Cameroun Journal of Biological and Biochemical Sciences, 2026, 34, 35-50.

DOI: https://doi.org/10.63342/cjbbs2026.34.25-O28.en

CAMEROON JOURNAL OF BIOLOGICAL AND BIOCHEMICAL SCIENCES
Published by the Cameroon Biosciences Society (CBS)

Original research article

Effects of post-harvest treatment methods on the shelf life, physico-chemical and sensory properties of pineapple (*Ananas comosus* (L.) Merr.) cv. 'Smooth Cayenne' fruits

KAMDA SILAPEUX ARISTIDE GUILLAUME[1,*], BOLDA ESTHER MARALOSSOU[1], TIENTCHEU BERNARD[2] and PONKA ROGER[3].

[1]Department of Social Economy and Family Management, University of Buea, P.O Box 249, Buea Road, Kumba, Cameroon

[2]Department of Biochemistry and Molecular Biology, Faculty of Science, University of Buea, P.O BOX 63, Buea, Cameroon

[3]Department of Agriculture, Livestock and Derived Products, National Advanced School of Engineering of Maroua, University of Maroua, P.O. Box 48, Maroua, Cameroon

**Corresponding author: silapeuxkamda@gmail.com*

Received: 07 Sep 2025, Reviewed: 06 Nov 2025, Revised: 17 Nov 2025, Accepted: 15 Dec 2025, Published: 30 March 2026.

ABSTRACT

Post-harvest loss of fruits, particularly pineapples are a matter of concern for countries with agriculture-based economies. Therefore, developing and implementing treatment methods to extend the shelf life of pineapples by reducing post-harvest decay and maintaining the physicochemical qualities of the fruit is of prime importance. We aimed to investigate the effects of different post-harvest treatment methods on changes in the physico-chemical and sensory properties of pineapple fruits during storage at room temperature. The experiment comprised three post-harvest treatments: Control (Untreated samples), NaCl solution (immersion in a 10% NaCl solution for 3 min), Citric Acid solution (immersion in a 10 mmol/L citric acid solution for 3 min) and Hot water treatment (immersion in hot water at 54°C for 3 min). The fruits were evaluated for physiological weight loss, decay percentage, total soluble solids, titratable acidity, shelf life and ascorbic acid content every 2 days. Sensory analysis was performed on the 4th day post-treatment. The experiment followed a completely randomised design with three replications. There were significant differences between the control and treated samples. Pineapple fruits treated with hot water exhibited the lowest weight loss (9.2 %) and the lowest decay rate (11.11 %) after 14 days of storage at ambient temperature (25°C ± 3). The maximum shelf life (10.1 days) was observed in fruits treated with hot water, followed by those treated with citric acid (8 days). Although hot water treatment significantly reduced vitamin C content (25.32 mg/100 ml), its effects on sensory attributes were not significant. Principal Component Analysis indicated a positive correlation between NaCl treatment, no treatment, physiological weight loss, and fruit decay rate. Hot water treatment of fresh pineapple fruits can be applied on a large scale as it is low-cost and improves the product's marketability.

Keywords: Pineapple, hot water treatment, citric acid, shelf life, Vitamin C, sensory properties.

RÉSUMÉ

Les pertes post-récoltes des fruits en général et de l'ananas en particulier sont une préoccupation pour tous les pays dont l'économie est basée sur l'agriculture. Il est impératif aujourd'hui de développer et de mettre en œuvre des méthodes de traitement pour améliorer la durée de conservation de l'ananas tout en maintenant ses propriétés physico-chimiques. L'objectif de cette étude était d'étudier les effets de différentes méthodes de traitement post-récolte sur les propriétés physico-chimiques et sensorielles des fruits d'ananas, conservés à température ambiante. La méthodologie a consisté à mettre en œuvre 3 traitements post-récolte: Immersion dans une solution de NaCl, 10 % pendant 3 min, immersion dans une solution d'acide citrique, 10 mmol/l pendant 3 min et immersion dans de l'eau chaude à 54 °C pendant 3 min. Une fois traités, les fruits ont été entreposés à température ambiante dans la chambre de séchage. Tous les 2 jours, 2 fruits ont été prélevés aléatoirement pour évaluer la perte physiologique de masse, le taux de pourriture, la totalité des particules solides solubles (STS), l'acidité titrable, la durée de conservation et la concentration en acide ascorbique. L'analyse sensorielle a été effectuée au 4^{e} jour d'entreposage après le traitement. L'expérimentation a été réalisée selon un plan randomisé complet (CRD) avec trois réplications. Les résultats ont montré qu'il y avait une différence significative entre les échantillons témoins et traités. Les fruits d'ananas traités avec de l'eau chaude ont montré la plus faible perte de masse (9,2 %), le taux de pourriture le plus bas (11,11 %) après 14 jours d'entreposage à température ambiante (25 °C ± 3). La durée de conservation maximale (10,1 jours) a été observée dans le cas des fruits traités à l'eau chaude, suivie par les fruits traités avec de l'acide citrique (8 jours) par rapport au témoin (4,3 jours). Le traitement à l'eau chaude a réduit significativement la teneur en vitamine C (25,32 mg/100 ml), mais l'effet sur les attributs sensoriels n'était pas significatif. L'Analyse en Composantes Principales (ACP) a indiqué une corrélation positive entre le traitement au NaCl, le contrôle, la perte physiologique de masse et le pourcentage de décomposition des fruits. Le traitement à l'eau chaude des ananas frais doit être appliqué à grande échelle car il est facile à mettre en œuvre, et a moins d'impact négatif sur la qualité marchande du produit.

Mots-clés: Ananas, **t**raitement à l'eau chaude, acide citrique, durée de conservation, Vitamine C, attributs sensoriels.

1. INTRODUCTION

Pineapple [*Ananas comosus* (L.) Merrill] is the 11th most produced tropical fruit globally(FAO 2020). It is a non-climacteric fruit that belongs to the *Bromeliaceae* family and is widely cultivated in tropical and subtropical regions (FAO 2020). It holds significant economic importance in Cameroon, where production was estimated at approximately 168,000 tons across a cultivated area of 4800 ha in 2014 (FAOSTAT 2021). By 2023, Cameroon ranked as the 37th largest exporter of fresh pineapples globally. Pineapple is the second most important fruit exported to EU markets with an exportation rate of 98% (FAO 2023). The remainder of the produce, <than 2%, is sold to neighbouring countries and consumed locally, primarily in the cities of Douala and Yaoundé. To meet commercial requirements, Cameroonian producers cultivate three varieties (Cayenne lisse, Queen and Red spanish) which have been disseminated throughout the country following extensive research (AGROCOM 2002).

Between 2021 and 2022, Cameroon dropped 10 places in the global ranking of fresh pineapple exporters (Competitiveness Committee 2023). This regression is primarily because producers struggle to meet the quality standards required by international markets, particularly in Europe (Gbenou et *al*. 2019). A significant quantity of fruit, often more than 50% of export shipments, is rejected for failing to meet European import criteria (Gbenou et *al*. 2019; Agbo et *al*. 2008; FAO 2020). Pineapples rejected for export are redirected to local and regional markets with lower quality standards and reduced prices. Unfortunately, if left untreated, most of these pineapples lose their quality within 4 to 6 days, resulting in substantial losses (Hajare et *al*. 2006, Gbenou et *al*. 2019, Kamda et *al*. 2020). This short shelf life is attributed to the fact that most fruits and vegetables are composed of 70 to 90% water and, once separated from their nutrient source, their respiration rates increase, leading to moisture loss, quality and nutrient degradation, and potential microbial spoilage (Barrett 2007).

Although research efforts have been made to increase pineapple production, maximum profitability can only be achieved if production gains are complemented by effective post-harvest treatment measures that minimise post-harvest losses, extend shelf life, preserve the fruits' sensory and physico-chemical properties, and reduce rejection rates for fruits intended for export (Sandarani et *al*. 2018). Traditional preservation methods commonly used for pineapples, such as sun drying and basic heat processing, have significant limitations, including substantial loss of nutritional value and sensory quality, short shelf life under ambient conditions, and a high risk of microbial spoilage (Ahmed and Siddiq 2016). Numerous technologies such as hot water treatments, edible coating and dipping in food grade chemicals solutions such as NaCl and citric acid, and other non-thermal treatments have been applied to several fruits to preserve their physicochemical properties and reduce post-harvest losses. These treatment methods have demonstrated effectiveness in controlling postharvest fungal diseases in mango and avocado (Hot water treatments), slowing ripening and senescence in tomato and papaya (Edible coatings) and controlling postharvest decay in fruits such as tomatoes (dipping in food-grade chemical solutions) (Feyera and Abdo 2022; Jamir and Khawlhring 2017; Baltazari et *al*. 2020). Several studies have assessed the effects of post-harvest treatments (hot water treatment and dipping in NaCl and citric acid solution) on controlling Thielaviopsis black rot in pineapple (Wijeratnam et al. 2005; Basumatary et al. 2021). However, these studies did not assess the effects of such treatments on the shelf life, sensory properties, and physicochemical characteristics (such as appearance, integrity, absence of defects, Brix level, and acidity) which are critical for export marketing. Studies indicate that hot water treatment as well as treatment with NaCl and citric acid solution serves as an effective method to extend the shelf life and enhance the physico-chemical properties of fruits by reducing decay and maintaining firmness. These treatment methods inhibit metabolic degradation and pathogen growth, rather than just surface sterilization (Akangtula and Chhungpuii 2017; La Oge 2025). We hypothesised that these treatment methods could effectively extend the shelf life of pineapple fruits without significantly affecting their sensory and physicochemical properties. Therefore, this study was conducted to assess the effects of hot water treatment and NaCl and citric acid dips on the shelf life of pineapple fruits at ambient temperature and their physicochemical and sensory qualities.

2. MATERIAL AND METHODS

2.1. Collection of Samples

For this study, we selected healthy and fresh "half-yellow" fruits (those in which approximately 50% of tubercles had turned yellow, corresponding to about 5.5 months after flowering) of the "Smooth Cayenne" pineapple (*Ananas comosus* L. Merr.) that were free from physical damage (cuts, sunburn), pests, and blemishes (met export quality standards). maturity stage (defined as when approximately 5.5 months after flowering. These fruits were healthy, fresh and met export quality standards (being free from physical damage [cuts, sunburn], pests, and blemishes). They were harvested from local fields in Njombe, Littoral Region, Cameroon; located approximately between 4° 40' 00" N and 4° 42' 30" N latitude, and 9° 40' 00" E and 9° 40' 30" E longitude. The average weight of the selected fruits was 951.60 ± 68.50 g. The pineapples were transported to the Agro Ecology Laboratory of the University of Buea with careful handling to avoid injury. They were then randomised and assigned to the various treatment methods. Before the treatment methods were applied, the fruits were rinsed in distilled water for 30 s and air dried to remove impurities.

2.2. Treatments and Experimental Design

The experiment was laid out in a Completely Randomised Design

with 3 replications of 3 treatment methods, namely NaCl solution (10 % w/v), Citric Acid solution (10 mmol/L) and hot water (54°C). Fruits were divided into 4 groups and treated as follows: Control (Untreated samples), NaCl solution, (immersion in a 10% NaCl solution for 3 min), Citric Acid solution (immersion in a 10 mmol/L citric acid solution for 3 min) and Hot water treatment (immersion in hot water at 54°C for 3 min). Each replication comprised 35 healthy early mature fruits, giving a total of 105 fruits per treatment.

Treatments were carried out in a metal tank that measured 70 x 145 x 45 cm containing either the treatment solution or distilled water maintained at 54°C. The fruits were placed in crates and dipped into the metal tanks. After treatment, fruits were removed and placed under an electric fan to eliminate excess surface moisture. The fruits were then stored at room temperature (25 °C ± 3). A sensory analysis was performed after 4 days of storage (day 4) using 3 fruits randomly selected from the 35 fruits in each replication. Of the 32 remaining fruits, 14 fruits were randomly selected at 2-day intervals (2 samples each) on 7 different dates (0, 2nd, 4th, 6th, 8th,10th and 12th day after treatment) to assess physico-chemical parameters (pH value, Total soluble solid, Titratable acidity, Vitamin C). The remaining 18 fruits were used to monitor shelf life, decay incidence and percentage weight loss throughout storage.

2.3. Preparation of sample for sensory and physico-chemical analysis

The fruits allocated for sensory and physico-chemical analyses were peeled and their cores and crowns were removed. The pineapple pulp was cut into small pieces and blended using an electric blender. The resulting product obtained was used for the assessment of the total soluble solids content (TSS). For the remaining analysis, the pulp was filtered to remove fibrous material. One portion of the filtrate was transferred into a clean, labelled container and stored at 40 °C for sensory analysis. The remaining portion of the filtrate was centrifuged for 10 min. The supernatant was then used to measure other physico-chemical parameters, including Titratable acidity and Vitamin C (ascorbic acid).

2.4. Assessment of physical parameters

2.4.1. Physiological weight loss

Fruits were periodically weighed and the loss in mass was recorded for each replicate. Damaged fruits (showing rotting or chilling injury) were also included in the measurements. Data were calculated as the percentage of the initial weight using the following formula, provided by Basumatary et *al*. (2021):

$$Fruit\ Weight\ Loss\ (\%) = \frac{\text{Initial weight} - Weight\ at\ specific\ interval}{\text{Initial Weight}} X\ 100$$

2.4.2. Decay Percentage (%)

A pineapple fruit was considered decayed if at least one visible symptom of biotic or abiotic disorder (black or soft rot, foul odour, brownish discoloration, softening) was present. Finally, fruit decay incidence was calculated as the percentage of decayed fruits using the following formula (Basumatary et *al*., 2021).

$$Decay\ Percentage\ (\%) = \frac{\text{Number of fruits at } n^{th} \text{ day}}{\text{Number of fruits at day 0}} X\ 100$$

2.4.3. Shelf life

Shelf life is defined as the duration during which a product remains usable, edible or marketable. In this study, shelf life was defined as the number of days it took for 50% of the fruit to become unmarketable due to visible symptoms of biotic or abiotic disorders (black or soft rot, foul odour, brownish discoloration, softening) (Baltazari et *al*., 2020). The fruits were assessed daily and when half of the fruits became unmarketable, they were discarded and the storage duration (in days) was recorded as shelf life. Ambient storage conditions ranged from 20–22 °C (minimum) to 23–35 °C (maximum), with relative humidity between 83% and 93%.

2.5. Assessment of chemical parameters

2.5.1. Total Soluble Solid content of pineapple pulp

TSS refers to the percentage concentration of sugar and soluble minerals present in any food or substance. The TSS content of the pineapple pulp was determined using an ATC portable hand refractometer. A drop of the pulp extract was placed on the prism of the refractometer and TSS values (%Brix) were obtained directly from the instrument reading.

2.5.2. Titratable acid content of pineapple pulp

Titratable acidity was determined following the AOAC 962.12 method (AOAC 2000). The pineapple peel extract contains several organic acids, which are readily neutralized by strong bases and can be titrated against standard bases such as sodium hydroxide. A 10 mL sample of pineapple extract was weighed, transferred to a 500 mL Erlenmeyer flask, and dissolved with 250 mL of deionised water. The solution was titrated against 0.1 N sodium hydroxide with 1 ml of phenolphthalein indicator until a faint pink endpoint was observed. The volume of 0.1 N sodium hydroxide used was recorded. The measurement was repeated at least three times, and the total acidity was calculated using an equation and expressed as the concentration of citric acid (g/L). The percentage of citric acid was calculated using the following expression:

$$\%\ \text{Acid (as anhydrous citric acid)} = \text{Volume of 0.1N NaOH (ml) x}\frac{0.64}{10} \qquad (3)$$

2.5.3. Vitamin C content of pineapple pulp

Vitamin C content was determined using the dichlorophenolindophenol (DCP) method of Convening (AOAC 2005) with slight modifications.

Standardisation of 5ml DCP with ascorbic acid

A mass of 9.7 mg of pure vitamin C ($C_6H_8O_6$) was accurately weighed, dissolved in 50 mL of distilled water, and stirred until it was fully dissolved. A volume of 5 mL of the DCP was accurately pipetted into a 50 mL Erlenmeyer flask; one drop of acetic acid (30%) was added to change the colour of DCP from blue to pink. The DCP was titrated against the vitamin C solution to a colourless endpoint (or equivalence point) using a burette. The volume of ascorbic acid used was recorded and the titration was repeated. The quantity of vitamin C that changed the colour of DCP was then calculated.

Titration of DCP with fruit juice

The procedure was repeated using 10 mL of a 1:2 dilution of fruit juice in place of vitamin C. After repeating the titration twice, the vitamin C content was calculated from the standard volume and expressed as mg vitamin C per 100 mL of juice.

2.6. Sensory analysis of pineapple fruit juice

Sensory analysis was conducted with 25 untrained panellists, immediately following the application of the different treatment methods. The sensory evaluation was conducted in a laboratory at room temperature. Each panelist was accompanied to a separate space to avoid interaction and ensure unbiased results. Panellists were served four pineapple juice samples, that is, the control and the three treated samples, in clean transparent disposable cups. Water was provided to panelists to rinse their palates before and between tastings. They were given a score sheet containing four coded samples and a 9-point hedonic scale ranging from 1 (like extremely) to 9 (dislike extremely). Panellists were instructed to evaluate each sample individually and rate it based on appearance, colour, taste, aroma, texture, and overall acceptability. All panellists provided informed consent before participating in the study.

2.7. Statistical analysis

The results of the treatments were analysed statistically using SPSS 20.0 for WINDOWS. All analyses were performed in triplicates, and standard deviations were calculated. Analysis of variance (ANOVA) was used to determine treatment effects. When significant differences were detected, Tukey's test was applied for post hoc comparisons at a significance level of $p<0.05$. To investigate the relationships between physico-chemical characteristics and treatment methods, Principal Component Analysis (PCA) was performed using XLSTAT version 2021.4. PCA was performed to classify the different post-harvest treatment methods applied to pineapple fruits based on their overall acceptability and physico-chemical characteristics (physiological weight loss, fruit decay percentage, TSS, Titratable Acidity, and Vitamin C content) after 4 days of storage (day 4).

3. RESULTS

3.1. Physiological weight loss

The various treatments had a significant effect ($P < 0.05$) on weight loss percentage throughout the storage period. There was a gradual increase in mass loss over time for the treated and untreated groups. The highest weight loss percentage was recorded in the control group, with values of 2.5%, 4.9%, 8.2%, 10.6%, 13.4%, and 15.6% after 2,4,6,8,10, and 12 days of storage, respectively. The smallest increase in mass loss was observed in pineapple samples subjected to hot water treatment (HWT), which recorded weight loss values of 2.4%, 3.5%, 4.8%, 5.7%, 7.4%, and 8.2% at the same 2-day intervals. Treatments with NaCl and citric acid solutions resulted in a cumulative increase in weight loss during storage. Although this increase was more pronounced than that of the hot water treatment samples, it was significantly lower than that of the untreated control (Figure 1).

3.2. Fruit decay percentage

Fruit decay evolved gradually and varied significantly ($P < 0.05$) depending on the treatment applied at each interval throughout the storage period. Fruits treated with hot water and citric acid showed greater resistance to decay than the untreated (control) and NaCl-treated fruits. The latter two groups exhibited high decay percentages of 50% and 38.8%, respectively, after 12 days of storage (Figure 2).

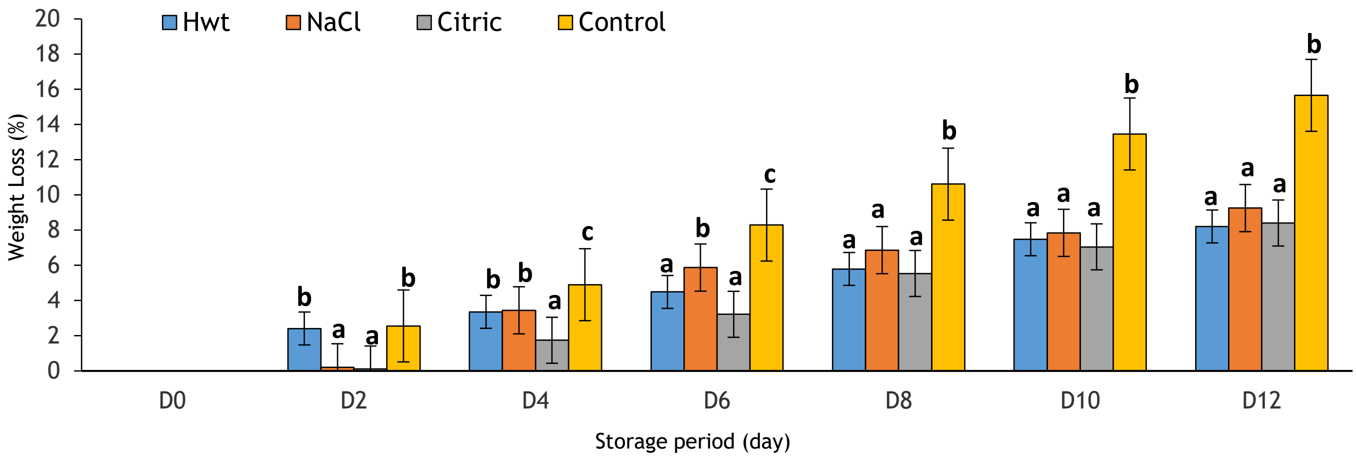

Figure 1: Effect of post-harvest treatment methods on weight loss (%) of pineapple during storage. Error bars represent the standard deviation, number of samples = 3. Values with the same superscript within the same storage period are not significantly different (p> 0.05). HWT=Hot Water Treatment (54^{0}C, 3 min); NaCl= NaCl solution (10 % w/v, 3 min); Citric acid= citric acid solution (10 mmol/l)

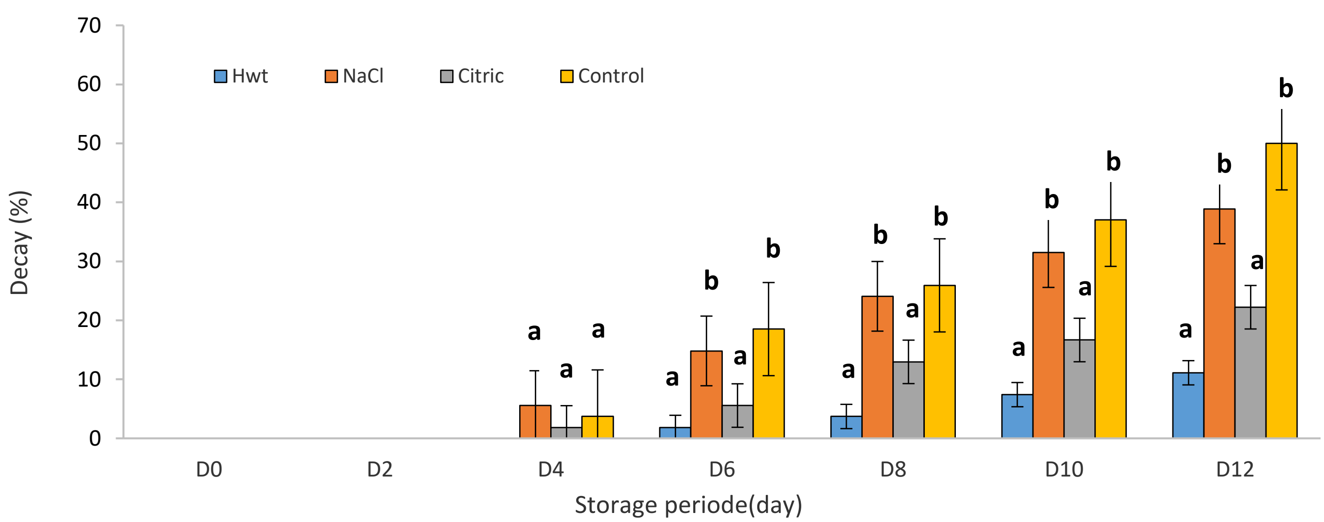

Figure 2: Effect of post-harvest treatment methods on fruit decay percentage of pineapple fruits during storage. Error bars represent the standard deviation, number of samples = 3. Values with the same superscript within the same storage period are not significantly different (p> 0.05). HWT=Hot Water Treatment (54^{0}C, 3 min); NaCl= NaCl solution (10 % w/v, 3 min); Citric acid= citric acid solution (10 mmol/l)

3.3. Total Soluble Solids

For both treated and untreated fruits, there was an increase in the °Brix, which stabilised after a plateau phase (Figure 3). There were no significant differences (P> 0.05) among the various treatment methods at each storage interval. However, the highest TSS values were recorded in the fruits treated with hot water (17.16 and 17.06°B) and those treated with citric acid (16.6 and 16.63°B) on days 8 and 12 of storage, respectively. The lowest TSS values were recorded in untreated fruits (15.7 and 15.3 °B) and in fruits treated with NaCl (14.7°B and 14.2°B) on days 8 and 12 post-storage, respectively. By the final day of storage (day 12), the TSS in the hot water treatment group reached 17.06 °Brix compared to 13.6°Brix immediately after treatment (day 0). These results indicate that the treatment methods significantly influence TSS accumulation in pineapple fruits during the ripening process.

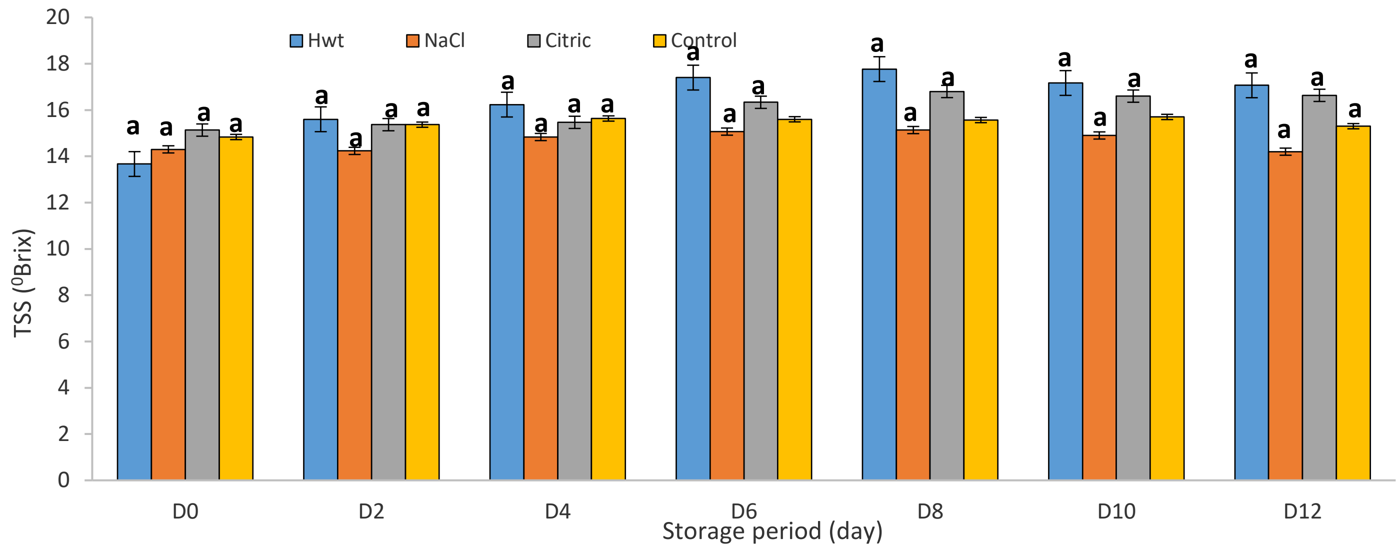

Figure 3: Effect of post-harvest treatment methods on Total Soluble Solids (^{0}Brix) of pineapple during storage. Error bars represent the standard deviation, number of samples = 3. Values with the same superscript within the same storage period are not significantly different (p> 0.05). HWT=Hot Water Treatment (54^{0}C, 3 min); NaCl= NaCl solution (10 % w/v, 3 min); Citric acid= citric acid solution (10 mmol/l)

3.4. Titratable Acidity

There was a subtle reduction in titratable acidity at each 2-day interval throughout the storage period. This decrease was more pronounced in untreated (control) fruits and in fruits treated with NaCl solution than in fruits treated with hot water or citric acid. The difference in titratable acidity between treated and untreated fruits became significant from the 8th day of storage onward ($P < 0.05$). On the 12th day of storage, titratable acidity values were 0.56 and 0.53% for fruits treated with hot water and citric acid, respectively (Figure 4).

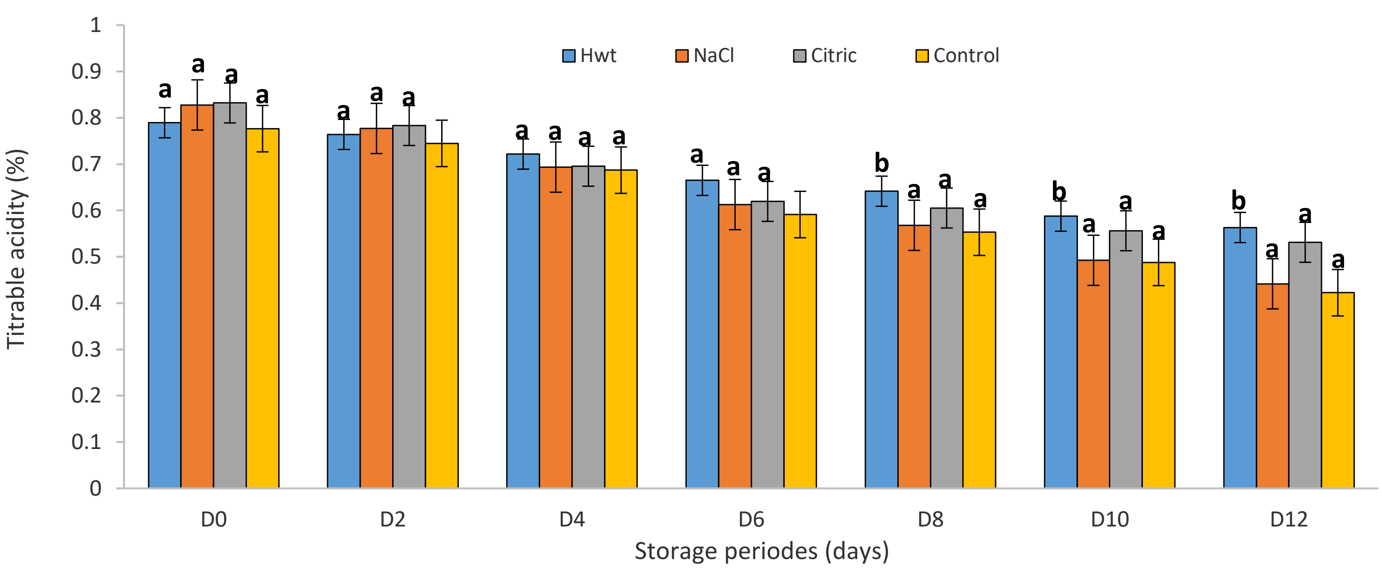

Figure 4: Effect of post-harvest treatment methods on titratable acid (%) of pineapple during storage. Error bars represent Standard Deviation; number of samples = 3. Values with the same superscript within the same storage period are not significantly different (p> 0.05). HWT=Hot Water Treatment (54^{0}C, 3 min); NaCl= NaCl solution (10 % w/v, 3 min); Citric acid= citric acid solution (10 mmol/l)

3.5. Vitamin C content

There was a significant difference (P < 0.05) between the vitamin C content in the treated and untreated fruits from the 6th day of storage. Fruits subjected to hot water treatment exhibited a significant drop in vitamin C content (around 35.3%) over the 12-day storage period, compared with a reduction of approximately 18% in fruits treated with citric acid solution. From the 10th day of storage onward, only minor variations in vitamin C content were observed, regardless of the treatment applied. Specifically, the vitamin C content was 25.2 mg/100 mL in fruits treated with hot water, compared to 32.3 mg/100 mL in fruits treated with citric acid solution on the 10th day of storage (Figure 5).

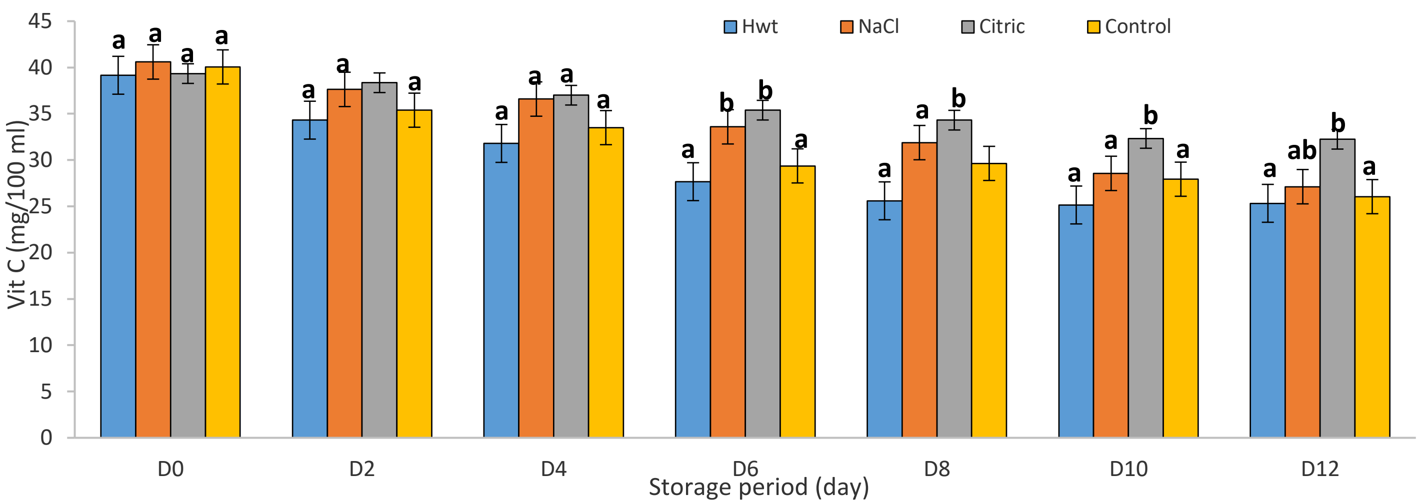

Figure 5: Effect of post-harvest treatment methods on vitamin C content (mg/100 ml) of pineapple during storage. Error bars represent the standard deviation, number of samples = 3. Values with the same superscript within the same storage period are not significantly different (p> 0.05). HWT=Hot Water Treatment (54^0C, 3 min); NaCl= NaCl solution (10 % w/v, 3 min); Citric acid= citric acid solution (10 mmol/l)

3.6. Shelf life

The various treatments had a significant effect on fruit shelf life (Table 1). The Maximum shelf life (10.1 days) was observed in fruits subjected to hot water treatment, followed by those treated with citric acid (8 days), compared with the control (4.3 days).

Table 1: Effect of post-harvest treatment methods on shelf life (days) of pineapple during storage.

Treatments	HWT	NaCl	Citric acid	Control
Shelf life (day)	10.1 ± 0.56^c	7.3 ± 1.49^b	8 ± 0.8^b	4.3 ± 1.15^a

Values are presented as mean±SD, n = 3. Values with the same superscript within the same row are not significantly different (p> 0.05). HWT, Hot Water Treatment (54^0C, 3min); NaCl, NaCl solution (10 % w/v, 3 min); Citric acid, citric acid solution (10 mmol/L)

3.7. Sensory properties of pineapple fruit juices

The effects of the treatment methods on the sensory properties of pineapple fruits after 6 days of storage are presented in Table 2. The treatment methods had a significant effect on all assessed sensory attributes. Additionally, fruits treated with citric acid received the highest scores for texture (7.32) and overall acceptability (7.32). Meanwhile, fruits treated with hot water achieved the highest scores for appearance (7.8) and colour (7.77). In most cases, untreated (control) fruits and those treated with hot water showed statistically similar sensory attribute scores. Texture, appearance, and colour received higher ratings than taste and flavor.

Table 2: Effect of post-harvest treatment methods on sensory properties of pineapple during storage.

Samples	Taste	Texture	Flavour	Appearance	Colour	Overall acceptability
HWT	7.22±0.79^{b}	7.30±0.64^{b}	6.96±1.02^{b}	7.8±0.71^{a}	7.77±0.91^{a}	6.8±0.96^{a}
NaCl	6.2±1.78^{a}	6.92±1.00^{a}	6.2±1.53^{a}	7.48±1.08^{a}	7.72±1.17^{a}	6.6±1.44^{a}
Citric A	7.32±0.85^{b}	7.32±0.95^{b}	7.16±1.07^{b}	7.36±0.99^{a}	7.16±1.03^{a}	7.32±0.80^{b}
Control	7.24±1.44^{b}	7.32±0.64^{b}	7.04±0.84^{b}	7.56±0.77^{a}	7.76±0.93^{a}	7.00±0.96^{b}

Values are presented as mean±SD, n = 3. Values with the same superscript within the same row are not significantly different ($p > 0.05$). HWT, Hot Water Treatment (54^{0}C, 3min); NaCl, NaCl solution (10 % w/v, 3 min); Citric acid, citric acid solution (10 mmol/L)

3.8. Principal component analysis

We performed PCA to investigate the relationships between physicochemical characteristics and treatment method. The first two principal components (F1 and F2) accounted for 89.69% of the total variance (Figure 6A). The F1 axis explains 62.79% of the variables observed, while the F2 axis explained 26.9%. The treatments were almost completely separated from each other (Figure 6A), indicating clear differentiation based on the evaluated parameters.

Figure 6 B illustrates the relationship between post-harvest treatment methods and the physicochemical characteristics after 4 days of storage (day 4). There was a strong association between hot water treatments and overall acceptability, TSS, and titratable acidity. Acute angles were observed between NaCl treatment, the control, physiological weight loss, and fruit decay percentage, indicating a positive correlation between these variables. Conversely, an obtuse angle was observed between overall acceptability and the NaCl treatment, indicating a negative correlation between these variables.

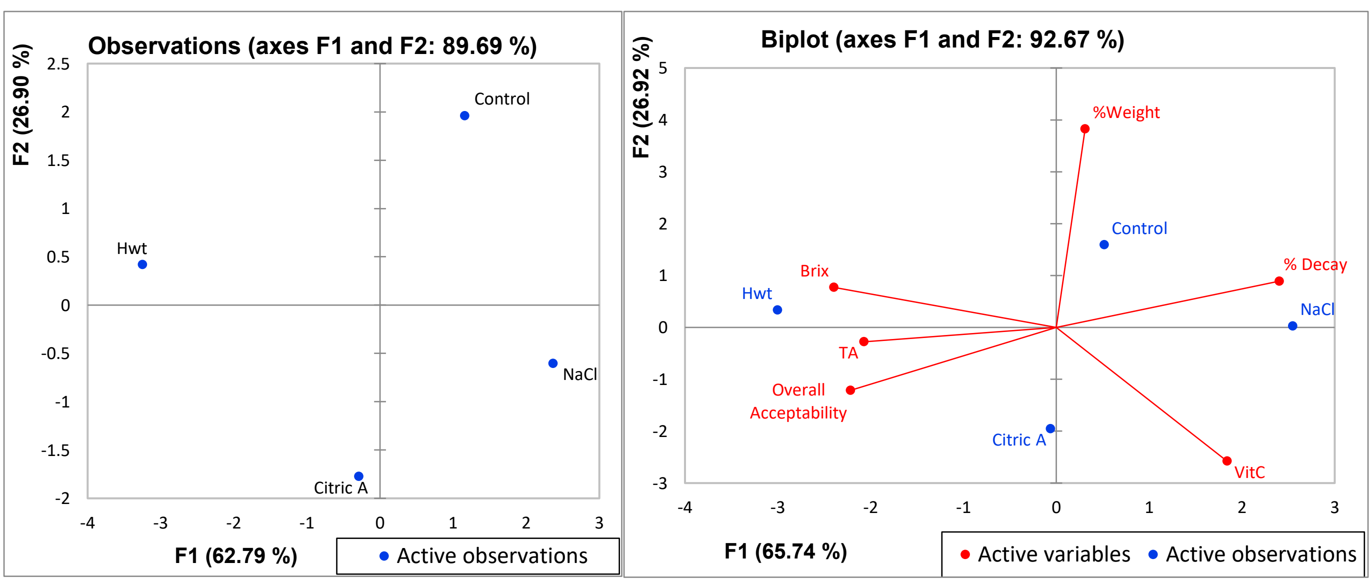

Figure 6. Principal component analysis (PCA) of physico-chemical characteristics of pineapple fruits measured at the 4th day of storage. (A) Observations plot of F2 against F1; (B) Biplot of F2 against F1.

4. DISCUSSION

Post-harvest treatment of fruits is crucial for maintaining quality, extending shelf life, and minimizing losses after harvest (Kader and Rolle 2004). We investigated the effects of post-harvest treatment methods on the changes of physicochemical and sensory properties of pineapples during storage at room temperature.

The percentage of weight loss in pineapple fruits depends on several factors such as the skin structure and nature of waxes on the fruit surface (Veraverbeke et *al*. 2003). The high physiological weight loss observed in the untreated pineapple fruits may be attributed to increased respiration and transpiration rates (Elgar et *al*. 1999). These observations substantiate the findings of several researchers such as Safdar (2009), Lum and Norazira (2011) and Pholoma et *al*. (2020) whose works revealed that there is a small cumulative increase in physiological mass loss of hot-water-treated mangoes, tomatoes, and bananas than untreated samples or those treated with saline or acidic solutions. In fact, Safdar (2009) reported that HWTs delay fruit softening by inhibiting the enzymes and gene expression involved in cell wall degradation while suppressing ethylene synthesis. This combination of effects reduces respiration and metabolic activity, thereby extending shelf life and decreasing physiological weight loss. Another explanation for the reduced mass loss observed in treated fruits may be the formation of a barrier (aqueous medium) between the plant cells and the surrounding atmosphere, which slows respiration and cellular dehydration (Willis *et al*. 1998).

Hot water and citric acid treatments were more effective in preventing or delaying fruit decay compared to NaCl or untreated samples. Citric acid delays fruit decay through multiple mechanisms, such as lowering pH to inhibit microbial growth, acting as an antioxidant to prevent browning, and modulating fruit ripening processes (Yang et al 2019). Previous studies have shown that Hot water treatment could reduce disease incidence, maintain postharvest quality during storage and prolong the shelf-life of fruits (Elgar et *al*. 1999). Extended storage stability and improved marketability have been reported for pineapple and avocado fruits treated with hot water at different temperature and time combinations (Li et *al*. 2013; Munhuweyi et *al*. 2020). This is because hot water limits the growth of bacteria, mould, yeast and fungus, thereby delaying food decay and increasing shelf life (Wijeratnam et *al*., 2005; Asghari and Ashdam 2010; Babalar et *al*. 2007). Fruit decay is commonly caused by the growth of rot-related pathogens, and accounts for the majority of harvest losses in most horticultural crops (Minh, 2021). Fungal and bacterial infections are particularly favoured at temperatures between 28 and 30°C, which promote microbial proliferation (Maqsood et al. 2014). HWT mitigates fruit decay through a dual mechanism: it exerts a direct germicidal impact on surface pathogens and simultaneously induces an internal resistance response in the fruit. HWT at a specific temperature of 46.5°C for 45 mins is efficiently used on mangoes intended for exports, for controlling microbial diseases and delaying fruit decay and the ripening process. This treatment does not significantly affect the quality attributes required for export markets (Jacobi et *al*. 2001).

TSS is a major quality parameter for pineapples and other fruits because it is a direct indicator of ripeness, sweetness, and overall flavour, which is intrinsically linked to the fruit's texture and chemical composition (Kamiloglu 2011). It is a primary indicator of fruit maturity and quality. The pattern of evolution of the Brix index as a function of storage duration, as examined in this study, had also been observed by Kabir et *al*. (2020) and Lu et *al*. (2010) on pineapple fruits stored at room temperature. Compared with untreated fruits (control), fruits treated with hot water had the highest TSS content. Similar findings were recorded in the study conducted by Wijeratnam et *al*. (2006) on pineapple fruits treated with hot water under the same conditions, to control Thielaviopsis black rot. Amin and Hossain (2013) also found that treating banana fruits with hot water at 53°C for 9 min resulted in a higher TSS content than the untreated ones. The initial increase in TSS in fruits during storage is primarily due to the hydrolysis of stored starch into simpler, soluble sugars (e.g., glucose, fructose, and sucrose). Subsequently, a decline in TSS occurs because these sugars and other organic acids are consumed as primary substrates in the process of respiration (Wills et *al*. 1998; Beaudry 1989).

Titratable acidity measures the total acid concentration in a food. The value of titratable acidity at T0 was similar to that obtained by Ngo Bogms et *al*. (2016) on pineapple fruits from the Littoral region (Cameroon). The changes in titratable acidity are significantly affected ($P < 0.05$) by the rate of metabolism, especially respiration, which consumes organic acid and thus declines acidity during storage (Clarke et *al*. 2003; Ghafir et *al*. 2009).

Ascorbic acid or vitamin C is an index of nutrient quality in pineapples. It is crucial for a strong immune system and overall health. Vitamin C acts as an antioxidant, protecting cells from damage, and is involved in collagen production, which is important for bone, cartilage, skin, and blood vessel health (Lata 2007). There was a similarity between the evolution of vitamin C during storage in the study by Adisa (1986) on pineapple fruits stored at room temperature. Lu et *al*. (2010) observed that post-harvest treatment with 5.0 mM salicylic acid delayed ripening and extended the shelf life of pineapple. Fruits treated with hot water had a significant drop in vitamin C content over 12 days compared to those treated with a citric acid solution. This large difference is likely because hot water accelerates the breakdown of vitamin C, which is sensitive to heat and oxygen, while the citric acid solution was more effective at preserving the vitamin (Touati et *al*. 2016). The ascorbic acid in fruits is sensitive to storage temperature or duration, and its degradation is enhanced by adverse handling and storage conditions such as high temperatures, low relative humidity, physical damage, and chilling injury (Adisa 1986). Besides abiotic factors, the ascorbic acid can be irreversibly oxidised (Pardio-Sedas et *al*. 1994), which decreases the edible quality and increases susceptibility to different physiological disorders during storage (Jung and Watkins 2008). The degradation reactions of vitamin C are often responsible for significant quality changes that occur during the storage of foods (Touati et *al*. 2016).

Shelf life is the period from the time of harvesting to the start of rotting of fruits (Mondal 2000). It is a basic measure of quality and a key focus in reducing loss by managing the biochemical reactions that occur within the fruit post-harvest. It is also the period of time during which food products retain their microbial safety, nutritive value, and sensorial attributes, from the time the food is harvested to the start of deterioration. The treatment with hot water (540 °C, 3 min) was more effective because it extended the lifespan of pineapples to 10.1 days. The efficiency of the hot water treatment can be explained by the effect of temperature on the control of bacteria and yeasts responsible for black rot on pineapple fruits. Indeed, the work of Wijeratnam et *al*. (2005) revealed that hot water treatment under similar conditions (540 °C, 3 min) eliminates populations of *T. paradoxa*, significantly reducing the incidence of black rot on pineapple fruits stored at room temperature for up to 6 days. The lifespan of fruits was lower than that obtained by Dhar et *al*. (2008) and Mandal et *al*. (2015) on fruits treated and preserved at room temperature.

The primary consideration for selecting and eating a food commodity is the product's palatability or eating quality, while other quality parameters, such as nutrition and wholesomeness, are secondary (Lawless and Heymann 2010). Sensory inputs interact to drive overall impressions; for example, ratings of flavour may be driven by appearance and texture inputs, as well as by pure flavour inputs (Moskowitz and Krieger 1995). Pineapple fruits treated with citric acid and hot water exhibited the best sensory attributes. Previous studies have shown that hot water treatment of fruits reduces post-harvest decay, maintains firmness and texture, improves colour and appearance (Prusky et *al*. 1999; Pholoma et *al*. 2020).

One of the main limitations of this study is that the treatment conditions (temperature, treatment duration, NaCl or citric acid concentration) applied may be unsuitable for pineapples that do not meet the specified maturity, shape, and size criteria. Such conditions could lead to significant changes in the fruit's sensory and physicochemical properties, rendering it unfit for consumption and unmarketable. Another limitation is the cost of implementing the treatment on a larger scale and the difficulties of replicating the experimental conditions (temperature, treatment duration, NaCl, or citric acid concentration) at that scale.

5. CONCLUSION

Our findings suggested that hot water treatment is a promising technique for improving the marketability of pineapples. The post-harvest treatment methods used effectively influenced the physico-chemical characteristics of fresh pineapple fruits throughout the storage period. HWT (540 °C, 3 min) was the most effective treatment as it delayed the decay rate and extended the shelf life of pineapple fruits to 10.1 days at room temperature without significantly affecting the sensory properties of the fruits. Fruits treated with hot water also exhibited lower weight loss (8.2%) and a higher content of TSS (17.06 ^{0}Brix), although they showed lower vitamin C content (25.32 mg/100 ml) after 12 days of storage. This post-harvest treatment method can be applied on a large scale, as it is low-cost and highly efficient.

AUTHOR CONTRIBUTIONS. Kamda Silapeux Aristide Guillaume: Conceptualization, Methodology, Software, Writing- Original draft preparation. Bolda Esther Maralossou.: Methodology, Data curation, Writing- Original draft preparation: Tientcheu Bernard: Conceptualization, Methodology, Data curation, Writing- Original draft preparation, Writing- Reviewing and Editing. Ponka Roger: Supervision, Visualization, Validation, Writing- Reviewing and Editing.

CONFLICT OF INTEREST. The authors declare no conflict of interest.

REFERENCES

Adisa V A (1986). The influence of moulds and some storage factors on the ascorbic content of orange and pineapple fruits. *Food Chemistry* 22, 139-146. https://doi.org/10.1016/0308-8146(86)90031-2

Agbo A E, Gnakri D, Beugre G M, Fondio L and Kouame C (2008). Maturity degree of four okra fruit varieties and their nutrients composition. *Electronic Journal of Food and Plants Chemistry*, 5:1-4.

AGROCOM (Agriculture, Agro-industrie, Communication) (2002). Guide de production et de protection de l'ananas. PDE-Cameroun. Les publications d'AGROCOM, 38p.

Ahmed J and Siddiq M (2016). Innovative processing technologies for pineapple processing. In María Gloria Lobo, and Robert E. Paull, Handbook of Pineapple Technology: Production, Postharvest Science, Processing and Nutrition, John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118967355.ch10

Akangtula J and Chhungpuii K (2017). Effects of Different Post-harvest Treatments on Physico-Chemical Attributes and Shelf Life of Tomato Fruits. Science and Technology Journal. Vol. 5 Issue: I ISSN: 2321-3388

Amin M N and Hossain M M (2013). Development of a hot water treatment plant suitable for banana. *Agricultural Engineering International: CIGR Journal*, 15(4): manuscript No. 2658.

AOAC (2005). Official Methods of Analysis of AOAC International. AOAC International suite 500. 481 North Frederick Avenue. Gaithersburg, Maryland 20877-2417, USA.

AOAC (2000). Official methods 960.19, 962.12. In Official Methods of Analysis of AOAC International, 17th Ed., Vol. II pp. 70–75, AOAC, Gaithersburg, MD.

Asghari M. and Ashdam M S (2010). Impact of salicylic acid on post harvest physiology of horticultural crops. *Trends in Food Science & Technology*, 21: 502-509. https://doi.org/10.1016/J.TIFS.2010.07.009

Babalar M, Asghari M, Talaei A, and Khosroshahi A (2007). Effect of pre- and postharvest salicylic acid treatment on ethylene production, fungal decay and overall quality of Selva strawberry fruit. *Food Chemistry*, 105, 449e453. https://doi.org/10.1016/j.foodchem.2007.03.021

Baltazari A, Hosea D, Mtui M, Mwatawala W, Lucy M, Theodosy M, Jaspa S and Jayasankar S (2020). Effects of Storage Conditions, Storage Duration and Post-Harvest Treatments on Nutritional and Sensory Quality of Orange (Citrus sinensis (L) Osbeck) *Fruits International Journal of Fruit Science*, 20:4, 737-749. https://doi.org/10.1080/15538362.2019.1673278

Barrett B C (2007). "Smallholder Market Participation: Concepts and Evidence from Eastern and Southern Africa." Prepared for FAO Workshop on Staple Food Trade and Market Policy Options for Promoting Development in Eastern and Southern Africa, Rome, March 1-2, 2007. *Journal of Food Policy*, 33: 299-317. https://doi.org/10.1080/23311932.2020.1783173

Basumatary I B, Mukherjee A, Katiyar V, Kumar S and Dutta J (2021). Chitosan-Based Antimicrobial Coating for Improving Postharvest Shelf Life of Pineapple. Coatings. 11, 1366. https://doi.org/10.3390/coatings11111366

Beaudry M C (1989). The Lowell Boott Mills complex and its housing: material expressions of corporate ideology. *Historical Archaeology*, 23(1): 19-32. FAO, 2020. *Major Tropical Fruits Market Review* 2019. Rome. 20 pp

Competitiveness Committee, Technical Secretariat. (2024). Report on the competitiveness status of Cameroon's economy in 2023. Ministry of Economy, Planning, and Regional Development. 66 p.

Clarke R, Liu M, Bouker K, Gu Z, Lee R, Zhu Y, Skaar TC, Gomez B, O'Brien K, Wang Y and Hilakivi-Clarke L (2003). Antiestrogen resistance in breast cancer and the role of estrogen receptor signaling. *Oncogene.*;22:7316–7339. https://10.1038/sj.onc.1206937

Dhar M, Rahman S M, and Sayem S M (2008). Maturity and postharvest study of pineapple with quality and shelf-life under red soil. *International Journal of Sustainability and Crop Production,* 3(2) 69-75.

Elgar H J, Lallu N, and Watkins C B (1999). Harvest Date and Crop Load Effects on a Carbon Dioxide–related Storage Injury of Braeburn Apple. *HortScience*, 34(2): 305-309. https://10.21273/HORTSCI.34.2.305

FAO. 2023. Major Tropical Fruits Market Review – Preliminary results 2022. Rome.

FAOSTAT (Food and Agriculture Organization Corporate Statistical Database) (2021). 2019 Food and Agricultural Organization-statistical Database, Recorded Data for Pineapples Production Quantity in Benin. FAO (Food and Agriculture Organization of the United Nations), Rome. http://www.fao.org/faostat/en/#data/QC.

Feyera and Abdo J (2022). Post Harvest Treatments and Shelf Life of Some Tropical Fruit. *Adv. Biol. Biotechnol., vol. 25, no. 9, pp. 48-55,; Article no. Journal of Advances in Biology & Biotechnology.91566.* https://10.9734/jabb/2022/v25i9598

Gbenou B, Adjolohoun S, Houndjo D B M, Saïdou A, Ahoton L, Houinato M, Dahouda M and Sinsin A (2019). Difficulties to the Crops Forage Integration in Agricultural Farms in the Sudanian Area of Benin (West Africa). *International Journal of Science and Research*. Vol. 8 (5): 152-159). http://dx.doi.org/10.21474/IJAR01/9801

Ghafir S M M, Gadalla S O, Murajei M N, El-Nady M F (2009). Physiological and anatomical comparison between four different apple cultivars under cold-storage conditions. *African Journal of Plant Science* Vol. 3 (6), pp. 133-138.

Hajare S, Dhokane V, Shashidhar R, Saroj S D, Sharma A, and Bandekar J R (2006). Radiation processing of minimally processed pineapple (Ananas comosus Merr.): Effect on nutritional and sensory quality. *Journal of Food Science*, 71, 501–505. https://doi.org/10.1111/jfpp.13467

Jacobi K K, MacRae E A and Hetherington S E (2001). Postharvest heat disinfection treatments of mango fruit. *Sciencia Horticulturae*, 89 (3), 171-193. https://doi.org/10.1016/S0304-4238(00)00240-5

Jamir A and Chhungpuii K (2017). Effects of Different Post-harvest Treatments on Physico-Chemical Attributes and Shelf Life of Tomato Fruits. *Science and Technology Journal,* 5 (2) 2321-3388. https://doi.org/10.22232/Stj-2017-05-01-09

Jung S K and Watkins C (2008). Superficial scald control after delayed treatment of apple fruit with diphenylamine (DPA) and 1-methylcyclopropene (1-MCP). *Postharvest Biology and Technology,* 50 (1): 45–52. https://doi.org/10.1016/j.postharvbio.2008.05.006

Kabir M S N, Rasool K, Lee W H, Cho S I and Chung S O (2020). Influence of delayed cooling on the quality of tomatoes (*Solanum lycopersicum* L.) stored in a controlled chamber. *AIMS Agriculture and Food,* 5(2): 272–285. https://doi.org/10.3934/AGRFOOD.2020.2.272

Kader A and Rosa S R (2004). The role of post-harvest management in assuring the quality and safety of horticultural produce. FAO AGRICULTURAL SERVICES BULLETIN 152. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS Rome, 52 p.

Kamda S A G, Ponka R, Frazzoli C, and Fokou E (2021). Waste of fresh fruits in Yaoundé, Cameroon: Challenges for retailers and impacts on consumer health. *Agriculture,* 11, 89. https://doi.org/10.3390/agriculture11020089

Kamiloglu O (2011). Influence of some cultural practices on yield, fruit quality and individual anthocyanins of table grape cv. 'Horoz Karasi'. *Journal of Animal and Plant Sciences,* 21(2):240-245.

La Oge (2025). Postharvest Physiological Studies on the Quality and Shelf Life of Tropical Fruits: A Literature Review. *JOURNAL OF AGRICULTURE, AGRIBUSINESS, WELFARE, TECHNOLOGY, HUMANITY, ENVIRONMENT, SOCIAL, AND ECONOMY*. Volume 1 Nomor 1. E-ISSN: 3110-3495

Łata B (2007). Relationship between Apple Peel and the Whole Fruit Antioxidant Content: Year and Cultivar Variation. *Journal of Agricultural and Food Chemistry*, 55(3):663-71 https://doi.org/10.1021/jf062664j

Lawless H, and Heymann H (2010). Sensory evaluation of food science principles and practices. 2nd. *Springer Science and Business Media Ithaca*, New York. p. 596.

Li X, Zhu X, Zhao N, Fu D, Li J, Chen W (2013). Effects of hot water treatment on anthracnose disease in papaya fruit and its possible mechanism. *Postharvest Biology and Technology*, 86:437-46. https://doi.org/10.1016/j.postharvbio.2013.07.037

Lu X H, Sun D Q, Xi Y W M and Sun M (2010). Effect of postharvest salicylic acid treatment on fruit quality and antioxidant metabolism in pineapple during cold storage. *The Journal of Horticultural Science and Biotechnology*, 85: 454-458. https://doi.org/10.1080/14620316.2010.11512697

Lum M S and Norazira M A (2011). Effects of hot water, submergence time and storage duration on quality of dragon fruit (Hylocereus polyrhizus). *Journal of Agricultural Science*, 3(1), 146-152. https://doi.org/10.5539/jas.v3n1p146

Mandal D, Lalremruata T K, Hazarika and Nautiyal B P (2015). Effect of Post-harvest Treatments on Quality and Shelf Life of Pineapple (Ananas comosus [L.] Merr. 'Giant Kew') Fruits at Ambient Storage Condition. International *Journal of Bio-resource and Stress* Management, 6(4):490-496. https://doi.org/10.5958/0976-4038.2015.00072.X

Minh N P (2021). Influence of hot water treatment to quality properties of pineapple (Ananas comosus) fruit during storage. *Food Research,* 5 (5) : 186 – 194.

Mondal M F (2000). Production and storage of fruits (in Bangla). Published by Mrs. Afia Mondal. BAU Campus, Mymensingh-2202. pp. 312.

Moskowitz H R and Krieger B (1995). The contribution of sensory liking to overall liking: An analysis of six food categories. *Food Quality and Preference,* 6(2):83–90. https://doi:10.1016/0950-3293(95)98552-T

Munhuweyi K, Mpai S and Sivakumar D (2020). Extension of avocado fruit postharvest quality using non-chemical treatments. *Agronomy*.;10(2):212. https://doi.org/10.3390/agronomy10020212

Ngo Bogmis M N, Newilah G N et Ndjouenkeu R (2016). Caractérisation des unités de séchage des ananas et qualités physicochimiques des produits alimentaires dérivés dans la région du Littoral Cameroun. *International Journal of Biological and Chemical Sciences*, 10(5): 2025-2038. http://ajol.info/index.php/ijbcs

Nyanjage M O, Wainwright H, and Bishop C F H (1998). The effects of hot-water treatments in combination with cooling and/or storage on the physiology and disease of mango fruits (*Mangifera indica* Linn.). *The Journal of Horticultural Science and Biotechnolog*y, 73:589–597. https://doi.org/10.1080/14620316.1998.11511019

Pardio-Sedas, V T, Waliszewski-Kubiak K N and Garcia-Alvarado M A (1994). Ascorbic acid loss and sensory changes in intermediate moisture pineapple during storage at 30–40°C. *International Journal of Food Science & Technology*, pp: 551. https://doi.org/10.1111/j.1365-2621.1994.tb02097

Pholoma S B, Emongor V and Tshwenyane S (2020). Physicochemical attributes in mango fruit (Mangifera indica) as influenced by storage temperature and hot water treatment. *Journal of Experimental Agriculture International*, 42(1), 133141. https://doi.org/10.9734/jeai/2020/v42i130459

Prusky D, Fuchs Y, Kobiler I, Roth I, Weksler A, Shalom Y, Elazar F, Giora Z , Edna P, Miriam A, Oded Y, Aharon W, Rafael R and Leonisa A (1999). Effect of hot water brushing, prochloraz treatment and waxing on the incidence of black spot decay caused by Alternaria alternata in mango fruits. *Postharvest Biology and Technology*, 15(2):165-74. nd Technology 15(2):165-174. https://doi:10.1016/S0925-5214(98)00082-9

Safdar, K M (2009). Effect of Post-harvest hot water and hot air treatments on quality and shelf life of tomato, p. 1-47. United Kingdom: *University of Reading*.

Sandarani M, Dasanayaka D and Jayasinghe C (2018). Strategies used to prolong the shelf life of fresh commodities. *Journal of Agricultural Sciences and Food Research, 9(1):1-6*

Touati N, Barba F J, Louaileche H, Frigola A and Esteve M J (2016). Effect of storage time and temperature on the quality of fruit nectars: Determination of nutritional loss indicators. *Journal of Food Quality*, 39(3):209–217. https://doi.org/10.1111%2Fjfq.12189

Veraverbeke E A, Verboven P, Van Oostveldt P and Nicolaï B M (2003). Prediction of Moisture Loss across the Cuticle of Apple (*Malus sylvestris subsp*. mitis (Wallr.) during Storage. Part 2. Model Simulations and Practical Applications. *Postharvest Biology and Technology*, 30: 89–97. https://doi.org/10.1016/S0925-5214(03)00082-6

Wijeratnam R, Hewajulige I, Perera M (2006). The control of black rot disease and the application of a novel wax formulation for extending storage life of pineapple. In Joubert PH (Ed.). Proceedings of the Vth International Pineapple Symposium Leuven 1: *International Society for Horticultural Science*, pp. 185-189. https://doi:10.17660/ActaHortic.2006.702.24

Wills R, McGlasson B, Graham D and Joyce D (1998). Postharvest: An Introduction to the Physiology and Handling of Fruit, Vegetables and Ornamentals (4 edition). *CAB International, Wallingford Oxen* 10 8 DE, U.K., pp: 262.

Yang C, Tao C, Borui S, Shuxia S, Haiyan S, Dong C and Wanpeng X (2019). Citric acid treatment reduces decay and maintains the postharvest quality of peach (*Prunus persica* L.) fruit. *Food Sciences and Nutrition*, 7:3635–3643.