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The Storage Performance of Sweet Potatoes with Different Pre-storage Treatments in an Evaporative Cooling Barn

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ABSTRACT

The storage of sweet potato tuberous roots in tropical countries is a major challenge to farmers and retailers due to unfavourable climatic conditions. In this research the storage performance of sweet potato roots in an evaporative cooling barn was investigated with three different pre-storage treatments - ash, brine and *Lantana camara* extract to evaluate their effects on weight loss, shrinkage, weevil damage, sprouting and decay over 12 weeks duration. The control comprised roots with no pre-treatment. Weight loss increased linearly from the inception of storage whilst shrinkage became apparent only after 2 weeks and rose linearly. The roots were held against weevil damage until the 6th week. Sprouting was initiated after 4 weeks of storage. By the 12th week, the *Lantana camara* treatment yielded better results, recording overall root wholesomeness of 76%, followed by the control (56%), the ash treatment (50%) and the brine treatment (48%). The *Lantana camara* treatment also recorded the lowest weight loss of 28%, lowest shrinkage of 3.8%, lowest severity of decay and sustained less weevil damage at 47.5% compared with the other treatments. Sprouting was however, higher than the other treatments. The brine and ash treatments performed poorest with the performance indicators.

Key words: Sweet potato, evaporative cooling barn, *Lantana camara*, brine, ash

INTRODUCTION

The recent awareness of the health values of sweet potato (*Ipomoea batatas* (L) Lam) in many developing countries has changed the negative perceptions about the crop with systematic policies to feature it prominently in the household food economy as a staple crop. Ranked as the seventh most important crop worldwide, sweet potato is a highly nutritious vegetable containing high energy, dietary fibre, biologically active phytochemicals, vitamins and minerals which offer a great benefit for use as a functional food ingredient (Brinley *et al.,* 2008). Currently, the newly introduced yellow-orange fleshed variety is being promoted to combat vitamin A deficiency that results in blindness and even death of 250,000-500,000 African children each year (Ooster, 1999). In Ghana, the utilization of the crop in many food recipes is also being promoted by the Root and Tuber Improvement and Marketing Programme (RTIMP) to enrich the diet of the people.

The contribution of sweet potato to incomes, food security and health in tropical developing countries is however, challenged by the difficulty in storage that results from heavy weevil infestation, fungal decay and physiological breakdown under the tropical weather. These are visibly expressed as physical lesions on the roots, dry and soft rots, weight loss and sprouting. Traditional barns and other forms of storage structures used extensively in tropical countries to protect the integrity of the crop have not yielded the desired results. Independent studies in Ghana by Osei-Gyamera (2000), Duku (2005) and Golokumah (2007) on various traditional storage techniques gave average shelf-life of 2 weeks. Van Oirschot *et al.* (2003) report an average shelf-life of no more than a week in East African marketing chain.

It is well known however, that temperature and relative humidity management are effective tools that may be used to extend the shelf-life of most horticultural crops. Combined with appropriate pre-storage treatment against pathological effects, the shelf-life can be extended even longer. According to Woolfe (1992) and Picha (1986), under optimum temperature of 12-15°C and relative humidity of 85-90%, sweet potato roots can store up to a year. However, the indigenous storage structures can hardly achieve these optimum conditions under the tropical weather. Neither are the resource poor farmers, whose farms are located off-grid, capable of accessing refrigerated storage. A more viable option to leverage traditional forms of storage therefore, is to customize the designs of the traditional storage structures to create suitable environmental conditions for long term storage of the roots.

In this light, this study was carried out to track the combined effects of some pre-storage treatments and the micro environmental conditions created by a purpose built evaporative cooling barn on the storage performance of sweet potato.

MATERIALS AND METHODS

The plant materials: The plant material comprised two released sweet potato varieties - Ukerewe and TIS 2. An experimental field (1 acre) was acquired at the UCC School of Agriculture Teaching and Research Farm to cultivate the test crops under standard agronomic practices. The research was carried out between August 2008 and January 2010.

The storage structure: The innovative storage structure for this experiment was an evaporative cooling barn. This was a naturally ventilated, walk-through structure comprising a wooden framework with a spear grass thatch-roof and wet sacks hanged over the side-walls to provide evaporative cooling effect. Ventilation openings were provided at the opposite sides of its length to allow air flow-through. The whole structure was built under a shade and faced against the direction of the wind to aid convective air flow and the cooling effect.

Measurement of the psychrometric properties of the air in the storage structure: A digital psychrometer was used to measure the relative humidity and temperature in the storage structure as well as the ambient. The psychrometric software (CYTPsyChart) was used to generate the other properties of air (specific volume, enthalpy and humidity ratio) in the storage structure and the ambient.

Pre-treatments: All the test roots were initially cured at 29-32°C and a relative humidity of 90% for 7 days to heal harvesting wounds. Pre-storage treatments comprised brine solution (1.2 mol dm^3), *Lantana camara* leaf extract (2 kg soaked in 10 L of water, pounded and mixed with water and then strained), wood ash and a control (no pre-treatment).

Brine pre-treatment: The roots were dipped into the brine solution and dried in the sun before storage. Brine possesses an alkaline property. This alkaline component is loathsome to most microbes and insects. Therefore, it can play important role in preserving sweet potato roots from decay and weevil damage.

Lantana camara pre-treatment: The roots were dipped into the solution of the *Lantana camara* leaf extract and dried in the sun before storage. The leaf possesses both larvicidal and insecticidal properties and is known to repel some insect pests. According to Raman *et al.* (1997) covering potato tubers with *Lantana camara* reduces potato tuber moth. An ethanolic, chloroform, hexane and water extract of *Lantana camara* releases flavonoids which is an active ingredient (Verma and Verma, 2006). This active ingredient is found to be effective against termite workers and reduces potato tuber moth (Kroschel and Koch, 1996). Decoction of the leaves is also used as a lotion for wound, anti-feedant, larval mortality, anti-bacterial and repellency (Verma and Verma, 2006). Applying *Lantana camara* extract as a pre-storage treatment is therefore capable of preventing or reducing insect pest infestation in storage.

Ash pre-treatment: The ash pre-treatment comprised dry application of powdered wood ash over the surfaces of the test tubers. Ash is an organic material derived from the burning of wood. This substance has an alkaline property, which is not favorable for the development of diseases. It also contains insecticidal property. Furthermore, ash acts as an absorbent to moisture and has a repelling effect on pests. According to Mutandwa and Gadzirayi (2007) farmers get best results in using the combinations of wood ash and soil for the preservation of sweet potato roots.

The experimental design and procedure: The experiment was conducted with a completely randomized design. Seven roots of approximately the same total weights were selected from each pre-storage treatment and packaged in woven mesh sachets. There were four pre-storage treatments and two sweet potato varieties (as narrated above) and each was replicated three times to give a total of 24 treatment combinations. They were randomly arranged in a wooden shelve having 24 pigeonholes. Similar treatment combinations were also stored in the ambient near the evaporative cooling barn to compare with the barn. Ambient conditions normally prevail in traditional storage barns.

Data collection: At 2 weeks intervals, a random sampling technique was used to select a sachet from each treatment replicate and both destructive and non-destructive assessments were carried out. Parameters observed were: The weight loss, shrinkage, extent of weevil damage, the sprouting index, the severity of decay and wholesomeness.

Determination of weight loss and shrinkage: Weight loss was determined as the difference between the current weight and the initial weight 2 weeks before. Shrinkage of the roots was determined by measuring the diameters with a caliper at the start of the research and also at every 2 weeks interval. The diameter measuring ring at the start was marked with a permanent marker and this served as the reference mark for subsequent measuring. The differences in the initial and final diameters were used to calculate for shrinkage.

Determination of the extent of weevil damage: Sweet potatoes from the selected samples that showed the presence of *Cylas* sp. or tunnels created by the weevils were recorded as damaged (Nicole, 1997). This was calculated as a percentage of the initial number of tubers.

Percentage decay in storage: The randomly selected samples were assessed for the surface showing visible decay. The percentage of sweet potatoes unmarketable due to decay was calculated for each pre-treatment on the basis that a root becomes unmarketable when >10% of the surface shows visible decay. Roots showing extensive rotting (> 50% surface) were removed from the sack (Rees *et al.,* 2003). The percentage severity was also recorded using a 1-5 scale depending on the percentage of the root surface showing decay (1 = 0%, 2 = 0-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-100%).

Sprouting index: The randomly selected samples were examined for the occurrence of sprouting and sprouting index calculated by the formula,

$$\text{Sprouting index} = \frac{\text{No. of sprouted roots}}{\text{Total No. of roots}} \times 100$$

Wholesomeness: Sweet potato roots that showed at least 20% deterioration were considered unwholesome (Mutandwa and Gadzirayi, 2007) and the percentage wholesomeness calculated.

Data analysis: The results were subjected to the analysis of variance (ANOVA) procedure using GenStat statistical soft-ware to investigate whether there were statistical differences in the parameters studied. Mean comparisons were done using Duncan's Multiple Range Test for separation of means (Russel, 1990).

RESULTS AND DISCUSSION

Psychrometric parameters in the storage structures: The mean values of the psychrometric parameters attained in the Evaporative Cooling Barn and the ambient air during the experimental period are presented in Table 1.

Average day-time temperature in the evaporative cooling barn was significantly lower than the ambient whilst night temperatures were comparable. Temperature is the most influential environmental factor on the physiological deterioration of horticultural crops. Higher temperatures induce higher respiration rates and subsequently, faster physiological activities leading to the depletion of dry matter reserves and the senescence of cells. Thus the evaporative cooling barn generated more conducive climate (25.2°C, 90% r.h.) and was therefore better poised to offer protection against physiological deterioration. The temperature difference between the barn and the ambient was 6°C. Given that physiological activity doubles for every 10°C rise in temperature within the physiological temperature range 5-35°C, it implies that all other factors being equal, the evaporative cooling barn would be capable of reducing physiological activity by about a quarter, or conversely, increasing the roots' shelf life by about one and half times that of ambient storage. The higher relative humidity attained in the structure may be attributed to moisture evaporation

Table 1: Psychrometric parameters of the air in the storage structure and the ambient

	Temperature (°C)					
Storage structure	Night	Day	Relative humidity (%)	Humidity ratio (water kg^{-1} dry air)	Enthalpy (kJ kg^{-1} dry air)	Specific volume (m^3 kg^{-1} dry air)
Evaporative C.Barn	23.9	25.2	90	17.89	70.90	8.69
Ambient conditions	23.7	32.5	68	19.88	82.51	8.90

from the moistened sacks, assisted with evaporation from bowls of water kept on the floor. At the same time, the evaporation created a cooling effect; hence the lower temperatures than the ambient. Optimum conditions for sweet potato storage are however, 13-15°C and 90% relative humidity.

As much as possible, sweet potato roots for storage must initially be cooled quickly to a low storage temperature, air with low enthalpy having the highest cooling capacity (Ooster,1999). This may explain why the evaporative cooling barn (enthalpy = 70 kJ kg^{-1}) produced more conducive environment for storage than the ambient (enthalpy = 82 kJ kg^{-1}).

Assessment of the factors of deterioration: Figure 1-5 that follow: A = Ash, B = Brine, C = Control and E = L. Camara extract treatments.

By the second week when measurements started, all the roots stored in the ambient had severely deteriorated by weevil infestation.

Percentage weight loss: Figure 1 presents the mean percentage weight loss due to the different treatments in the evaporative cooling barn over the first 12 weeks of the study.

Weight loss is a phenomenon associated with root tubers in storage and is attributed to both transpiration and dry matter loss due to respiration. All the treatments in the barn exhibited steady weight loss from the beginning of storage, increasing fairly linearly over time. ANOVA showed that the ash and brine treatments recorded significantly higher weight loss ($p<0.05$) at the 12th week than both the *Lantana camara* extract and the control. There was however, no significant difference in the weight loss between the ash and brine treatments or between the *Lantana camara* extract treatment and the control. Given that ash is an absorbent of moisture, the higher weight

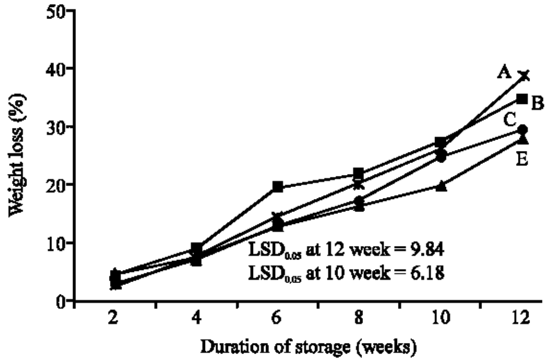

Fig. 1: Mean percentage weight loss of tubers in the evaporative cooling barn

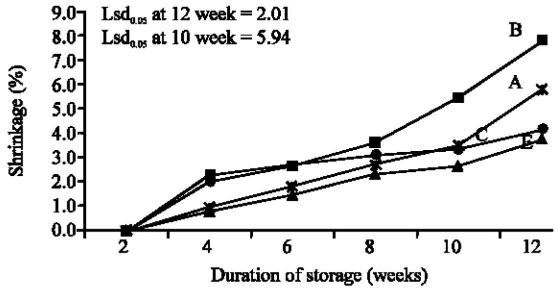

Fig. 2: Mean percentage shrinkage of the different treatments

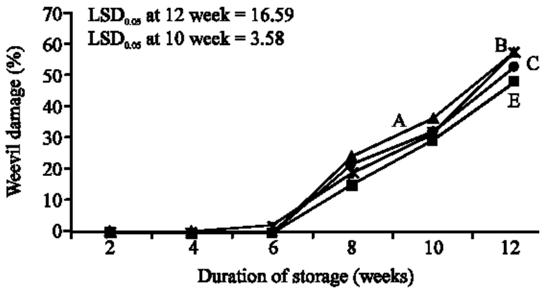

Fig. 3: Mean percentage weevil damage in the evaporative cooling barn

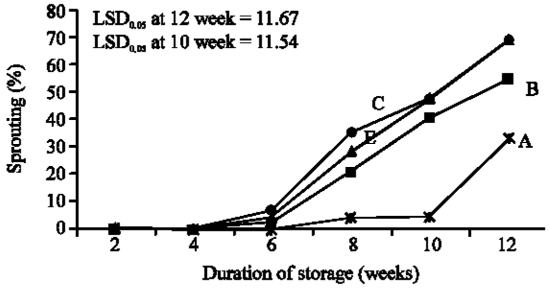

Fig. 4: Mean percentage sprouting due to the different treatments

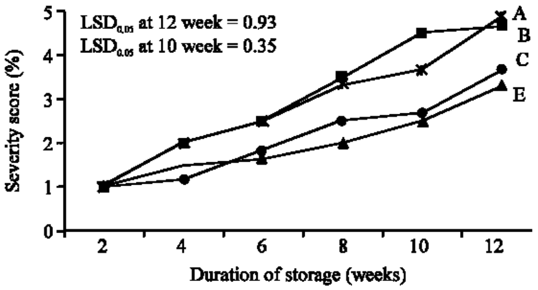

Fig. 5: Mean severity of decay (Severity score 1 = 0%, 2 = 0-25%, 3 = 25-50%, 4 = 50-75, 5 = 75-100%)

loss experienced by the roots with ash treatment may be accounted for by higher dry matter loss due to respiration. The same reason holds true for the brine treated roots (Fig. 1).

Shrinkage: Figure 2 shows the mean percentage shrinkage over the study period, all tubers in the structure showed increasing shrinkage over time initiating from the 2nd week. Our study also showed that shrinkage followed a somewhat sigmoid pattern i.e. the percentage rate of shrinkage initially rose from the 2nd week to the 4th week, slowed down over the next 4-5 weeks and then showed indefinite rise towards senescence. The high initial water loss may be attributable to the transpiration of moisture from the surface layers, followed by moisture migration towards the surface which slowed down transpiration temporarily. The rise in shrinkage and hence transpiration rate at the latter stages may be attributed to the gradual collapse of the cells and the consequent loss of turgidity of the cell membranes which allowed easy efflux of moisture. To maintain the turgidity and freshness of the roots over a longer period, it may be necessary to increase the relative humidity higher than the 90% attained as low relative humidity results in higher moisture loss (Ooster, 1999).

Shrinkage is related to water loss due to transpiration. Transpiration involves the transport of moisture through the outer layers of the product, the evaporation of moisture from the product surface and the convective mass transport of moisture to the surroundings. Bakker-Arkema *et al.* (1999), have described transpiration from the surfaces of root crops with the mathematical model:

$$M_w = k_t\,(P_s\text{-}P_a)$$

where, M_w is the moisture loss per unit product surface, is the transpiration coefficient (dependent on the skin resistance and the air flow) and P_s and P_a are the vapour pressures at the surface and in the surrounding air respectively. For storage conditions in which natural convection is significant, the air flow rate is caused by internal heat generation and by evaporative cooling resulting in more transpiration. Thus, the evaporative cooling in the barn may have also contributed higher transpiration and consequently, water loss from the roots resulting in the shrinkage. Our study showed that roots treated with *Lantana Camara* extract exhibited less shrinkage throughout the study period, giving them greater market value.

Weevil damage: The percentage weevil damage of the roots in the storage structure is presented in Fig. 3, from above figure; weevil damage became significant from the 6th week among the treatments although some weevils were detected in the control as early as the 4th week. Weevil damage increased almost linearly for all the treatments from the 6th week onwards. By the 12th week an average of about 53.6% of the roots in the evaporative cooling barn had suffered weevil damage whilst for the roots stored in the ambient, all suffered so severe weevil damage as early as the 2nd week as to render the roots completely unwholesome. It shows that storage in the structure offered some protection against weevil infestation than the freely exposed roots. ANOVA results ($p<0.05$) at the 12th week showed no significant differences in the weevil damage between the treatments. Comparing absolute values over the storage period with the other treatments however, the *Lantana camara* treatment produced better resistance against weevils. This agrees with the observations of Kroschel and Koch (1996) and Raman *et al.* (1997), that covering potato tubers with *Lantana camara* reduces tuber moth.

Sprouting, severity of decay and wholesomeness: The results for sprouting, severity of decay and wholesomeness are presented in Fig. 4-6, respectively.

From Fig. 4, sprouting of the roots was initiated after 4 weeks of storage, the rate being slower initially than at the latter stages. By the 12th week, it was highest for the control, followed by roots treated with the *Lantana camara* extract and the brine in that order but with no significant differences between them. This may indicate higher cell potency with active physiological activity in the control and *Lantana camara* treated roots. The brine treated roots recorded the lowest sprouting index. Though low sprouting in stored roots is desirable, in this instance, the low sprouting in the brine treated roots may rather be an indication of loss of potency as they subsequently showed greater severity of decay and unwholesomeness.

There was a near-linear rise in the severity of decay over time, the *Lantana camara* treatment proving superior. This confirms the effectiveness of the active ingredients in *Lantana camara* against pathogens as observed by Verma and Verma (2006), Kroschel and Koch (1996) and

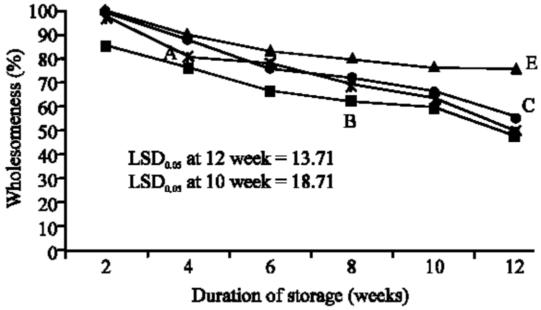

Fig. 6: Percentage wholesomeness of roots in the evaporative cooling barn

Raman *et al.* (1997). The brine and ash treated roots decayed most reflecting subsequently on their lower sprouting ability (Fig. 4).

The percentage wholesomeness (Fig. 6) of the roots in the evaporative cooling barn at the end of the 12th weeks of storage averaged about 56.6%. The wholesomeness of the roots reduced linearly, with the Lantana camara treated roots being more wholesome.

CONCLUSIONS

The study has affirmed that low temperatures and high relative humidities, in combination with appropriate pretreatment are important to protect the integrity of fresh sweet potato tubers against various forms of deterioration. The use of traditional storage structures to achieve optimum climatic conditions in tropical climates however, requires careful engineering. The evaporative cooling barn promised some solutions for storage although the temperature attained (ca. 23-25°C) was still high compared with the 13-15°C storage requirement. Further engineering with the choice of appropriate building materials and heat transfer considerations may be needed to manipulate the store environmental conditions to achieve the optimum. Generally, it may be concluded, comparing the mix of performance indicators, that the *Lantana camara* treated roots had better storage performance. The use of the evaporative cooling barn in combination with *Lantana camara* pre-treatment may therefore be explored to improve the shelf-life of sweet potatoes.

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