Evaluation of a Ventilated Underground Storage for Cocoyams (Taro)

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ABSTRACT

An experimental investigation, using 106 *Colocasia esculenta* (alternatively called Taro) corms, was conducted to determine the dormancy of cocoyams in three underground pit storage structures for a period of 8 weeks. The structures consisted of pit 1 with two pvc-vents which served as the improved pit, pit 2 with one vent which was regarded as a semi-improved pit and pit 3 without any vent and served as the control pit. Pit air temperatures were monitored and these varied from 27.5 ^{o}C to 29.4 ^{o}C with a mean of about 28.6 ^{o}C in pit 1; and from 28.8 ^{o}C to 30.5 ^{o}C with a mean temperature of 29.6 ^{o}C in pit 2 while in pit 3 the temperatures varied from 30.0 ^{o}C to 31.8 ^{o}C with a mean of 30.9 ^{o}C. The relative humidities attained in the three pits were 83%, 82.5% and 72 % respectively. Corms stored in the improved pit, sustained a weight loss of 1 to 11 % in 8 weeks. Sprouting in this pit started in the second week of storage and the sprouting index was only 34% in 8weeks. Corms stored in pit 2, sustained a weight loss of 1.5 to 15 % in 8 weeks while its sprouting index was 37.7 % In pit 3, weight loss was from 2.5 % to 16.1 % in the 2 months with sprouting index of 47 %. These results may be useful in providing some engineering design specifications for the storage conditions for wholesome cocoyam corms.

Keywords: Cocoyam, underground storage, sprouting index, pvc-vents, Nigeria

1. INTRODUCTION

Taro, a perennial herb, originated in South Central Asia and it is presently grown widely around the continents of the World (Nail, 1984). Its production ranged from 6 tonnes/ha in Nigeria; 14 tonnes/ha in Japan, 15 tonnes/ha in Trinidad, to 75 tonnes/ha in Hawaii (FAO, 1974). Cocoyams have diverse use but in most of the production areas, they have a prominent role of a staple food. Like most tubers, the storage of taro (*Colocacia esculenta*) corms has remained a problem due to inadequate storage systems, and this problem hinders its use and further research into the various needs of the produce. Losses of about 50 % to 95 % have been recorded in a storage period of 2 to 5 months (Passam, 1982). These losses are due mainly to physical damage during harvest as a result of rough handling, punctures, cuts and abrasion, which cause high rate of moisture loss. Physiological processes are known to have contributed to the losses in corm storage especially sprouting activities. Praquin and Miche (1972) had reported losses of between 25 to 86 % as a result of sprouting in a storage period of 5 months. Corms stored at high temperatures above ambient experience natural endogenous respiratory and transpiratory losses and these conditions directly influence the quality of produce and even make them highly susceptible to microbial attack. Another loss factor is that of pathogens. They cause rapid and excessive breakdown of corm tissues. Most of these pathogens are traumatic parasites at wound sites. Initial attack is usually by a few specific pathogens followed by a massive infestation by weaker ones and saprophytes that grow on the dead tissues remaining from the primary infection. The fungi reported as important to pathogen include *Fusarium solani*, *Botyodiplodia theobronia*, *Rhizopus stolomfier*, *Aspergillus niger* and *Sclerotium rolfsii* (Ogundama, 1975; Nwufo, 1980; Maduewese and Onyike, 1981). Nwufo (1980) reported specifically that the mode of infection is through wounds. Some difficulties have been expressed in the fresh tuber and root storage as observed in Obetta and Ezeike (1996) and also reported in Ezeike (1984). Methods used to store fresh corms are many and varied. They include storage in traditional barns, (Onwueme, 1982); cribs and heaps, (Asiedu, 1992); in ditches, (Sussan and Anne, 1988) as well as the use of irradiation and sprout inhibitors. Added to these methods, factors such as corm maturity, environmental conditions, agro-climatology, degree of physical damage and a host of pre-harvest factors contribute to the variability of results reported in the literature.

Even within the same environmental conditions, storage stability varies among and between root species. For instance, under high storage temperatures of 25 ^{o}C and above and relative humidity of 85% and above, it has been found that more sprouting and decay occurred with Taro than another variety Tannia cormels (Agbo-Egbe and Rickard, 1991). Soil type condition conducive for successful underground storage is a well drained sandy soil profile. 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, 1979).

In the Makurdi farming area and Eastern part of Nigeria where the production of cocoyam is predominant, underground storage is common and adopted especially if the goal is to preserve corm seeds and cuts for future planting. The excesses therefrom are usually processed into cake, and dry chips as may be desirable. The imperative need of having these crop varieties stored successfully for the purpose propagation in new seed cropping season that informed the necessity for this study. The objective of this study is therefore to develop underground pits structures with built-in flues; and to evaluate the storage performance in terms of temperature and relative humidity of the air within the pit; as well as weight loss and sprouting index of the corms.

2. MATERIALS AND METHODS

Three identical storage systems essentially pit structures were constructed, equal in shape, size and height measuring 1.2 m deep, 0.9 m wide, 1.1 m long each as in Fig. 1 and are designed to hold up to 5 kg quantity of corms. The covers of the pits are made of

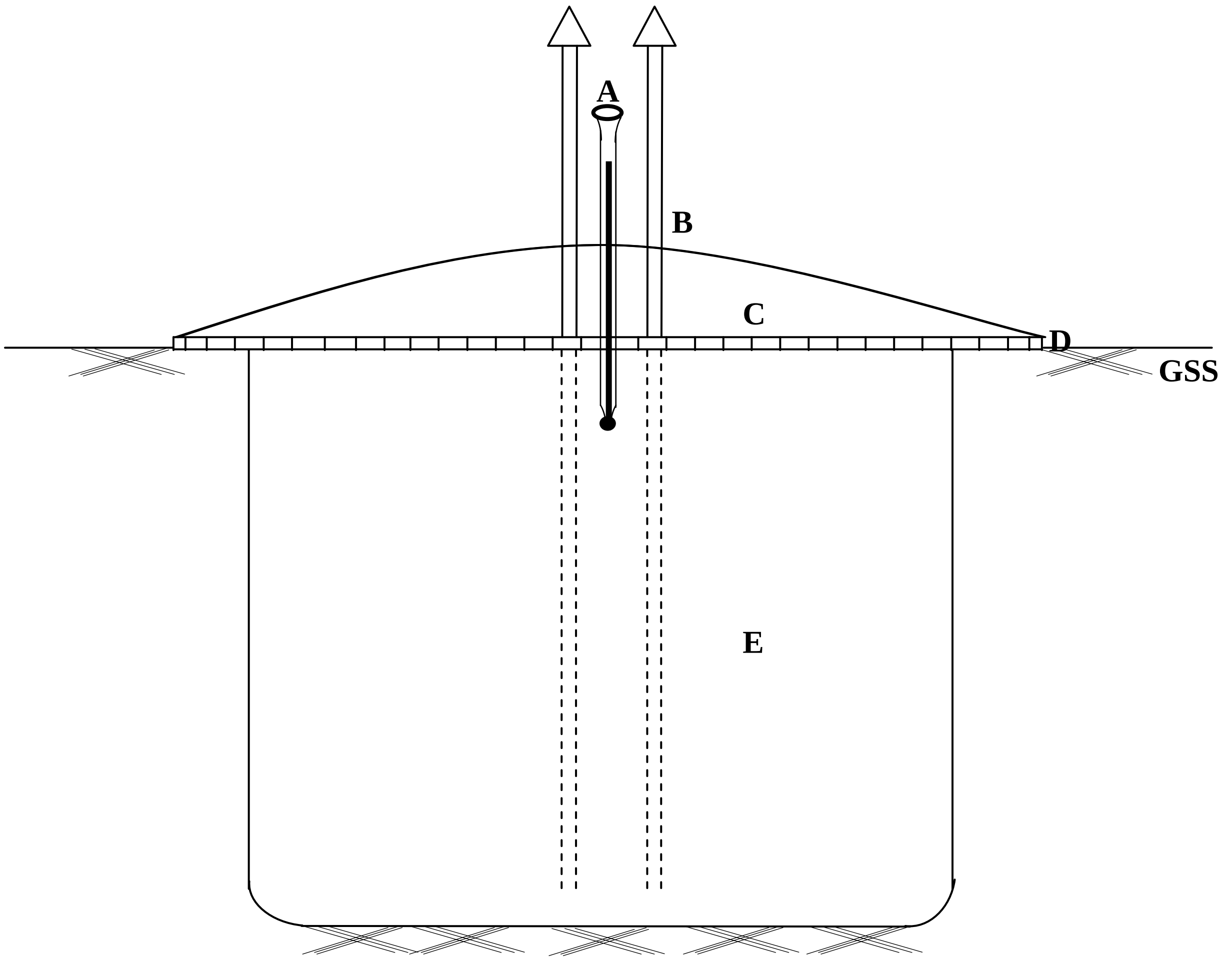

Figure 1: A Schematic Diagram of the Underground Pit Storage Structure.
A – Thermometer; B – Vent Flues (2 No.); C – Cover; D – Hard Built Carton; E - Underground Pit; GSS – Ground Soil Surface

hard-built carton material and are of equal dimensions with each measuring 1.52 m long, 1.2 m wide and 0.3 m thick. These covers were placed over the pits in such a way that they could be removed to allow access into the pit. To enhance vertical air flow through the pit, three PVC pipes, each measuring 1.87 m long and 0.037 m diameter, were located centrally through the cover structure down enough to be in contact with the corms. The pipes were painted black to aid the natural upward flow of air and also serve as vents. The three pits were each fitted with industrial thermometer for pit air temperature measurements. These arrangements were situated in a shed in an area within the University of Agriculture, Makurdi, where the soil type formation was a layered profile made up of sandy soil that forms the top soil, followed by a stony soil layer, and then by a layer of coarse sand mixed with fine sand and finally by a layer of clay soil good enough for proper water drainage. The pits were arranged in an open air to facilitate natural air draft through the vents.

Colocasia esculenta (taro) was used for the experiment. The corms were obtained from the farm in Makurdi about 4 days after harvest. They were carefully selected, identified and cured at about 30 - 40 ^{o}C and 90 – 95 % RH for between 1 - 7days (Osagie, 1992). They were then thoroughly cleaned by trimming off every other roots attachment and dusted with ashes. A wet and dry-bulb thermometer was prepared and mounted to record the relative humidity. 1/7th of the corms were loaded into a basket ready for storage after weighing with a Mettler balance sensitive to 1 gm. The three storage structures used for this study were: pit 1 with two vents which served as the improved pit, pit 2 with a vent which served as the semi-improved pit; and pit 3 which was without any vent and served as the control.

2.1 Experimental Procedure

Before loading was done, the bottom and sides of the pits were overlaid with ashes to prevent the attack of termites as well as reduce the incidence of unusual decay. Dry plantain leaves were also spread to prevent the corms from making contact with the moist soil, which may encourage deterioration of the corms.

The pits were then loaded with the dusted corms. Baskets were weighed empty, loaded and weighed again; the difference giving the weight of the corms. A basket of corms was then suspended in each pit to ease removal from the pit for subsequent weighing with the Mettler balance. The pits were then covered with the constructed covers. The weights of the corms were measured on weekly basis.

The dry- and wet-bulb temperatures of the pit were measured daily by the thermometer. With the dry- and wet-bulb temperatures recorded, the corresponding relative humidity values were determined from the psychrometric chart. The readings were obtained at noon hour and at 6:00 pm. Corms were observed for rot development and sprouting (first occurrence of sprouts in the eyes, not exceeding 10 mm) during each observation visit. The sprouting index was determined from the expression:

$$\text{Sprouting Index} = \frac{\text{Number of sprouted corms}}{\text{Total number of corms}} \, x \, 100 \;\ldots\ldots\ldots (1)$$

For instance, a second visit to pit 1 showed the number of sprouted corms to be 2 while the total number of corms was 106. If these values are substituted into equation (1) above, the sprouting index is obtained thus:

$$\text{Sprouting Index} = \frac{2}{106} x100 = 1.87\ \% \approx (1.9\ \%)$$

The various measured temperatures (pit air, wet- and dry-bulb and ambient temperatures) were collected twice daily: at noon and evening at 6:00 pm. The thermometers used were fixed permanently throughout the storage period.

The average data per week for the storage period of 8 weeks was tabulated as shown on Table 1 while the average humidity and the ambient temperature of the storage area as shown on

Table 1: Average data per week for the storage period of 8 weeks

Table 1-A	Pit air temperature (^{o}C) vs storage time (weeks)							
Week	1	2	3	4	5	6	7	8
Pit 1	28	27.9	29.4	28.9	28.5	28.8	28.5	29
Pit 2	29	28.9	30.5	30.1	29.5	29.5	29.5	30
Pit 3	30	30.1	31.6	31.3	30.8	30.8	31	31.5
Table 1-B	Relative humidity (%) vs storage time (weeks)							
Week	1	2	3	4	5	6	7	8
Pit 1	50.6	77.1	66.6	76.8	79.3	83	82.5	83
Pit 2	44.8	69.8	60.4	69.9	72.1	72.5	76	76.5
Pit 3	39.6	63.7	55.1	63.6	66.7	72	67.5	68.5
Table 1-C	Sprouting index (%) vs storage time (weeks)							
Week	1	2	3	4	5	6	7	8
Pit 1	-	1.9	9	16.9	18.9	19.8	28	34
Pit 2	-	2.8	11	20.8	22.6	23.6	33	37.7
Pit 3	-	4.7	13	23.6	27	28	37.7	47
Table 1-D	Various temperature in the pit area vs time (weeks) fig 6							
Week	1	2	3	4	5	6	7	8
Ambient	36.4	37.9	38.7	38.9	38.6	40	40	39
Wet-bulb	19.9	24.4	23.9	25.5	25.6	26.5	26	26.5
Pit 1	27.5	27.9	29.4	28.9	28.5	28.8	28.5	29

Table 2 are 32.63 % and 38.69 °C respectively. The weekly weight loss, in percentage, was

Table 2: Average relative humidity and ambient temperature for the period of storage

Week	Ambient (dry-bulb) Temperature (°C)	Wet-bulb Temperature (°C)	Relative Humidity (%)
1	36.4	19.9	21
2	37.9	24.4	32
3	38.7	23.9	30
4	38.9	25.5	35
5	38.6	25.6	36
6	40	26.5	35
7	40	26	34
8	39	26	38

calculated and presented on Table 3.

Table 3: Cumulative Weight Loss (%) of Corms stored over an 8-week period

No of weeks	Weight Loss (%)			Cumulative Weight Loss (%)		
	Pit 1	Pit 2	Pit 3	Pit 1	Pit 2	Pit 3
1	1	1.5	2.5	1	1.5	2.5
2	1.5	3.0	3.4	2.5	4.5	5.9
3	2.1	3.5	6.3	4.5	8.0	12.2
4	3.5	7.0	8.0	8.1	15.0	20.2
5	4.9	9.4	11.5	13.0	22.4	31.7
6	6.5	11.5	13.6	19.5	35.9	45.3
7	8.0	13.0	15.5	27.5	48.9	60.8
8	11.0	15.0	16.1	38.5	63.9	76.9

3. RESULTS AND DISCUSSION

Figure 2 of table 1-A shows the variation of pit air temperature in the controlled pit 1, pit

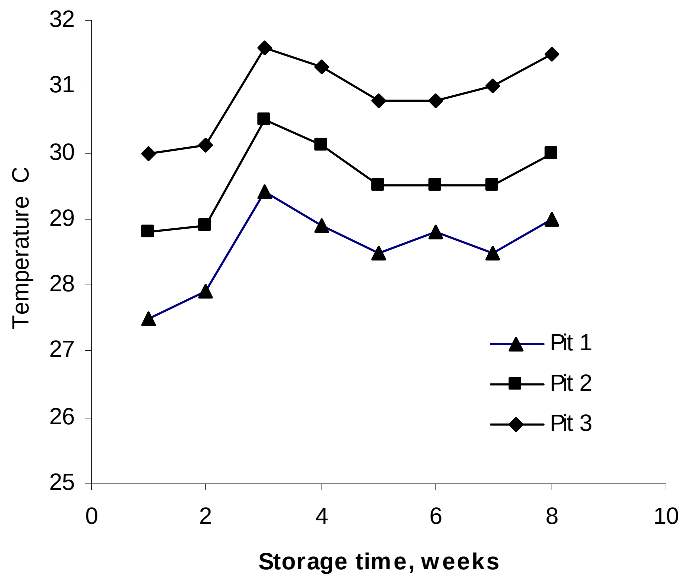

Fig. 2: Variation of pit air temp. (oC) vs storage time

2 and pit 3 storage structures over a period of 8 weeks. Air temperature varies from 27.5 ^{o}C to 29.4 ^{o}C with a mean of about 28.6 ^{o}C in pit 1, and from 28.8 ^{o}C to 30.5 ^{o}C with a mean of 29.6 ^{o}C in pit 2 while the air temperature range in pit 3 varies from 30.0 ^{o}C to 31.8 ^{o}C with a mean of 30.9 ^{o}C.

The pit air temperature showed a patterned increase as the number of vents' insertion in the storage pit decreases from pit 1, to pit 2 and down again in pit 3 in that order. It would be observed that an increase in the number of vents in pit 1 would subsequently result in a greatly reduced air temperature. This trend of temperature distribution is significant when the analysis of weight loss of cocoyam corms in a given environment becomes a subject of study. High temperature environments facilitate increased rate of respiration, exerting high corm vapour pressure and enhance significantly the sprouting activity during the later stages of storage of the corms and subsequent loss of weight. This is because at high temperatures, there is the tendency for increased metabolic activity and transpiration associated with the total energy content of the corm that could result in greater weight losses. Figure 3 shows a comparison of the cumulative

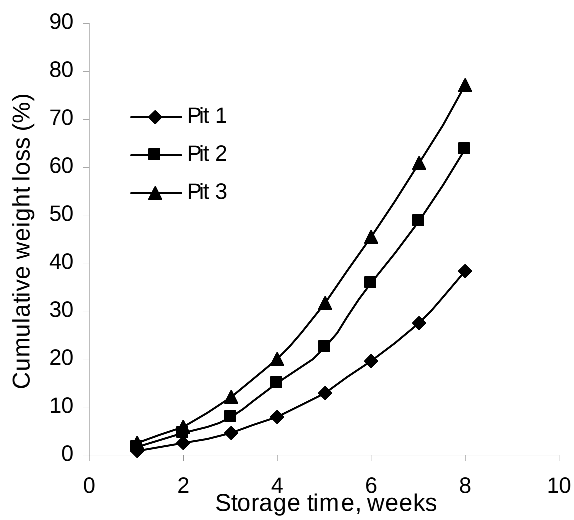

Figure. 3: Cumulative weight loss (%) vs storage time

weight loss of the corms stored in pit 1, pit 2 and pit 3. The data shown on table 3 of this plot were obtained from corms of identical weight with intrinsic quality and corms that showed no visible signs of decay. It was observed that corms in the improved pit 1 sustained a weight loss of 1.5 to 11 % in 8 weeks of storage, while those in pit 2 had weight loss ranging from 3.0 to 15.0 % and the corms in pit 3 structure experienced up to 16.1 % weight loss in the same storage period.

Also shown on table 1-B of plot Fig. 4 is the variation of relative humidity in the storage structure over the storage period. Due to normal diurnal variation of relative humidity, readings taken at noon hour will represent the minimum values attained in the structure. The readings taken at 6:00 pm local time are approximately the maximum values of relative humidity. It can be seen that humidities in pit 1 are near optimum necessary for curing of the periderm cells. The lower humidities attained in pit 3 are observed to be capable of enhancing the dehydration of the

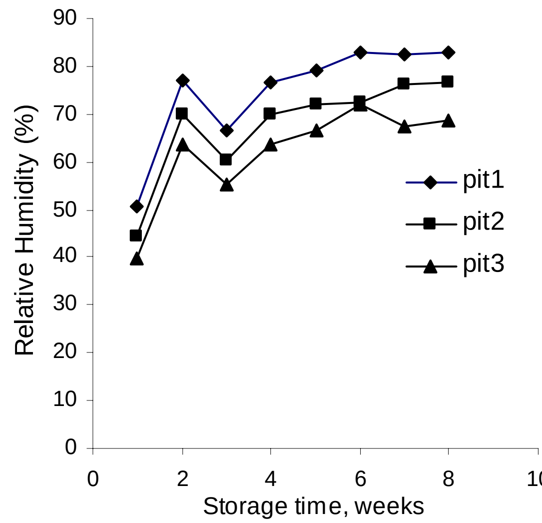

Figure. 4: Relative humidity (%) vs storage time

corm due to the reason that the generated ambient vapour pressures are relatively lower. This therefore ensured greater driving potentials for the exchange of moisture than would have been experienced in pit 1 and pit 2.

One reason for the high humidity values attained in pit 1 is that the soil was always in a moist condition and thus the air in contact with it was often laden with moisture. In addition, lower temperatures tend to condense moisture from air.

An important problem associated with the storage of root crops, especially underground, is the mechanism that will regulate dormancy and check sprouting. The sprouting activity of corms stored in the experimental storage structures is shown in Fig. 5 from the data on table 1- C. It was observed that sprout development was appreciably less in the pit 1 storage where the temperature range was relatively lower. Because of the early rains, the storage period could not reach the point where the corms in pit 3 would have attained 100 % sprouting. The temperatures in pit 1 and pit 2 are lower than those in Pit 3, but the absence of the vents and limited ventilation in pit 2 might have resulted in localized heat pockets in this structure and therefore promoting the

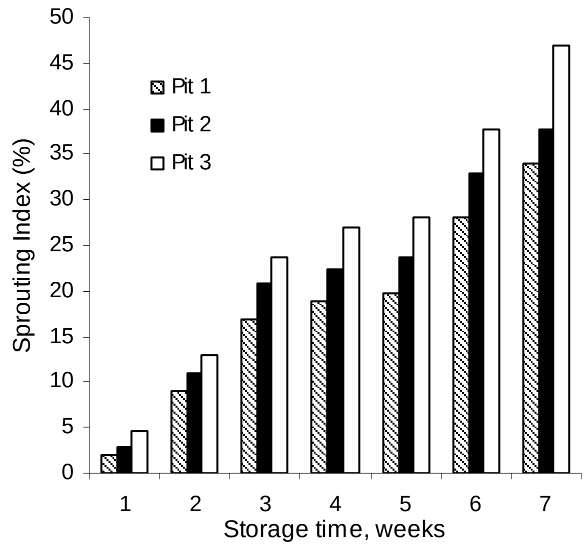

Figure. 5: Sprouting pattern of cormels in the three storage structures

increased sprouting activity.

One probable explanation for the lower temperatures attained in pit 1 is the heat balance within the storage structure. Figure 6 of table 1-D shows a typical relationship among the

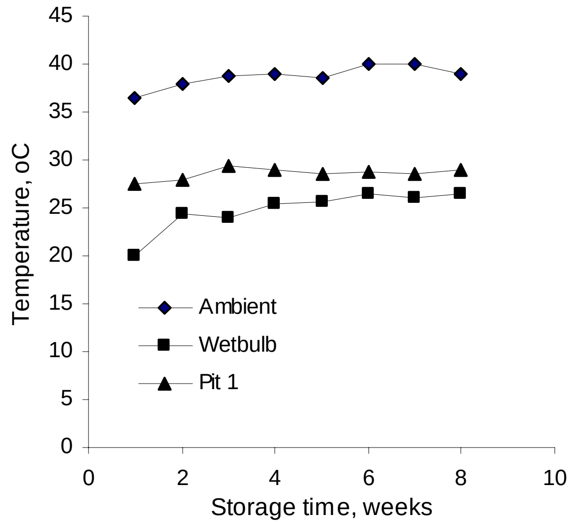

Figure. 6: Various temperatures in the storage environment

ambient air temperature, air temperature in pit 1 and the wet-bulb temperature. The low temperature in pit 1 might also be as a result of sensible latent heat exchange between the air and soil.

4. CONCLUSION AND RECOMMENDATIONS

A total of 5 kg (106 corm units) cocoyam corms (*Colocasia esculenta*) stored under tropical conditions for 2 months were used to obtain quantitative data on corms' weight loss as affected by environmental factors such as temperature, and relative humidity. Three pits were dug for this experimental work. Two of the pits have one and two PVC vents respectively inserted in them to provide vertical airflow while the third, without a vent, served as a control. Pit air temperatures and relative humidities were monitored as long as the corm storage lasted in addition to the weight loss of the stored corms.

The stored cocoyam sprouting patterns were observed weekly and subsequently, the various sprouting indices were calculated while the weight loss was recorded weekly. From the results generated, it was observed that Pit 1 with two vents had the lowest air temperature, followed by pit 2 and lastly pit 3 in that order. This behaviour was attributed to the insufficient air flow especially with pit 2 and pit 3. This air ventilation also affected the sprouting pattern and weight loss in that order. However, the relative humidity in pit 1 was the highest among the three pits because of the presence of the vents. The variations in the pit air temperature affected the storability of the product. This was observed in pit 3 with the highest air temperature. Significant deterioration in corm quality accelerated sprouting and the consequent weight loss occurred more in the pits with lesser or no ventilation.

This preliminary study is indicative of the prospects of effective subterranean storage techniques for cocoyam corms. Further studies are needed to be conducted on the effects of increased ventilation on the storage performance indices. More ventilation will likely expose the stored cocoyam to relatively low temperatures, which on the other hand can encourage the growth of deleterious pathogens, desiccation or greater loss in weight especially in the low relative humidity conditions of the harmattan weather. It is therefore recommended that a simulated modelling of the storage structure be carried out since information on the physical parameters of the structure are readily available. The advantage of this is immense as the study will eliminate endless experimentations, yet produce results that can conveniently establish all the critical limiting factors. Corms of different varieties with intrinsic qualities of low minimum damage from harvest activities, handling and transportation should be employed in a further study. With such studies, efficient cocoyam storage facility can be prescribed and the supply and utilization of cocoyam in the food economy of Nigeria will have increased.

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