**DISCUSSION**

Analysis of the survey data showed that farmers in the study area preserve their harvested cocoyam in a variety of ways/techniques. Some the techniques include under shade, storage in pits with addition of some botanicals, storage in pits without botanicals, storage in pits with addition of wood ashes among others. This is similar to the report of the Food and Agricultural Organization (FAO) (2003) that cocoyam is stored in a variety of traditional low-cost structures such as shade, hut and underground pits. The report also noted that cocoyams were stored in heaps in a shade and/or covered with straw or plantain leaves. In parts of southern China, it is
common practice to pile the corms in heaps and cover them with soil or seal them in leaf-lined pits in the ground (Plucknett and White, 1997).

The present study has revealed that farmers in the study area acquired the storage techniques from experience suggesting that no new technology has been developed. However, the result also confirmed that farmers learnt out of experience that the addition of plant extracts (Plucknett and White, 1997) leaf extracts to store for 16 weeks with less than 40% rot for corms and cormels without leaf extract treatments and less than 30% rot where leaf extracts were applied could be attributed to the effectiveness of these botanicals as anti rot causing organisms. This does not agree with Anaele and Nwauisi (2008) report that after 4 months of storage, 94.9% of the stored corms and 36.7% of the cormels got rotten in the pit storage. However, other workers have reported that it was possible to control postharvest rots in other plant products using botanical extracts/fungicides (Uzuegbu and Okoro, 1999). The higher percentage weight loss recorded for the corms could be attributed to the smoothness of the skin which probably enhanced water evaporation. The corms recorded higher rots than the cormels. This is not surprising because when cormels were dethatched from corms at harvest they, the spots on the skin being the attachment points of the cormels, probably created entry points for rot causing organisms. It has been reported (Eze et al., 2006) that yam tubers with wound during storage rotted faster than tubers without bruises. Higher sprout relative weight in the corms was not surprising since the corms were bigger than cormels in size and expectedly produced more vigorous sprouts.

Storage of cocoyam in pit + C. alata + soil reduced weight loss and cocoyam rots in this study. This result suggests that C. alata may have some bio-activities on some rot causing organisms. Similar result on the control of weight loss using ashes from the bark of kolanut tree, neem tree and inflorescence of oil palm has been reported earlier (Eze, 1991).

Very high positive correlation existed between rot incidence and sprout relative weight (r = 0.82) and also between rot incidence and total damage (r = 0.93). These relationships can be explained in the light of report of yam tuber studies by Girardin et al. (1998) that yam is less susceptible to fungal attack than during germination. Shannen (2003) also noted that growth of sprouts increased the respirating rate of yam tuber and predisposed the tubers to invasion by micro-organisms that caused dehydration and rot of yam tuber in storage. It is possible that sprouting of the cocoyam corms and cormels in this study pre-disposed them to pathogenic invasion that caused rot incidence which also caused total damage at higher degree of microbial activities.

**Conclusion**

Cocoyam is an important root crop that has very little period of shelf life. Unfortunately, the preservation methods remain the traditional way and therefore, they are vulnerable to post-harvest losses after harvest. The low period of shelf life could be attributed to their high moisture contents and chemical composition. It can be concluded that cocoyam is one of the neglected crops in the southeastern Nigeria. Therefore, farmers, research scientists and policy makers should combine efforts to develop improved storage technologies of cocoyam preservation in order to make food available for feeding increasing human population.

**Conflict of Interest**

The authors have not declared any conflict of interest.

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