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Richard A. Atuna, Edward E. Carey, Jan W. Low, Francis K. Amagloh*

Wound healing and dry matter content of orange-fleshed sweetpotato cultivars as influenced by curing methods

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Abstract: Curing in sweetpotato is a crucial pre- or post-harvest practice that could guarantee improved shelf-life, but rarely practised by sweetpotato farmers in Sub-Saharan Africa, principally due to lack of knowledge. Wound healing ability of cultivars has been associated with good root storability. In this study, two orange-fleshed sweetpotato cultivars (Apomuden and Nane) were either cured in-ground by dehaulming prior to harvest or field-piled over a seven-day period to study their responses to wound healing and changes in dry matter content. Apomuden is a low dry matter content (19%) variety in Ghana while Nane is a high dry matter content (27%) farmer cultivar under evaluation for formal release. A potato peeler was used to deliberately create the wounds on 21 storage roots. The curing treatment was applied and the subsequent post-treatment quality status of the storage roots was monitored daily over a seven-day period. Wound healing ability was scored as follows: *0 = no lignification, 0.5 = patchy lignification and 1= complete lignification*. Wound healing ability score was not significantly different for Apomuden and Nane (0.83, 0.78, respectively; p = 0.120). However, storage roots cured by field-piled curing method resulted in significantly better wound healing ability than dehaulming (0.86, 0.75, respectively, p = 0.001). Over the seven-day curing period, Nane had a significantly higher and stable dry matter content compared with Apomuden (p = 0.008), whose dry matter content was lower and fluctuating. The field-piled curing resulted in higher (p = 0.020) dry matter content, 24%, compared with in-ground curing (22%). The field-piled curing method, which can easily be adopted by sweetpotato farmers, increased the dry matter content of the storage roots; therefore, it could potentially reduce the post-harvest losses in sweetpotato. The high dry matter content of Nane is a desirable root quality attribute for orange-fleshed cultivars and could augment existing cultivars in Ghana.

Keywords: Curing, Dry matter, Field-piled, Orange-fleshed, Sweetpotato, Wound healing

***Corresponding author: Francis K. Amagloh,** Department of Food Science and Technology, University for Development Studies, Tamale, Ghana, E-mail: fkamagloh@uds.edu.gh
Richard A. Atuna, Department of Biotechnology, University for Development Studies, Tamale, Ghana
Edward E. Carey, International Potato Center, Kumasi, Ghana
Jan W. Low, International Potato Center, Nairobi, Kenya

1 Introduction

Sweetpotato (*Ipomoea batatas* L. Lam) is an important root crop that meets the economic and nutritional needs of people in low income countries such as Ghana. However, the short shelf life (usually 3 weeks) greatly hinders its use as a food and nutrition security crop (Rees et al., 2001). The orange-fleshed sweetpotato (OFSP) cultivars in particular have significant amounts of β-carotene, a vitamin A precursor, capable of ameliorating vitamin A deficiency (VAD) (Hagenimana and Low 2000; Low et al. 2001). There is a high prevalence of VAD among children in sub-Saharan Africa (SSA), slightly higher than that of Asia (World Health Organization 2009). However, Low et al. (2007) reported on the potentials of food-based approaches as a sustainable strategy in combating VAD. For instance, the vitamin A status of young South African school children improved with the introduction of boiled and mashed OFSP to their diet (van Jaarsveld et al. 2005). Therefore, efforts to reduce the high post-harvest losses associated with OFSP are of great importance.

Plant tissues generally possess an innate ability for wound healing (Bloch 1952; León et al. 2001). Curing of sweetpotato is a crucial post-harvest practice that ensures healing of wounds that are inevitably caused during harvest and resistance to wounding during transport and marketing (van Oirschot et al. 2003). Storage roots are cured by keeping them in moderate temperature (29-33°C) and high relative humidity (90-95%) for approximately a week prior to storage (Edmunds et al. 2008). Achieving the temperature and relative humidity (RH) condition is not difficult in the tropics. However, it is difficult and expensive to maintain optimal storage conditions of 13-15°C at 90% RH once curing is completed. Curing promotes wound healing through the formation of wound periderm (Woolfe 1992). Therefore, curing is mainly done to heal harvest-inflicted wounds before storage, thus improving sweetpotato shelf life (Walter et al. 1989).

In developed countries, improved storage structure maintains favourable conditions for curing and long-term storage (Edmunds et al. 2008). However, in low income tropical countries like Ghana, the high initial and running costs of a suitable storage structure serves as a disincentive for curing (Ray et al. 2010). Thus, curing is rarely practiced by farmers in SSA, but could occur spontaneously as the ambient tropical conditions may be similar to the ideal commercial curing conditions at certain times during the day.

Several low-cost curing alternatives have been proposed in low income countries. These include covering freshly harvested storage roots with polythene sheet and storing sweetpotato in moist saw dust (Ray et al. 2010). In Ghana, some sweetpotato farmers cover freshly harvested, heaped storage roots with the sweetpotato vines and hold them in the field pending availability of storage space in their stores. This may result in "incidental" curing. The suitability of this practice is unknown and needs further investigation as a potential curing process. In-ground curing (dehaulming), an alternative to controlled atmosphere post-harvest curing (Tomlins et al. 2002) has been reported to reduce skin injury in sweetpotato by 62% after removal of sweetpotato canopy 14 days prior to harvest (La Bonte and Wright 1993). Other researchers found no effect on the recovery of marketable storage roots (Ndunguru et al. 2007). The progress of wound healing while in-ground would provide information on whether sweetpotato storage roots are able to efficiently cure wounds incurred during piece meal harvesting.

Sweetpotato cultivars vary greatly in their wound healing ability during curing. The variability in wound healing efficiency is attributed to the difference in dry matter content. Dry matter content of sweetpotato cultivars inversely relates with lignification score, an index for wound healing (van Oirschot et al. 2006). Thus, cultivars with low dry matter content heal their wounds better than those with high dry matter content.

The objective of the study was to assess the wound healing and changes in dry matter content of two OFSP cultivars as influenced by either in-ground or "incidental" (field-piled) curing methods.

2 Materials and methods

2.1 Experimental design

A 2×2 factorial experimental design in a split plot arrangement was used. Thus, two sweetpotato cultivars (Apomuden and Nane) and two curing methods: in-ground (dehaulming) and field-piled.

2.2 Cultivars

Two OFSP cultivars: Apomuden and Nane were planted in a split plot design with cultivar being the main plot factor and curing method the sub-plot factor with three replicates. The cultivars were planted between mid-July and early August 2015 at Bontanga in the Kumbungu district of Ghana. Appropriate agronomic practices such as weed, rodents and insect pest control were adhered until the cultivars were harvested at optimum maturity: Apomuden at 3.5 months and Nane at 4 months). Nane was planted 15 days earlier than Apomuden to synchronize the harvesting time. Apomuden is a Ghana variety that was released in 2005 by the Crops Research Institute (CRI), Kumasi, whereas Nane is a farmer cultivar that is undergoing field evaluation for formal release in Ghana.

2.3 Curing methods

In-ground curing (dehaulming) was done by removing sweetpotato canopies and leaving about 30 cm to the base of the plants in the respective sub-plots seven days prior to harvest. In the field-piled curing, storage roots from the respective sub-plots were carefully harvested to avoid wounding, sorted and heaped on the field covered with fresh sweetpotato vines for seven days. No rainfall was detected during the curing period.

2.3.1 Wound healing score

Twenty-one (21) storage roots from each curing method were randomly selected and deliberately given three wounds; approximately 2 cm × 5 cm and 1.7 mm deep on the first day using a potato peeler. In the in-ground curing method, the soil surrounding the selected storage roots was removed, thus exposing the root to create the wounds. Later, the roots were covered again with soil and allowed to cure in-ground. In the field-piled curing method, harvested storage roots were randomly selected and wounded, then returned to their respective field-piles for the wound healing test. Three (3) storage roots from each cultivar were randomly selected daily, for seven days, from the wounded storage roots in both curing treatments. The Weiners' Phloroglucinol-HCl test was used as described by van Oirschot et al. (2001): wound sections were cut and stained with phloroglucinol (1% in 95% ethanol) for two minutes and transferred to concentrated HCl for 30 seconds and rinsed in water for 30 seconds. The wounds were stained with phloroglucinol for the presence or absence of lignin. A wound healing score of 0, 0.5 or 1 was given based on the level of lignin formed, respectively: no lignification, patchy lignification and complete lignification.

2.4 Dry matter content determination

Three storage roots from each curing treatments were harvested daily for dry matter content determination. The dry matter content determination was done immediately after the wound healing test. Thus, once the wound sections were removed for the wound healing test, the individual storage roots were sliced for dry matter content determination as described elsewhere (AOAC 2005). Percentage of dry matter was calculated by weighing approximately 10 g of each storage root triplicate of raw and peeled storage root, then drying the slices in a Heratherm oven at 108°C for 16 hours until constant weight was attained.

2.5 Statistical analysis

Wound healing and dry matter data were subjected to Two-Way Analysis of variance (ANOVA) using Minitab v16.2.2 (Minitab® Inc., US). Tukey's studentised range test was used to compare differences between means when the ANOVA result was significant ($p < 0.05$).

3 Results and Discussion

The data presented in this study showed no significant difference between Apomuden and Nane (0.83 *vs.* 0.78, respectively; $p = 0.120$) in terms of wound healing scores (Figure 1). The wound healing efficiency of sweetpotato cultivars has been associated with good root storage (van Oirschot et al., 2006). However, wound healing ability has been previously reported to vary greatly among cultivars (van Oirschot et al. 2006) and to be inversely correlated to dry matter content (Rees et al., 2003). Thus, cultivars with low dry matter content tend to heal wounds more efficiently which leads to increased storage quality. In this present study, the dry matter content of Nane (27%) was significantly ($p < 0.001$) higher than Apomuden (19%), and both cultivars also had good wound healing abilities. Our findings disagree with those of Rees et al. (2003), possibly due to different environmental and soil conditions as well as genotypes. However, the findings are valuable since high dry matter content (related to preferred culinary quality (Rukundo et al. 2013) and good wound healing score are desirable qualities in sweetpotato.

The field-piled curing method resulted in a significantly higher (0.86) wounding healing score relative to the in-ground curing (0.75) ($p = 0.001$) as shown in Figure 2.

Curing induces suberisation of exposed parenchyma cells and development of wound periderm (Ray and Ravi 2005). The field-piled curing resulted in high wound healing score than the in-ground curing because the field-piled provides an ideal atmosphere for the suberisation process of the parenchyma cells and wound periderm development of sweetpotato. Therefore, it is possible that in the field-piled curing method, storage roots are able to heal wounds than in dehaulming method because wound desiccation is likely to occur faster in the former than the later. Nonetheless, the percentage mean difference between the field-piled cure and in-ground was about 13%.

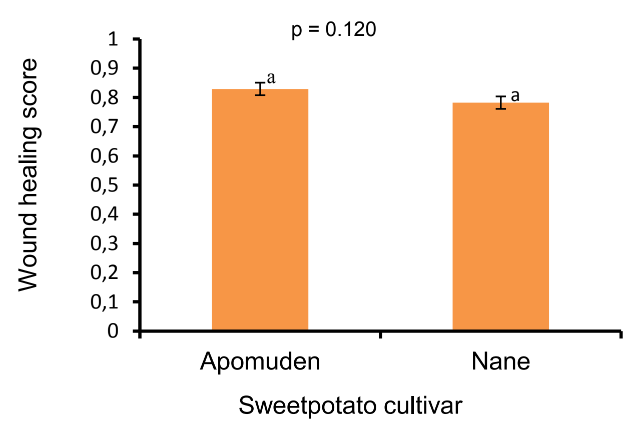

Figure 1: Average wound healing score of sweetpotato cultivars over 7-day curing period. Bar values (least square means ± SEM, $n = 3$). Least square means with the same letters are not significantly different ($p > 0.05$)

Generally, wound healing score increased steadily until the 5th day and then leveled off during the curing period. The wound healing score was significantly affected ($p < 0.001$) by the curing day (Figure 3). However, the combined effect of cultivar and curing day as shown in Figure 4 was not significantly different ($p = 0.706$).

Dry matter content of Nane variety was significantly higher (27% *vs.*19%, $p < 0.001$) than that of Apomuden (Figure 5). Such characteristic is an important root quality trait for OFSP since most consumers in Africa prefer high dry matter content cultivars (Tomlins et al. 2004; Baafi et al. 2015). The dry matter content of Nane was fairly stable compared with Apomuden's, which varied greatly throughout the curing period (Figure 6).

Therefore, the high dry matter content of Nane coupled with its stability during curing are desirable traits for OFSP cultivars. Zhang et al. (2002) reported the need to consider the stability of dry matter and other traits over time when screening for sweetpotato genotypes.

The data presented in Figure 7 shows that field-piled curing had a significantly high (24%, $p = 0.020$) dry matter content relative to in-ground curing (22%). The differences in the dry matter content between the two curing methods

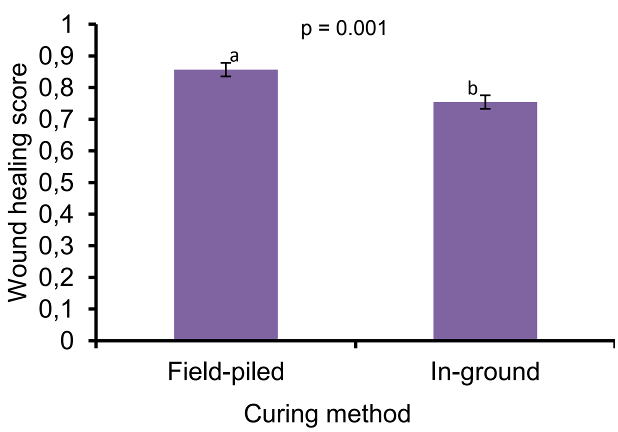

Figure 2: Wound healing as affected by curing method averaged across 7-day curing period. Bar values (least square means ± SEM, $n = 3$). Least square means with the same letters are not significantly different ($p > 0.05$)

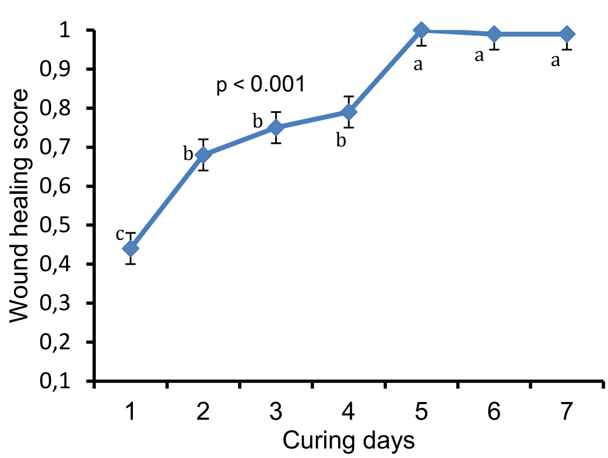

Figure 3: Daily average wound healing score for both cultivars over 7-day curing. Values are least square means ± SEM, $n = 3$. Least square means with the same letters are not significantly different ($p > 0.05$)

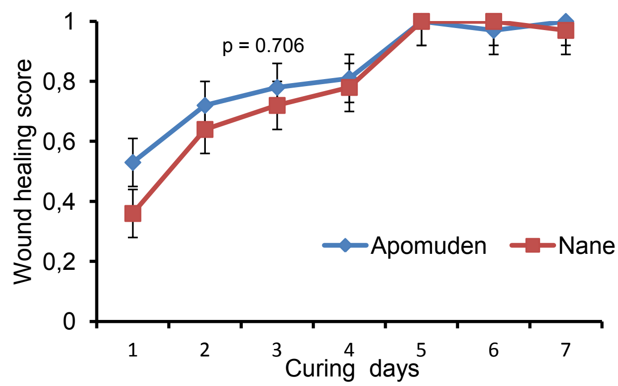

Figure 4: Daily average wound healing score of each cultivar over 7-days curing. Values are least square means ± SEM, $n = 3$

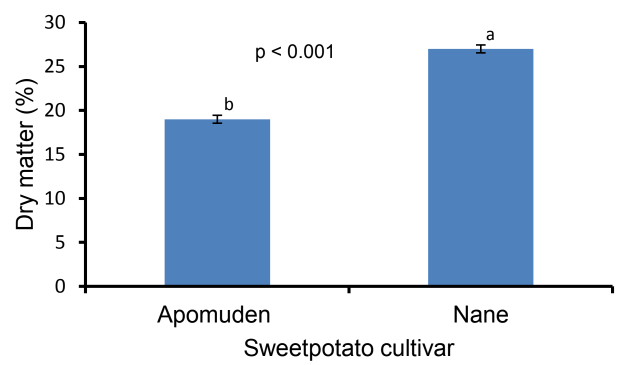

Figure 5: Dry matter content of sweetpotato cultivars. Bar values (least square means ± SEM, $n = 3$). Least square means with the same letters are not significantly different ($p > 0.05$)

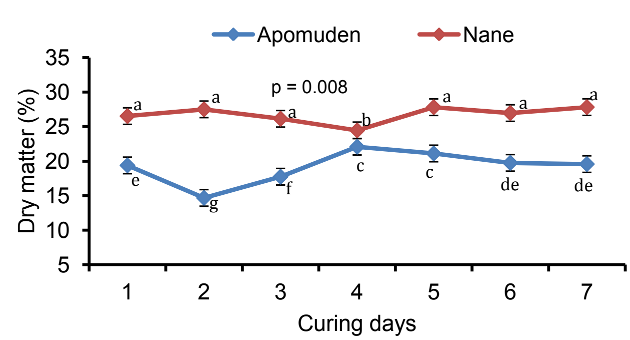

Figure 6: Influence of curing days on the dry matter content of sweetpotato over a 7-day curing period. Values are least square means ± SEM, $n = 3$. Least square means with the same letters are not significantly different ($p > 0.05$)

could be attributed to high water loss resulting in increased dry matter content (Ravi et al. 1996) for field-piled cured storage roots compared with in-ground curing. Curing and storage greatly influence dry matter content of sweetpotato storage roots (Picha 1986).

4 Conclusion

Apomuden and Nane sweetpotato varieties had similar wound healing abilities, which could imply that they have similar storage properties despite the differences in their dry matter contents. However, we acknowledge that fewer roots were selected for this test, which could have influenced our findings. The high dry matter content of Nane is a desirable root quality attribute for orange-fleshed cultivars and could augment existing cultivars in Ghana. The field-piled curing method, an indigenous technique developed by farmers in the Bawku area of Ghana, could be promoted to reduce the postharvest losses in sweetpotato in sub Saharan African.

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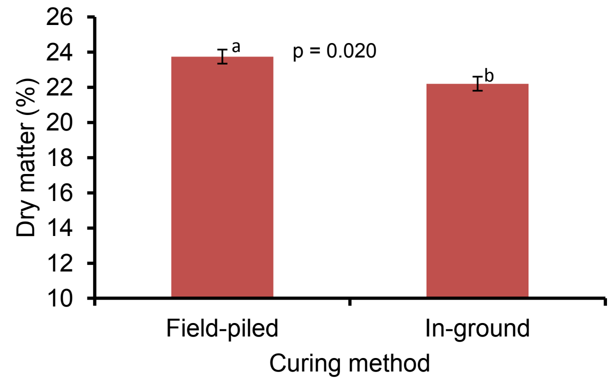

Figure 7: Dry matter as influenced by curing method after 7-day curing period. Bars value (least square means ± SEM, $n = 3$). Least square means with the same letters are not significantly different ($p > 0.05$)

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