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Storability of *Puna* as Influenced by Sprout Control Method and Stage of Harvested Yam

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Abstract

Sprout development, which is the break of dormancy period in yams, affects its quality and dry matter quantity as well as its market value. This study assessed the effect of various sprout control methods on *puna* yam variety at different harvesting stages during storage in both traditional and improved barns. The traditional structure was constructed by local farmers and improved structure by scientists from the CSIR-Crops Research Institute, Kumasi using locally available materials. A total of 160 *puna* yam tubers were sampled and randomly stocked into both yam structures. Weight, sprouting (number, length and weight of sprouts) and externally visible rot data were taking at stocking and at 30 days' interval for 120 days' storage period. Sprout control treatments/methods considered were; control, hand snap, full cut and half cut. Environmental conditions in both structures were conducive for yam storage. However, the traditional storage structure maintained relatively higher moisture resulting in the higher mean monthly relative humidity experienced. Full cut control method had the highest percentage weight loss (51%) and half cut method, the highest sprouting rate and percentage visible rot at 9.2 cm/d and 36% respectively. In terms of yam sprout control, hand snap was best at reducing weight loss, tuber rot and sprout rate. Also, unmilked condition recorded highest percentage weight loss and rot. Therefore, milked condition of *puna* yam is a better option for minimized weight loss and rot. There was no significant difference ($p<0.05$) in percentage weight loss and rot for sprout control methods and harvesting stages. However, there was significant difference ($p<0.05$) in number of sprout and rate of sprout for sprout control method and harvesting stage. Weight loss had a negative relationship with number of sprout, rate of sprout, sprout length and weight whereas percentage visible rot had a good positive correlation with weight loss. It is however recommended that similar study be conducted on other yam varieties under varying storage conditions and ecologies. Again, the effect of yam positioning at storage on sprout control could also be looked at.

Key words: Sprout control methods, yam condition, storability, weight loss, yam storage structures

Introduction

Yam is the second most produced tuber crop in Ghana and West Africa (Robertson and Lupien, 2008) and contributes over 2,000 dietary calories daily to over 60 million people across West Africa (Bolarinwa and Oladeji, 2009). Yams *(Dioscorea spp.)* are starchy large tuberous staple food crops and they are produced by annual and perennial vines, roots and tubers (IITA, 2007). It has a high calorie content of 381 kcal per 100 g, good amount of protein of 4.94 per 100, vitamins of 64 mg 100 g, fiber of 13.23 g per 100 g and minerals of 2.97 g per 100 g (Jonathan et al., 2011). The Northern, Brong Ahafo and northern Volta regions are the major producers of yams in Ghana. Some common varieties produced in the country are *Puna*, *Asena (Mpuanu), Dente (Punjo) and Orlondor (also called Nigeria)* with *Puna* being the most preferred variety due to its early maturing, high yielding and sweetness (MiDA, 2010).

The storage of fresh yam tubers has been confronted with major postharvest losses over the years. Physiological and pathological factors have been discovered as the two major factors contributing to losses in storage (Ravi et al., 1996;

Kader, 2005; Imeh et al., 2012). Physiological activities are transpiration and respiration which causes weight loss, sprouting thus, turning of edible tuber carbohydrates to inedible sprout, and desiccation (Osunde, 2008; Imeh et al., 2012). Moulding and bacterial infection were classified under pathogenic causes of postharvest losses in yams (Dumont, 1995). Sprouting which is a physiological activity that causes postharvest losses in yam tubers in storage bring about some changes in their internal composition, thereby, resulting in loss of nutritional qualities (Serge and Agbor-Egbe, 1996; Afoakwa and Sefa-Dedeh, 2001; Osunde, 2008). It can also cause 10 % weight losses within 3 months and up to 25 % weight losses in 5 months under normal storage condition (Robertson and Lupien, 2008). Ezeh (1995) and Osunde (2008) classified sprouting amongst weight loss, insect attack and microbial as the major cause of postharvest losses in yams. Weight loss is greatly influenced by respiration and transpiration whereby transpiration is accelerated by sprouting (IITA, 1995; Kader, 2005). In yams, metabolic losses may account for one-third of the total weight losses of sound tubers during storage. Sprouting contributes immensely to metabolic losses and this is one of the most important causes of deterioration in stored yams. Sprouting could occur in 100% of the yams after 4 months' storage under ambient conditions (Coursey, 1961; Coursey, 1967; Adesuyi and Mackenzie, 1973 all cited in: IAEA, 1997).

Stage of yam harvest has been found to affect its storability. Okwuowulu et al. (1999), found out that, yam age at harvest significantly affected its storability and tubers harvested at 6 or 7 months after planting stored best. Yams are either harvested once (single harvesting) or twice (double harvesting) during the season. Topping, beheading and milking is the term for first harvest all of which have been considered inadequate and obsolete. The time of harvest affects tuber maturity, yield and postharvest quality which include sprouting, weight loss and rot (Opara, 2003).

The ideal optimum temperature favourable for sprout development among tropical species is between 25 and 30°C (Osunde, 2008) and when yams are exposed to higher temperatures of 35°C, about 85% of sprouting is expected to occur after 95 days of storage (Passam, 1977). Temperatures between 15°C and 16°C were found to extend dormancy. Due to temperature fluctuations in yam barn, sprouting takes place steadily and/or progressively earlier during warmer conditions until it reaches the optimum (Elsie, 2011). Storage environment for yams must inhibit the onset of sprouting which increase the rate of dry matter and subsequent shrivel and rotting of tubers. Tubers transit and storage life of 6 to 7 months can be achieved under these conditions (Plucknett, 1979; Passam et al., 1978; Opara, 1999). Moisture, temperature and relative humidity are major factors influencing the growth and production of microorganisms in yams (Kay, 1973). These factors must be controlled at minimum levels to extend dormancy in yam storage.

Sprout development is the break of dormancy period in yams. The onset of sprouting in yams that are meant for the market seriously affect their market value. Therefore, controlling sprouts development by extending dormancy period of yams will largely benefit both farmers and yam marketers. Prices of yam tubers do increase towards the lean season, beginning from February each year and farmers who have yam tubers, especially white yam varieties *(e.g. puna and dokoba)* during the lean season period (February to June), make much profit (Dramani, 2013). One way to store *puna* variety of yam for much profit in the lean season is to control sprouting. Therefore, the objective of this study was to assess the effect of various sprout control methods on storability of *puna* at different harvesting stages during storage in both traditional and improved barns.

Materials and Methods

Study location and materials

The study was conducted at Abour community in the Atebubu-Amantin District in the Brong Ahafo Region of Ghana. Abour is located within the transitional zone between the wet semi-equatorial and tropical savannah climate regions. The district covers a land area of 1,996km^2 (ADA, 2013). The vegetation comes under the interior wooded savannah type, although due to its transitional nature, the area does not totally exhibit typical savannah conditions. Soils in the District range from fine sandy loams to clayey loams, and are mostly poorly drained. The mean monthly temperature ranges from 30^{o}C in March to 24^{o}C in August. Mean annual temperature ranges between 26.5^{o}C and 27.2^{o}C. In extreme cases temperatures rise to about 40^{o}C. Relative humidity ranges from 90% - 95% in the rainy season to 75% - 80% in the dry season. The total annual rainfall is between 1400 mm to 1800 mm and occur in two seasons. The first rainy season (major) begins in May or June whilst the second rainy season which is the minor season, begins in September or October (ADA, 2013; GSS, 2014).

The sprout control experiment was done with *Puna* yam variety at different stages of harvest (milked and unmilked). Two yam storage structure/barn types namely, improved (Fig. 1) and traditional (Fig. 2) were used for the study. Yam barns were constructed at suitable sites at study location.

Fig. 1. Improved yam storage barn

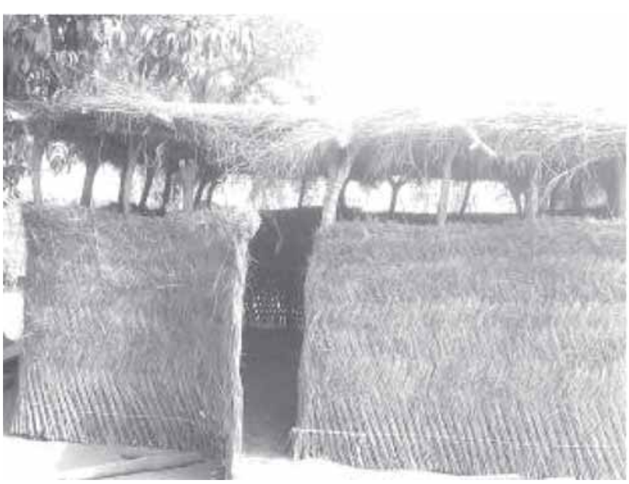

Fig. 2. Traditional yam storage barn

The improved yam barn was constructed by scientists from the CSIR-Crops Research Institute, Kumasi together with the yam farmers' group in the community using locally available materials. The traditional yam storage barn however was constructed by the farmers in the same manner as is practiced in the locality. Some locally available materials used for constructing the yam barns included *Borassus* palm wood pieces, thatch (grass) and straw. In terms of capacity, the improved barn with a specification of 10 feet width × 22 feet length × 6 feet height, could take up to 10,000 pieces of average sized yam tubers whilst the traditional barn could take up to 5000 pieces (Amponsah et al., 2015).

Data collection and analysis

Tinytag sensor TGP-4500 was used to determine the environmental/climatic conditions (Relative Humidity and Temperature) within and outside each yam barn type. They were installed to record data before loading yams into barns (pre-loading) and during (loading) storage process.

A total of 160 *Puna* yam tubers were sampled per storage structure/barn and initial weight of each tuber determined with an electronic balance. Each yam tuber was labelled from 1 to 160 with a marker pen and randomly placed within respective barns. All 160 tubers were assessed after 1 month for weight, sprouting (number, length and weight of sprouts) and externally visible rot. Sprouting tubers were divided into 4 treatments as follows; control (no treatment), hand pick (snap off the sprouts by hand), full cut (cut sprouts off close to the base using a knife) and half cut (cut sprouts off half way up to the first node).

After treatments were applied, tubers were not weighed but returned to store until next assessment. All 160 tubers were assessed for weight, sprouting and externally visible rot at 30 days' intervals for 120 days' storage period. Tubers that were not previously sprouting, but had sprouted in next assessment were divided into the 4 treatments, ensuring that tuber number is recorded against respective treatments. Tubers previously sprouted were retreated where there has been new growth.

Number of sprout were determined by counting all visible sprouts on sample. Sprout is then removed with a kitchen knife and longest sprout measured with a rule. Sprout rate was measured by dividing the length of longest sprout by the storage duration under assessment. All sprouts are removed from sample and weighed on an electronic balance to determine the weight of sprouts per sample. Final weight of sample is determined by subtracting sprout weight from the monthly determined weight. This was used to calculate the weight loss or gain by a sample for that storage period.

Visible rot in yam tuber/sample was also assessed by transversely cutting it into eight parts using a kitchen knife; head, six middle parts and tail. Percentage visible rot on each cut surface was assessed by dividing the surface into quadrants and estimating each as 25%. Overall visible rot was determined for each tuber.

Analysis of variance was done with Genstat version 9.2 using two-way ANOVA in randomized blocks. The two structures for the experiments (improved yam storage structure and traditional yam barn) were blocked and yam conditions and sprout control methods considered as treatments. All interactions were determined from the analysis. The same was repeated by blocking stage of harvest and considering storage structure as treatment. These were done at a confidence level of 95 % (thus, $p < 0.05$). Correlation was done amongst parameters in Genstat. MS Excel 2016 was used for descriptive statistics and plotting of graphs.

Results and Discussion

Storage conditions

Mean monthly temperature and relative humidity at the study location from January to June within and outside both traditional and improved storage structures are shown in Fig. 3.

Mean monthly temperature ranged from 27°C to 29°C inside both improved and traditional barns and from 27°C to 30°C outside both storage barns. Temperature range inside barns was similar to that in improved barns reported by Adebowale et al., (2016). The improved barn had better temperature range compared to barn with fan which fluctuated between 20.5 and 36°C (Osunde and Orhevba, 2010). Mean monthly relative humidity ranged from 46% to 79% inside the improved barn, from 47% to 83% inside the

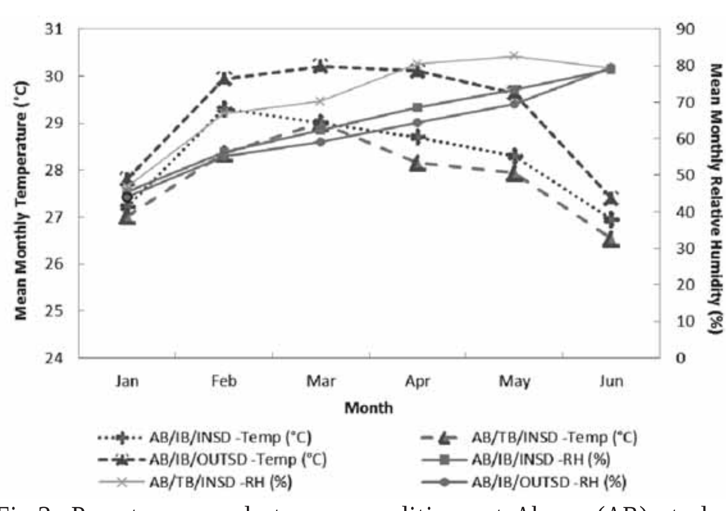

Fig.3. Pre-storage and storage conditions at Abour (AB) study location within (INSD) and outside (OUTSD) both traditional (TB) and improved (IB) yam storage barns

traditional barn and from 44% to 79% outside both storage structures. This is similar to the range of modern barn used by Osunde and Orhevba (2010) which was between 26.5 - 60.4% and 23 - 55% for barn with and without fans respectively.

From Fig. 3, the mean monthly temperatures inside both storage structures generally increased from January (pre-storage) to between March and April before experiencing a steady decline from May to June (end of storage). This could be attributed to the fact that respiration rate for freshly stored yams was increasing, causing a corresponding increase in temperature within the barns in the first three months (PHTB, 2004). Due to the loss in yam weight over time resulting from expenditure of carbohydrates, respiration rate tends to decrease getting to the end of the storage period causing the steady decline in temperature within the storage barns. The temperatures inside both improved and traditional yam barn fall within the optimum temperature for sprouting among tropical species (Osunde, 2008). Since is not up to 35°C sprouting is expected to be less than 85% (Passam, 1977). High temperature has been found to raise the level of enzymatic catalysis leading to biochemical breakdown of fresh produce compound (Osunde and Orhevba, 2009). Continuous air flow in yam barn as experienced in improved barn has a significant reduction on weight loss and sprouting of white yam tubers (Osunde, 2008). The mean monthly Temperature outside the barns was generally higher than within for both storage structures.

The mean relative humidity inside and outside both traditional and improved storage structures increased steadily from January (pre-storage) to June (end of storage). This trend was expected due to the fact that the dry season (Harmattan) phases out from January through to June with the gradual onset of rains which results in increased atmospheric moisture; thus increased relative humidity as the month goes by. However, the mean monthly relative humidity inside the traditional yam storage barn was relatively higher than both within and outside the improved yam storage barn but comparatively lower than a modern yam barn used for sprout control experiment in Nigeria (Adebowale et al., 2016) which ranged between 80.4 – 91.1%.

Percentage weight loss

The average percentage yam weight loss at 30, 60, 90 and 120 days of storage as influenced by method of sprout control; hand snap, half cut, full cut and control is shown in Fig. 4. It could generally be deduced that percentage yam weight loss increased with increasing period of storage for all methods of sprout control.

At the end of yam storage trial (after 120 days), it could clearly be seen that cutting the sprout fully at the base of yam resulted in the highest weight loss of 51% as compared to hand snap method which was 42.4% as the least weight loss. Removal of sprouts has been found to reduce weight loss during storage and increases shelf life of yams (Martin, 1977; Gerardin et al., 1998; Osunde et al., 2003). After 90 days of storage, control had about 6% weight loss above the others which might be attributed to the continuous growth of sprout. Low rate of respiration at the beginning of yam storage which is later followed by respiration rate coinciding with sprouting is a factor contributing to the continuous weight loss (PHTB, 2004). The result is confirmed by Robertson and Lupien (2008) who reported 10-20% weight loss after 3 months of storage and about 50% after 6 months of storage. Weight loss was higher than that of white yam *(D. rotundata)* stored for 110 days under normal storage condition (28°C), which was found to be 31% (Serge and Agbor-Egbe, 1996). It implies that *puna* as a variety

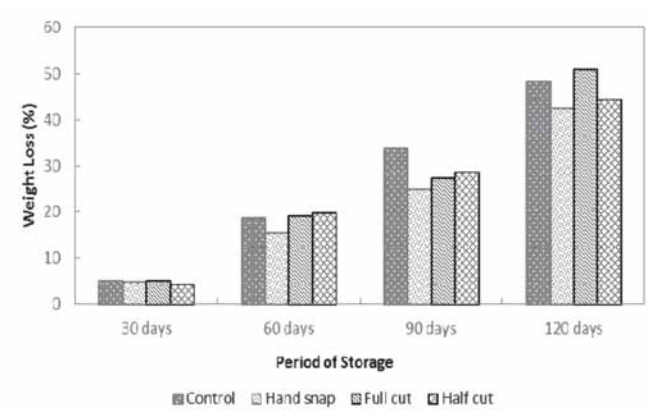

Fig.4. Average percentage tuber weight loss as influenced by sprout control methods at 30, 60, 90 and 120 days after storage.

of white yam in Ghana losses moisture faster despite the similar temperature during storage. Results after 2 months of the study can be compared to tubers treated with neem leaf slurry and neem bark extract before storage in barns with fans which was between 21 – 26 % and that of 3 months comparable with same treatments stored in barns without fans averaging 28 % (Osunde and Orhevba, 2010).

However, there was no significant difference among treatments at probability level of 5% under the same yam conditions but significant difference was recorded between milked and unmilked yams for the sprout control methods at $P < 0.05$. Percentage weight loss of $64.79 \pm 13.45\%$ in an un-irradiated being significantly ($p \leq 0.05$) higher than the irradiated water yam tubers (Imeh et al., 2012) qualifies the improved storage structure to be considered for water yam storage and its sprout control.

Sprout length and rate

Mean length of longest sprout as influenced by sprout control methods is shown in Table 1.

Table 1. Average length of longest sprout (cm) at storage for *Puna*

Sprout control methods	30 days	60 days	90 days	120 days
Control	0	0	0	145
Hand snap	2.29	48.8	50.6	73
Full cut	2.06	62.3	89.3	112.5
Half cut	3.75	36.2	72.1	70.1

Control had the longest length of 145 cm after 120 days whereas half cut recorded the least at 70 cm after same storage period. The 60 cm average difference recorded between control and other methods was attributed to the fact that sprout of control were allowed to grow till the 120 days elapsed. From Table 1, it could be established that yam tubers under the control treatment at 120 days after storage recorded the highest significant (5% probability level) sprout length of 145 cm. This implies that no sprout control highly affects weight loss. Fig. 5 shows the average sprout rate as influenced by method of sprout control; hand snap, half cut, full cut and control after 30, 60, 90 and 120 days of storage.

From Fig. 5, it could be deduced that sprouting took place steadily or progressively earlier during warmer conditions in February until it reached the optimum as

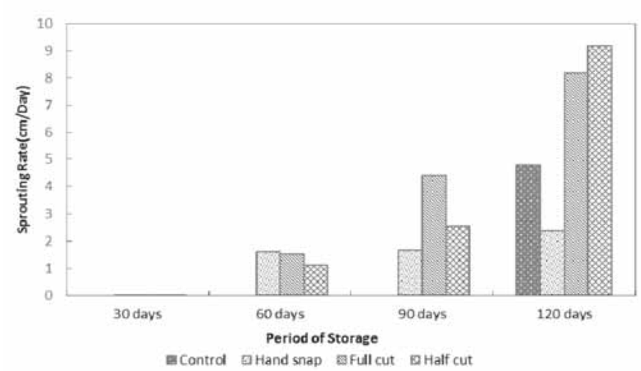

Fig.5. Average sprout rate as influenced by sprout control methods at 30, 60, 90 and 120 days after storage

influenced by fluctuations in yam barn temperature (Elsie, 2011). Again, it could be established that after 30, 60 and 90 days of storage, sprout rate of yam tubers under the control treatment was negligible because sprouts were not cut from tubers for measurement. After 120 days of storage, cutting the sprouts half way recorded the highest sprouting rate of 9.2 cm/d whilst hand snapping the sprouts recorded the lowest value of 2.4 cm/d; though differences among treatments was not significant (5% probability level) within and between the stages of harvest (milked and unmilked).

Number and weight of sprout

Fig. 6 depicts the mean number of sprouts as influenced by sprout control methods at 30, 50, 90 and 120 days of storage.

It could be established from Fig. 6 that number of sprouts increased with increasing period of storage for full cut and half cut whereas control and hand snap decreased from 60 days to 90 days before increasing again after 120 days of storage.

From Fig. 6, it could clearly be seen that hand snapping the sprouts at the base of yam resulted in the highest average number of sprouts whilst that of control recorded the lowest value of 1 after 120 days of storage. The study confirmed the findings of Passam (1977) who discovered that exposure to higher temperatures (35^{o}C) causes about 85% sprouting of yam tubers after 95 days of storage. However, there was no significant difference among treatments at probability level of 5% with *Puna* at the same stage of harvest but there was a statistical significant difference between the two stages of harvest.

Fig. 7 shows the average sprout weight across both improved and traditional barns as influenced by method of sprout control; hand snap, half cut, full cut and control after 30, 60, 90 and 120 days of storage.

The negligible sprout weight under the control treatment recorded at 30, 60 and 90 days after storage of yam tubers was due to the fact that sprouts were allowed to grow till the end of the experiment. It could also be seen from the graph that average sprout weight generally increased steadily from the beginning to the end of storage for all treatments except hand snap that dropped in average weight between 60 and 90 days. After 120 days of storage, the control recorded the highest significant (5% probability level) sprout weight of 97g whilst cutting the sprouts half way to yam base recorded the lowest value of 35g (Fig. 7). Control sprout weight was as twice as that reported by Osunde and Orhevba (2010) which also reported statistical

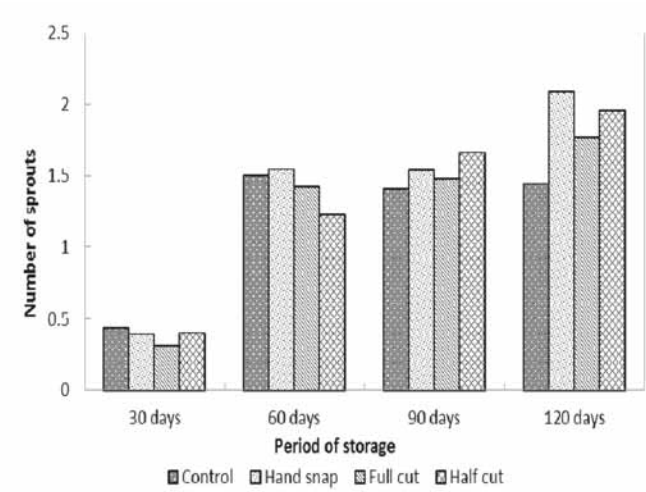

Fig.6. Number of sprouts as influenced by sprout control methods at different storage periods

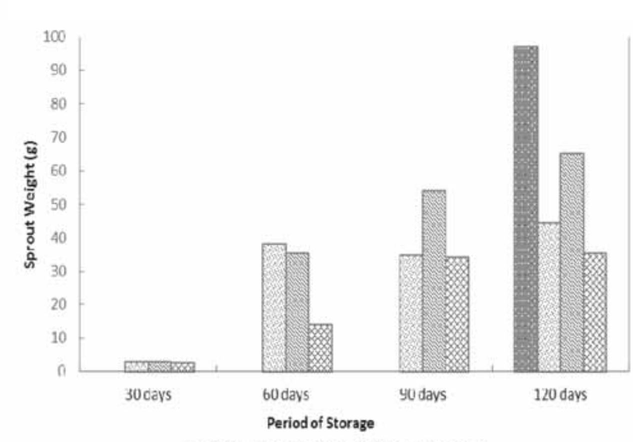

Fig.7. Sprout weight as influenced by sprout control methods at different storage periods.

significant difference at p≤ 0.05 between barn with fan and without fan for sprout control under neem treatments.

Percentage of visible rot

Fig. 8 shows the mean percentage visible rot of *Puna* as influenced by sprout control methods after 30, 60, 90 and 120 days of storage. Results from the assessment of visible rot shows that tuber rot across all four treatments (control, hand snap, half cut and full cut) generally increased with increasing period of storage. From graph, it could also be seen that interestingly, no tuber rot was recorded for all treatments after 30 days of yam storage.

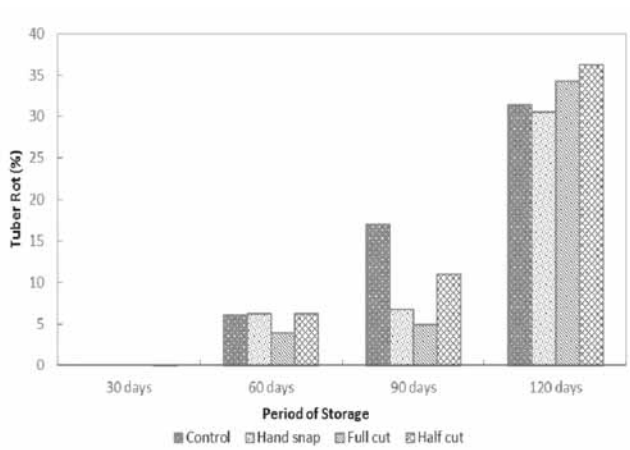

Fig.8. Visible rot (%) as influenced by sprout control methods at different storage periods.

The findings of FAO (2003) which reported 10-12% of yam tubers getting rotten in the first 3 months of storage confirms the results of the study except control which had rot about 15% in the first 3 months of storage. This might be due to the low temperature at the beginning of the storage period which slows down metabolism of pathogens thereby arresting rot effect (Afoakwa and Sefa-Dedeh, 2001; Okigbo, 2004). At the end of yam storage trial (at 120 days), it could be deduced that cutting the sprout half way to the base with scissors resulted in the highest tuber rot of 36% whilst that of hand snapping the sprouts resulted in the least rot of 31%. These were also within the range of rot (30 – 50%) for 6 months storage (FAO, 2003; Okigbo, 2004). However, there was no significant difference among treatments at 5% level of significance. Percentage rot had lower values under storage structures, stage of harvest and sprout control methods compared with than un-irradiated water yam which recorded 80% rot after 7 months of storage under different storage structures and sprout control methods (Imeh et al., 2012).

Analysis of variance and correlations

Analysis of variance at $p < 0.05$ for sprout control methods between milked and unmilked *Puna* for the period of study is shown in Tables 2 and 3.

From results in Table 2, it could be seen that except for percentage rot, other parameters such as number of sprout, rate of sprout and weight loss recorded significant differences ($p < 0.05$) between milked and unmilked *Puna* for some sprout control methods after 30 days of storage. However, there was no significant difference amongst

Table 2. Summary statistics for sprout control methods at 30 and 60 days storage period as influenced by stage of harvest for *Puna* yam variety

Stage of harvest	Treatment	30 days storage period				60 days storage period			
		Weight loss (%)	No. of sprout	Sprout rate (cm/d)	% rot	Weight loss (%)	No. of sprout	Sprout rate (cm/d)	% rot
Milked *Puna*	Control	3.80[a]	0.185[a]	0.000[a]	0.000	15.23[a]	1.572	0.00	9.5
	Hand snap	3.83[a]	0.218[a]	0.009[a]	0.000	12.35[a]	1.706	1.27	10.0
	Full cut	4.11[a]	0.125[a]	0.017[a]	0.000	15.96[a]	1.646	1.42	4.6
	Half cut	3.88[a]	0.176[a]	0.060[a]	0.278	17.52[a]	1.155	0.93	8.4
Unmilked *Puna*	Control	6.59[b]	0.690[b]	0.000[a]	0.000	21.93[a]	1.426	0.00	2.8
	Hand snap	6.26[b]	0.569[ab]	0.144[b]	0.000	19.36[b]	1.377	1.98	2.3
	Full cut	6.45[b]	0.493[ab]	0.074[a]	0.000	21.98[a]	1.194	1.66	3.1
	Half cut	4.9[a]	0.620[b]	0.101[a]	0.000	21.93[a]	1.292	1.34	3.9
	LSD	1.114	0.4028	0.1021	ns	6.86	ns	ns	ns

Figures with the same alphabets as superscripts in the same column are not significantly different from each other ($p < 0.05$).

Table 3. Summary statistics for sprout control methods at 90 and 120 days storage period.

Stage of harvest	Treatment	90 days storage period				120 days storage period			
		Weight loss (%)	No. of sprout	Sprout rate (cm/d)	% rot	Weight loss (%)	No. of sprout	Sprout rate (cm/d)	% rot
Milked *Puna*	Control	30.8[a]	1.727	0.00	15.8[b]	44.7	1.96[a]	4.6[a]	32.9
	Hand snap	22.9[a]	1.789	1.54	5.4[a]	38.2	2.60[a]	2.9[a]	35.8
	Full cut	21.9[a]	1.676	4.20	4.6[a]	46.2	2.32[a]	5.2[a]	36.3
	Half cut	26.5[a]	1.891	2.56	17.8[b]	42.3	2.00[a]	2.6[a]	32.1
Unmilked *Puna*	Control	36.6[a]	1.083	0.00	18.1[b]	51.9	0.91[b]	5.1[a]	29.9
	Hand snap	27.0[a]	1.282	1.83	7.9[a]	46.6	1.59[a]	2.0[a]	25.2
	Full cut	32.7[b]	1.280	4.61	5.1[a]	55.8	1.23[b]	11.1[b]	32.1
	Half cut	30.8[a]	1.431	2.55	4.3[a]	46.6	1.91[a]	15.8[b]	40.3
	LSD	10.21	NS	NS	11.87	NS	1.00	8.23	NS

Figures with the same alphabets as superscripts in the same column are not significantly different from each other ($p < 0.05$).

sprout control methods under the same stage of harvest for weight loss. Also half cut method had no significant difference on weight loss between stage of harvest at $p < 0.05$. The highest percentage weight loss was control for unmilked *Puna* whereas the least was same control for milked *Puna*. It implies that yam condition before storage has a significant impact on percentage weight loss after 30 days of storage. Half cut and control had significant differences ($p < 0.05$) between stage of harvest for number of sprouts whereas only hand snap was significantly different under rate of sprout.

Again it could be seen that only weight loss had significant difference ($p < 0.05$) between stage of harvested yam for hand snap sprout control method after 60 days of storage. The highest percentage weight loss was full cut method for unmilked *Puna* and the least being hand snap for milked *Puna*.

Percentage weight loss and rot had significant difference ($p < 0.05$) after 90 days of storage (Table 3). There was no significant difference in stage of harvested yam for weight loss, however control and full cut methods recorded significant differences ($p < 0.05$) for milked *Puna* whiles rot under the control method was significantly different ($p < 0.05$) for unmilked *Puna* after 90 days. Full cut unmilked *Puna* recorded highest significant ($p < 0.05$) percentage weight loss and was significantly different from full cut milked *Puna*. Control recorded the highest significant ($p < 0.05$) percentage rot although no significant difference when compared with milked *Puna*. This further implies that milked *Puna* offers lower weight loss and rot as storage period increases as compared to unmilked *Puna*.

From Table 3, number of sprout and rate of sprout were significantly different after 120 days of storage whereas percentage weight loss and rot were not. Despite the not significant difference ($p < 0.05$) for percentage weight loss and rot, full cut and half cut recorded the highest percentages under unmilked conditions respectively after 120 days of storage. Therefore, it can be concluded that, milked *Puna* offers lower weight loss and rot than unmilked *Puna*. Significant difference ($p < 0.05$) was recorded for control and full cut sprout control method between stage of harvest and with unmilked *Puna* on number of sprouts. Interestingly, hand snap method recording the highest number of sprout for milked *Puna* was not significant. The highest significant rate of sprout was recorded by the half cut method for unmilked *Puna*. Again there was significant difference in rate of sprout for milked and unmilked *Puna* at $p < 0.05$ after 120 days of storage.

After 120 days of storage, control method under unmilked condition had the least number of sprout and half cut method under milked conditions had the least rate of sprout and were statistically significant ($p < 0.05$) compared with counter yam conditions. Control and half cut recorded the least and highest percentage rot respectively under unmilked conditions but not statistically significant. Highest percentage weight loss was full cut method under unmilked conditions whereas hand snap method under milked conditions recorded the least after

120 days of storage although not statistically significant at $p < 0.05$.

Analysis of variance for the two structures done for 90 days and 120 days after storage is reported in Table 4. It could be established that all evaluation parameters (weight loss, number of sprout, percentage rot and rate of sprout) for both traditional and improved storage structures were significantly different ($p < 0.05$) after 90 days of storage. Control had the highest significant ($p < 0.05$) percentage weight loss and rot whereas full cut recorded the highest, though not statistically significant, rate of sprout in the traditional yam barn. Number of sprouts was highest in the improved barn under the half cut method after 90 days of storage.

Again from Table 4, there was no significant difference ($p < 0.05$) for percentage weight loss and rot after 120 days of storage. However, highest percentage rot was recorded by half cut method under traditional yam barn whiles full cut method under improved barn had the highest weight loss. The highest significant ($p < 0.05$) number of sprout and rate of sprout was recorded by half cut method under improved yam barn after 120 days of storage and there was significant difference ($p < 0.05$) with improved barn amongst sprout control methods and between yam storage barns. Therefore, both the stage of yam harvest and storage barn type had significant ($p < 0.05$) effect weight loss, percentage visible rot, number of sprout and rate of sprout as confirmed by Osunde and Orhevba (2010).

Table 5 reports the correlation between percentage weight loss and all other parameters considered in this study. It could be seen that number of sprout on a tuber has a negative relationship with weight loss after 60 days to 120 days. This implies that as number of sprout increases weight of yam also increase thereby increasing weight loss to dry matter (Sahore et al., 2007; Osunde, 2008; Osunde and Orhevba, 2009). Weight of sprout and rate of sprout also exhibited negative correlation with weight loss after 90 and 120 days of storage to confirm that sprouting increases weight loss in dry matter of yams. Sprout length had a positive relationship with weight loss during the first 60 days of storage although the relationship was weak and changed to negative during the last 60 days of storage. Sprouts depended on moisture in yam tuber to grow thereby affecting moisture content (weight) negatively. Interestingly, percentage visible rot had a good positive relationship with weight loss. Higher the weight loss, the greater possibility of rot in the yam tuber. This was confirmed by results from Table 2, 3 and 4 whereby all treatments recording high values of weight loss had a corresponding high percentage visible rot.

Table 4. Summary statistics for sprout control methods at 90 and 120 days storage period as influenced by type of storage structure

Storage structure	Treatments	90 days storage period				120 days storage period			
		Weight loss (%)	No. of sprout	Sprout rate (cm/d)	% rot	Weight loss (%)	No. of sprout	Sprout rate (cm/d)	% rot
Traditional yam storage barn	Control	38.7^{a}	0.961^{a}	0.00^{a}	25.4^{n}	50.5	1.01^{a}	7.50^{n}	38.7
	Hand snap	23.3^{b}	1.516^{a}	2.90^{b}	5.0^{m}	40.4	1.67^{a}	4.37^{n}	31.5
	Full cut	25.5^{b}	1.634^{b}	5.07^{b}	3.0^{m}	50.5	1.55^{a}	6.48^{n}	41.0
	Half cut	32.9^{a}	1.220^{a}	3.90^{b}	12.5^{m}	48.4	1.33^{a}	3.92^{n}	43.3
Improved yam storage barn	Control	28.8^{b}	1.850^{b}	0.00^{a}	8.4^{m}	46.1	1.86^{ab}	2.19^{n}	24.1
	Hand snap	26.6^{b}	1.556^{a}	0.47^{ab}	8.3^{m}	44.5	2.52^{ab}	0.49^{n}	29.5
	Full cut	29.1^{b}	1.322^{ab}	3.73^{ab}	6.7^{m}	51.5	2.00^{ab}	9.89^{n}	27.5
	Half cut	24.3^{ab}	2.102^{b}	1.21^{a}	9.6^{m}	40.6	2.58^{b}	14.40^{m}	29.1
	LSD	9.50	0.602	2.578	11.42	ns	1.019	7.986	ns

Figures with the same alphabets as superscripts in the same column are not significantly different from each other ($P < 0.05$).

Table 5. Correlation (R) results of weight loss (%) with other parameters across storage structure and yam conditions

	Weight loss: R (significance)			
	30 days	60 days	90 days	120 days
Number of sprout	0.311	-0.357	-0.577	-0.411
Sprout length	0.039	0.155	-0.254	-0.025
Rate of sprout	-0.034	0.075	-0.122	-0.018
Weight of sprout	0.094	0.056	-0.307	-0.024
Visible rot	-0.089	0.364	0.577	0.538

Conclusion

The study establishes that both stage of harvest and type of storage structure affects sprouting and weight loss in *Puna*. After 120 days of yam storage, traditional barn had the highest rate of weight loss and rot whereas improved barn recorded the highest sprout number and rate of sprout under the half cut control method. Full cut control method had the highest percentage weight loss (51%) and half cut method, the highest sprouting rate and percentage visible rot at 9.2 cm/d and 36% respectively. In terms of yam sprout control, hand snap was best at reducing weight loss, tuber rot and sprout rate for *Puna*. In addition, cutting sprouts half way to the base of yam generally resulted in the least sprout weight and sprout length for *Puna*. Also, unmilked *Puna* recorded higher percentage weight loss and rot than milked irrespective of storage structure type. Therefore, milked condition of *puna* yam is a better option for minimized weight loss and rot. Control method for unmilked yam had the least number of sprout and half cut method for milked yam had the least rate of sprout and were statistically significant ($p < 0.05$). There was no statistical significant difference ($p < 0.05$) for percentage weight loss and rot amongst sprout control methods and between yam conditions. However, number of sprout and rate of sprout recorded significant difference ($p < 0.05$) between yam conditions and with control methods for unmilked *Puna*. Similar significant difference was true for analysis of variance between yam storage structures. Weight loss had a negative relationship with number of sprout, rate of sprout, sprout length and weight whereas percentage visible rot had a good positive correlation with weight loss.

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