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Research Article

Effect of hot water treatment on some post-harvest qualities of stored sweet potato tuber

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Abstract: Postharvest losses constitute a major problem for sweet potato tuber production worldwide. The losses are often initiated by pathogen infection causing sprouting and rotting during storage. Sweet potato tuber sprouting and rotting causes loss of weight, firmness and undesirable appearance, affecting market value. Hot water treatment (HWT) can potentially preserve sweet potato tuber. The current study investigated the effect of hot water treatment on some post harvest quality of stored sweet potato tuber. The qualities studied included weight loss, thickness, firmness and appearance using standard methods. All samples were treated in HWT (50^{o}C) for 10-, 15- and 20-minutes'immersion, and stored at a room temperature of 27 ± 2^{o}C for 4 weeks. The results showed that all the treatment times (10, 15 and 20 minutes) had significant effects ($p \leq 0.05$) on the quality of stored sweet potato tubers. Application of HWT for 10 minutes maintained tuber qualities- weight loss, thickness and firmness ($p \leq 0.05$), and resulted in the best appearance. It is showed that HWT at 50^{0}C for 10 minutes' had great potential in extending the shelf-life and preserving the post harvest qualities of sweet potato tuber.

Keywords: Sweet potato tuber, sprouting, storage, post harvest, quality

1. Introduction

Sweet potato (*Ipomoebatatas L.*) tuber is an important crop cultivated in many parts of the world. It is a drought-tolerantcrop, with a short growth cycle of up to four months (Kassali, 2011; Ray et al., 2015; Guiriba, 2019).Sweet potato tuber consists of carbohydrate, fiber, vitamins and minerals and its consumption has numerous health benefits (Serio et al., 2006; Wang et al., 2016; Anchundia et al., 2019; Alam, 2021; Nguyen et al., 2021; Bahadur & Chauhan, 2022; Pazos et al., 2022). However, sweet potato tuber has short life due to high moisture content and the activity of microorganisms (Ray & Byju, 2003; Tortoe et al., 2010). Many studies have shown that up to 50% harvested produce is lost in storage due to sprouting and rotting (Anukwuorji et al., 2013; Agu et al., 2015; Mohammed et al., 2017; Abdulrahman et al., 2019). Sweet potato tuber sprouting causes loss of weight, firmness and undesirable appearance. These challenges have reduced the production of potato tuber and affected its storage life, inflicting the economy of the world. Many methods have been applied to ameliorate the activities of microorganisms and discourage sprouting and rotting during storage of sweet potato tuber. Some methods applied include spraying of agrochemicals, such as fumigants and insecticides, and curing after harvest prior to storage (Tijaniet al., 2013). While chemicals pose serious challenges to consumer's health, curing causes negative effect on the final quality (Ray et al., 2015; Guiriba, 2019). As a matter of fact, world food regulatory agencies have discouraged the use of chemicals as a preservative method for food materials (Behrens, 2013; Bouldin et al., 2020; Vieira, 2020). Therefore, there is a need for novel method of preservation that can be easily applied by potato tuber producers. Hence, the aim of the current study is to

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investigate the effect of hot water treatment on some post harvest qualities, including weight loss, firmness, thickness and appearance, of stored sweet potato tuber.

2. Materials and methods

2.1. Sample preparation

One bag of freshly harvested sweet potato tubers was purchased from Gamboru Market, Maiduguri, Nigeria and transported early in the morning to the postharvest laboratory of Ramat Polytechnic (latitude 11°50'12.7"N, longitude13°07'56.46"E) The samples were cleaned and cooled for 1hr. Hot water treatments, at temperatureof 50°C, and treatment time of 10, 15 and 20 minutes were carried out on the samples and stored at room temperature (27 ± 2°C) for 4 weeks. The effect of the treatment time on weight loss, firmness, thickness and appearance was evaluated and compared with the untreated ones.Plate 1 shows the hot water treatment process of sweet potato tubers.

Plate 1: Hot water treatment process of sweet potato tubers

2.2. Weight loss

Stored treated and untreated (control) samples were weighed using sensible weighing balance with accuracy of 1 g and range 0-5000 g (5000g x 0.001 g –Sf – 400c, China) and the weight loss of each samples were calculated according to Alabi et al. (2016), as given in equation (1):

$$W_L(g) = \frac{W_1 - W_2}{W_1} \qquad (1)$$

Where: W_L is weight loss, W_1 is initial weight before pretreatment, W_2 is final weight after storage.

2.3. Firmness

The firmness of the treated and control samples was evaluated by using laboratory penetrometer (Gy-4 digital, Zhejiang) according to Alabi et al. (2016).

2.4. Thickness

The thickness of the treated and control samples wereevaluated by using laboratory vernier caliper (RS 300 mm NEIKO tools USA).

2.5. Appearance

Stored treated and untreated sweet potato tubers were assessed for appearance using a visual quality scale test: (1= excellent, 2=very good, 3 = good, 4 = poor and 5 very poor) according to Funtua et al. (2020), with some slight modifications. Nine trained panelists were used based on their experience and product familiarity.Plate 2 shows the stored treated and untreated (control) sweet potato tubers.

Plate 2: Treated and untreated sweet potato tubers after 4 weeks of storage

2.6. Statistical analysis

All measurements taken from the experiments were analyzed in terms of effect of treatment time on some qualities of stored sweet potato tubers. The treatment time were selected as fixed factors. The qualities studied including weight loss, thickness, firmness and appearance were regarded as response variables. Analysis of variance (ANOVA) was employed using design expert (6.0) statistical package, and the significance was set at the 95% confidence level ($P \leq 0.05$), considering the main effects to arrive at the best results of the treatments.

3. Results and discussion

3.1. Weight loss

Figure 1 presents data on the effect of treatment time on weight loss in sweet potato tubers. The key finding is that significant differences exist between the control group (untreated sweet potatoes) and all the treated groups (sweet potatoes exposed to different treatment times). However, there was no significant difference between the groups treated for 15 and 20 minutes.

The control group (untreated sweet potatoes) had the highest weight loss (35 g). The sample treated for 10 minutes showed a significantly lower weight loss (15 g), than the control group. The sample treated for 20 minutes lost 25 g, which was greater than that of the 10-minute group but still lower than that of the control group. As treatment time increased, the weight loss in the treated sweet potatoes generally increased as well, suggesting that longer treatment durations may enhance drying or weight reducing, possibly through increased water evaporation. The lower weight loss observed in treatment samples compared to the control group may be attributed to physiological changes in the sweet potatoes, such as reduced respiration. Following treatment, the tubers likely experienced a slowdown in metabolic processes, including respiration and moisture loss, thereby reducing overall weight loss. Additionally, microorganisms that could accelerate weight loss are likely inactivated during the treatment process (e.g., steam blanching), thereby helping to preserve the tuber weight.

These results are consistent with the findings of Huang et al.(2014) and Song et al. (2021) who reported that steam treatment, which may involve blanching, slows respiration and reduces weight loss. This is also supported by Jethva et al. (2016), who showed that steam blanching sweet potatoes for 10 minutes can help preserve their weight for up to 90 days of storage.The treatment appears effective at reducing weight loss in the sweet potatoes, especially compared to the control group. Longer treatment times (15-20 minutes) seem to provide similar benefits for weight retention, although 15 minutes did not offer a significantly better result than 10 minutes. The decreased weight loss in the treated samples is likely attributable to cessation of metabolic activities and inactivation of microorganisms that might contribute to the degradation of the sweet potatoes. Understanding the effect of treatment time effect on weight loss can help optimize the storage and preservation methods for sweet potatoes. The observation that longer treatment times do not substantially reduce weight loss suggests that 10-15 minutes may represent the optimal duration for maintaining weight while avoiding over-treatment, which could potentially damage the tubers.

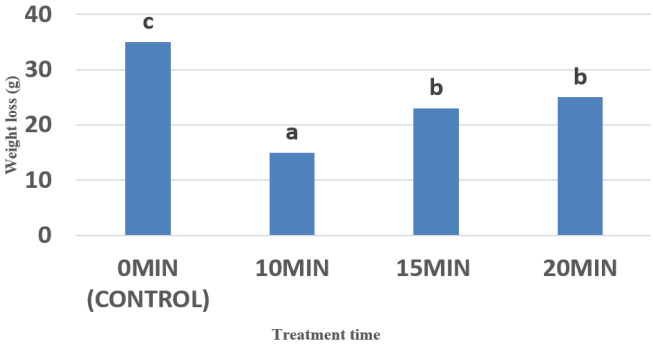

Figure 1: Effect of treatment time on the weight loss of stored sweet potato tubers

*Samples with the same alphabet are not significantly different

3.2. Thickness

The effect of different treatment times on the thickness of sweet potato tubers is presented in Figure 2. The data demonstrates a significant difference ($p < 0.05$) in thickness between the untreated (control) samples and those subjected to different treatment durations. Specifically, the results show a notable difference between the control group and all treated groups, whereas no significant difference was observed between the samples treated for 15 minutes and 20 minutes.

The control samples had an average thickness of 0.9 mm, whereas, samples treated for 10 minutes showed a substantial increase, reaching 2.1 mm on average. This significant change suggests that the hot water treatment, when applied for a short duration (10 minutes), effectively influenced the structural properties of the sweet potato tubers, leading to an increase in their thickness.

Further analysis revealed that samples treated for 15 minutes had a thickness of 1.5 mm, whereas those treated for 20 minutes had a slightly higher average thickness of 1.6 mm. Despite the small numerical difference between the 15 and 20 minutes treatments, statistical analysis confirmed that the variation was significant ($p < 0.05$) when compared with the untreated samples. This suggests that beyond 10 minutes, the effect of hot water on the thickness of the sweet potato tubers plateaus, with minimal additional benefit from extending the treatment beyond 15 minutes.

The results indicate that hot water treatment is highly effective in altering the physical characteristics of sweet potato tubers, particularly their thickness. The observed increase in thickness following treatment is

likely a result of several physiological changes within the tubers. The treatment may induce swelling or tissue expansion, possibly due to the denaturation of cell wall enzymes and the inactivation of physiological processes such as respiration, which could otherwise contribute to the degradation or shrinking of the tubers.

Interestingly, the 10 minutes treatment group showed the most pronounced effect, with thickness increasing dramatically from 0.9 mm to 2.1 mm. This suggests an optimal duration for achieving the maximum effect on thickness. While the 15 minutes and 20 minutes treatments resulted in additional thickening, the benefits appeared to diminish after the initial 10 minutes, implying that extended treatment times do not significantly further enhance the thickness. The increase in thickness in the treated sweet potato tubers is an important observation from a preservation standpoint. Enhanced thickness may correlate with better resistance to physical damage and a lower rate of moisture loss during storage, which is critical factor for extending shelf life. The thickness change observed in the 10 minute group may indicate an improvement in the cellular integrity of the tubers, which could play a role in their ability to retain moisture and resist external stress.

Additionally, the lack of significant difference between the 15 and 20 minute treatments suggests that there is a point of diminishing returns in terms of physical changes to the sweet potatoes. Once the cellular modifications induced by the hot water treatment reach a certain threshold, further increase in treatment duration may not offer substantial additional benefits. This finding underscores the importance of optimizing treatment time to balance effectiveness and energy efficiency.This approach can serve as platform to efficiently develop sweet potato tubers with multiple nutritional qualities (Kolawole et al., 2020).

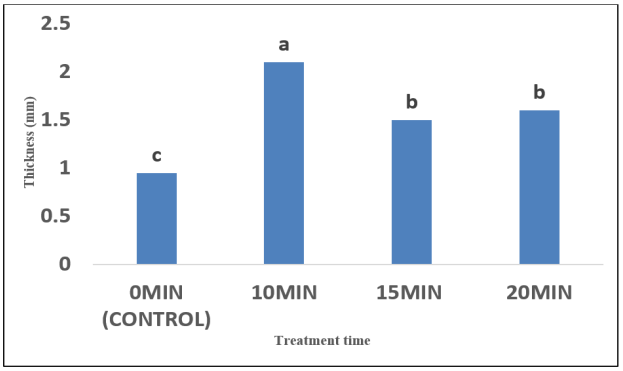

Figure 2: Effect of treatment time on the thickness of stored sweet potato tuber

*Samples with the same alphabet are not significantly different

The results demonstrate that hot water treatment significantly impacts the thickness of sweet potato tubers, with the most substantial effects occurring at 10 minutes. While increasing treatment times beyond 10 minutes leads to further thickening, the differences between the 15 and 20 minute treatments were minimal and statistically significant. These findings suggest that 10 minutes may represent an optimal treatment time for maximizing thickness without the need for longer treatments. In summary, hot water treatment is a promising technique for altering the physical characteristics of sweet potato tubers, which may contribute to improved storage properties. Future studies could explore the underlying mechanisms of tissue expansion and investigate the long-term effects of thickness change on the shelf life and quality of sweet potatoes during storage.

3.3. Firmness

Firmness is a critical quality attribute for the evaluation of sweet potato tubers, as it directly correlates with their texture, storage capacity, and overall consumer acceptability. A firmer tuber is generally considered to have better handling and longer shelf life due to its structural integrity, making it a valuable indicator of quality. The impact of hot water treatment time on the firmness of stored sweet potato tubers is presented in Figure 3. The figure clearly demonstrates a significant difference ($p < 0.05$) in firmness between the treated and control groups. The untreated control samples exhibited the lowest firmness, with a mean value of 20 N, suggesting a loss of structural integrity. This reduction in firmness is consistent with the natural degradation processes occurring in untreated sweet potato tubers, which typically result in softening due to enzymatic activity and physiological changes during storage.

In contrast, the samples treated for 10 minutes displayed the highest firmness, with a mean value of 45 N, indicating that this treatment duration significantly preserved the tuber structural integrity. The substantial increase in firmness is likely due to hot water stabilizing cell wall components and reducing the activity of softening enzymes, such as pectinase and cellulase. The treatment may also cause the formation of cross-links within the pectin matrix, contributing to the maintenance of firmness.

Further, the firmness values for samples treated for 15 minutes and 20 minutes were 30 Nand 29 N, respectively. While these values are higher than the control group, they are significantly lower than those observed in the 10minute treatment group. This suggests

that extending the treatment time beyond 10 minutes does not result in further significant improvements in firmness. In fact, the slight decline in firmness after 10 minutes of treatment may reflect a diminishing return in the effectiveness of hot water treatment at longer durations.

The results underscore the effectiveness of hot water treatment in preserving the firmness of sweet potato tubers during storage. The 10 minute treatment not only maintains the structural integrity of the tubers but also enhances their firmness to the greatest extent. Hot water treatment is known to induce several biochemical changes within plant tissues, such as the inactivation of enzymes involved in cell wall degradation, which likely accounts for the observed increase in firmness. Additionally, the heat may cause the cell walls to become more resistant to mechanical stress, improving the tubers' ability to withstand handling and transportation.

However, the decrease in firmness, observed in the 15 minute and 20 minute- treatment groups, raises an important consideration. While these treatments still provide better firmness than the control group, the slight reduction in firmness after 10 minutes of treatment suggests that there may be an optimal treatment time for firmness preservation. Prolonged exposure to heat could potentially lead to over softening or changes in the tuber's internal structure that negates the benefits of increased firmness.

The improvement in firmness with hot water treatment can be attributed to several factors. First, the heat from the water may denature enzymes involved in the degradation of cell wall components, such as pectin and cellulose. These enzymes are responsible for breaking down the plant's structural polysaccharides, leading to softening. By inactivating these enzymes, hot water treatment effectively prevents the breakdown of cell walls, thus maintaining the tuber's firmness.

Additionally, heat may cause gelation of pectin, a key polysaccharide in the cell wall, which contributes to increased rigidity and resistance to mechanical damage. This process is commonly observed in fruit and vegetable processing, where heat treatment is used to maintain texture and firmness.The results are consistent with findings in other studies that have reported the beneficial effects of hot water treatments on the texture of root crops, including sweet potatoes. For instance, Song et al. (2021) found that hot water treatments helped preserve the firmness of tubers by halting enzymatic activity that typically leads to softening during storage. Similarly, Huang et al. (2014) demonstrated that heat treatment can extend the firmness of root vegetables by inactivating microorganisms that contribute to texture loss. More sothe findings is in agreement with Rico et al.(2007)who reported that storage at 43.5oC gave slightly tougher tubers.

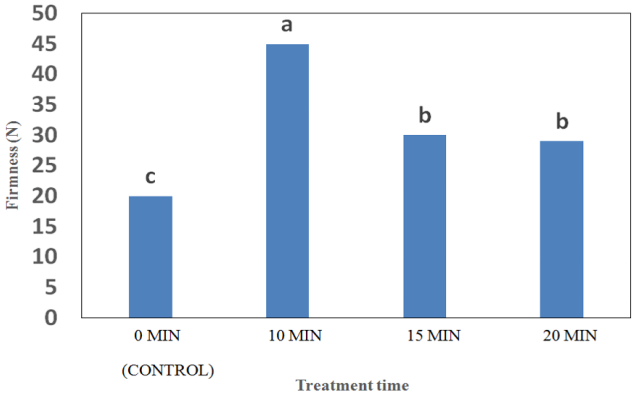

Figure 3: Effect of treatment time on the firmness of stored sweet potato tuber

*Samples with the same alphabet are not significantly different

3.4. Appearance

The appearance of stored products is a crucial indicator of their overall quality and shelf-life. In the case of sweet potato tubers, appearance can be significantly influenced by various post-harvest treatments, including hot water treatment. Figure 4 illustrates the effects of hot water treatment on the appearance of stored sweet potato tubers over a four week period.

The results indicate no significant difference ($p < 0.05$) in the appearance between sweet potato tubers treated under 15 minutes and those treated under 20 minutes. Both groups exhibited similar levels of visual quality suggesting that this duration of hot water exposure does provide additional benefits for maintaining appearance during storage. This finding is noteworthy because it challenges the expectation that longer hot water treatment durations would improve appearance or quality retention in stored tubers. Conversely, sweet potato tubers treated with hot water for 10 and 15 minutes exhibited markedly better appearance scores. The 10 minute treatment resulted in tubers that were rated as having "very good" appearance, while the 15 minute treatment resulted in tubers with a "good" appearance. These results are consistent with the hypothesis that a moderate hot water treatment can enhance the post harvest quality of sweet potato tubers by potentially inhibiting microbial activity and slowing the progression of spoilage.

However, the appearance of tubers treated for 20 minutes deteriorated significantly after four weeks of storage, with these samples showing poor appearance

compared to those treated for shorter durations. This decline may be attributed to the overexposure of the tubers to hot water, which could lead to thermal damage, cell wall breakdown, or excessive stress on the tubers, thereby accelerating their deterioration during storage. The finding aligns with previous research, including the work of Suhaizan et al. (2019), which reported that hot water treatment at temperatures ranging from 45 to 50°C for 10 minutes can retard microbial activity and decay in stored tubers. However, prolonged exposure beyond this duration may not yield further benefits and could, in fact, contribute to negative effects on the tubers' overall quality.

In summary, the results suggest that moderate hot water treatments, such as a 10 minute exposure, are effective in preserving the appearance of sweet potato tubers during storage, while longer treatments may be detrimental. Further studies exploring the physiological and biochemical impacts of varying treatment durations could provide deeper insights into optimizing postharvest handling practices for sweet potatoes.

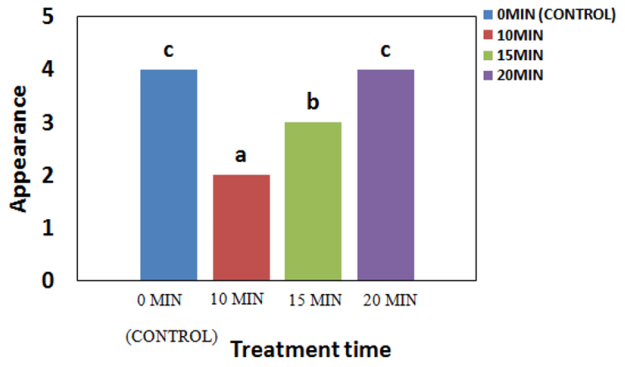

Figure 4: Effect of hot water treatment of the appearance of stored sweet potato tuber

*Samples with the same alphabet are not significantly different

4. Conclusion

Sprouting in sweet potato cause loss of weight, firmness and undesirable appearance, thereby shortening storage life. Various methods have been employed to mitigate these issues. In this study, hot water treatment was applied on sweet potato tubers, and the effect of treatment on key post-harvest qualities-weight loss, thickness, firmness and appearance was evaluated over four weeks of storage at 27 ± 2oC. The results showed that the treatment time (10, 15 and 20 minutes) significantly influenced the quality of stored sweet potato tubers. Among the treatments, 10 minutes hot water exposure consistently maintained the best overall These findings provide practical insights for optimizing hot water treatment to enhance the storage and post-harvest quality of sweet potatoes, which may maybe valuable to the food industry.

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