Effect of UV-C radiation intensity on post-harvest quality of two eggplant varieties (*Solanum aetipicum anguivi L* and *Solanum macrocarpon L)*

Abstract

In Côte d'Ivoire, eggplant is one of the most cultivated and consumed vegetables. However, this vegetable is very perishable. This work was developed to evaluate the effect of different UV-C concentrations on the conservation of eggplants with a view to identifying which one would provide better conservation of eggplants grown in Côte d'Ivoire. In this study, two eggplant varieties *Solanum aetiopicum anguivi L* (Klongbo) and *Solanum macrocarpon L* (Gbokouman) were treated with three doses of UV-C (960 Kj m^{-2}; 1920 Kj m^{-2} or 2880 Kj m^{-2}) in order to determine the optimal dose: non-deleterious while preserving or enhancing the qualitative attributes of the vegetable. The proximate composition and the infection rate were determined according to standard and referenced methods. Treatment at 960 Kj m^{-2} had no significant effect on fruit quality attributes compared to untreated fruit, while treatment at 2880 Kj m^{-2} accelerated fruit color changes and loss fruit mass. The treatment at 1920 Kj m^{-2} allowed the fruits to better preserve their quality over time. During this treatment, the infection rate was reduced by 45 % for the "Gbokouman" variety and 40 % for the "Klongbo" variety. With this same dose of UVC, mass loss was reduced by 10.74% for the "Klongbo" variety and 33.48 % for the "Gbokouman" variety. An increase in the content of phenolic compounds as well as that of antioxidant activity was also observed. The dose of 1920 Kj m-2 is therefore the optimal dose which would allow the "Gbokouman" and "Klongbo" eggplant varieties to be preserved for a long period of marketing and conservation.

Keywords: Eggplant, UV-C, Conservation, Post-harvest,

• Introduction

Eggplant is the 6th most produced vegetable worldwide with 54 million tonnes. China is the largest producer, with nearly 65 % of the world harvest followed by India (23 %) [1] while Africa produces only 3,9% of global harvest (2087592 tonnes). Côte d'Ivoire is at the head of West African eggplant producers with 130,000 tonnes for a yield of 5,223 tonnes per hectare [2]. Eggplant in Côte d’Ivoire is consumed mostly in sauces (biaukosseu, gouagouassou, gnangnan etc.), fried or boiled. Four main varieties are grown there: N'drowa (*Solanum aethiopicum gilo L*), Klongbo (*Solanum aethiopicum anguivi L*), Gbokouman (*Solanum macrocarpon L*) and purple eggplant (*Solanum melogena L*) [3]. However, under high temperatures and humidity conditions all year round, the storage of fruits and vegetables is limited by lack of appropriate storage means and techniques. In addition, during a long-term storage, fruits and vegetables are affected by fungal diseases leading to huge post-harvest losses. According to FAO (2022), post-harvest losses of fruits and vegetables on farms in sub-Saharan Africa reach 50 percent, the highest rate in the world. Eggplants harvested at maturity and stored in ambient conditions have a shelf life limited to a few days for certain varieties due to the rapid degradation of their constituents [4]. In Côte d’Ivoire, these losses are estimated between 30 and 50% of production according to the Ministry of Agriculture [5]. Post-harvest losses are a crucial factor affecting both food security and nutrition. They affect the quality, availability and prices of food [6]. Limiting post-harvest losses would not only improve food availability and nutrition, but would also have positive impacts on the income of producers and traders [7].

To reduce post-harvest losses, several storage technologies have been developed including modified atmospheres, low temperature and chemical or physical postharvest treatments. These technologies aim mainly to delay the fruit ripening process and inhibit the development or destroy spoilage pathogenic flora. All these technologies have proven to be effective if managed correctly. However, for eggplant, low temperature storage is susceptible to cold damage (chilling injury) when stored at temperatures below 10 °C [8]. Chilled eggplant gradually develops symptoms such as shrinkage and pitting of the pericarp, browning of the pulp and blackening of the seeds, accompanied by the development of an unpleasant flavor and rotting [9]. This situation ultimately leads to a decline in the economic value of eggplant [9,10]. On the other hand, the acquisition of a refrigeration system remains expensive for most producers or sellers. Regarding other technologies, there appears to be no significant advantage in storing eggplants in a controlled or modified atmosphere. According to the work carried out by Cantwell [11], the use of a controlled or modified atmosphere by increasing the oxygen content from 3 to 5% only delays deterioration by two or three days. Additionally, the use of chemicals to extend the shelf life of eggplants after harvest is not recommended. Also, the use of chemicals is not easily accepted by the consumer given the potential risks to humans and the environment [9]. Therefore, it is necessary to identify or evaluate innovative technologies that should be safe, environmentally friendly and resource-saving while preserving eggplant fruit quality after harvest. The use of ultraviolet (UV) radiation could be a credible and effective alternative to chemical and thermal treatments to reduce post-harvest eggplant losses in Côte d'Ivoire. Indeed, ultraviolet (UV) radiation is optical radiation whose spectral range extends from 100 to 400 nm [12]. UV rays are classified into three categories: UV-A, UV-B and UV-C whose respective wavelength ranges are 320 – 400 nm, 280 – 320 nm, 200 – 280 nm [13]. Also, UV treatment is measured by the amount of energy emitted to the surface of the product. Thus, the smaller the emission wavelength, the greater the energy of the radiation transmitted to the treated matrix. This also means that to deliver an equivalent amount of energy, short-wavelength radiation requires shorter processing times. The exploitation of UV-A and UV-B proves difficult because prolonged exposure is necessary to be effective and prolonged exposure to UV rays causes damage to fruits. While UV-C, being very energy, require shorter processing times and are therefore easier to manage in the case of field application. They have shown beneficial effects on the preservation of several foods including tomatoes, mangoes, strawberries and many others [13,14].

The objective of this study is to evaluate the effect of different concentrations of UV-C on the conservation of eggplants with a view to identifying the concentration which would provide better conservation of eggplants grown in Côte d'Ivoire.

2. Material and methods

- **Plant material sampling**

Figure 1: (a) Solanum aetipicum anguivi eggplant fruit (Klongbo variety); (b) Solanum macrocarpon eggplant fruit (Gbokouman variety) (Kouacou, 2022).

Two varieties of eggplant, *Solanum aetipicum anguivi L* (Klongbo) and *Solanum macrocarpon L* (Gbokouman) 144 plants/variety, were grown on a device of four Fisher blocks with two repetitions in an experimental plot located in Grand Bassam (Côte d'Ivoire) according to agroecological practices and using biosourced inputs. Fruits were harvested every two weeks, at mature stage three months after planting. Four harvest sessions were carried out for this study. Three of them were used for biophysical analyses. For each harvest session, 12 of fruits were harvested for both varieties. The additional harvest session of 4 kg carried out was used for measurement of fruit-decay rate. Fruits were sorted and only those with uniform size and color and without any defects or external infections were selected for further experiments. For biophysical analysis, a total of 120 fruits for both varieties were collected, and for assessment of fruit decay rate, 50 were selected from each batch. For each variety, fruits were divided into 4 batches of equal amounts of fruits for further analysis.

2. 2. Fruit UV-C treatment

Fruit UV-C treatment was performed using a high wooden box (180xLxP) lined inside with aluminum foil, composed of 4 wire drawers each equipped with four UV-C radiation lamps, two at the top and two at the bottom. The intensity applied to fruit (3.2 mw/cm^2) was determined using the UVX digital radiometer AnalytikJena with sensors able to measure UV wavelengths of 254 nm, 365 nm or 302 nm (Fisher Bioblock, Illkirch, France) placed inside the box.

Three treatments duration were applied on 3 of the 4 batches of fruit prepared as previously described: 30, 60 and 90 seconds corresponding to irradiation doses of 960 Kj/m^2, 1920 Kj/m^2 and 2880 Kj/m^2, respectively based on the Cristiano *et al* [15]. formula. The last batch used as control was not treated. After UV-C treatment, all samples including treated and control were kept at room temperature and for each batch, fruits were sampled randomly every 3 days for biophysical analysis and 2 days for fruit-dacay rate assessment. For biophysical analysis, a part of fruits was ground into puree another one was dried and ground in powder.

2.3. Measurement of physicochemical parameters during postharvest storage

2. 3.1. Determination of pH, titratable acidity and total soluble sugar

Ten grammes of puree obtained separately from three fruits sampled randomly as described above, were diluted in 100 mL of distilled water and the mixture was homogenized with a magnetic stirrer (AGIMAG, Mixel, Lyon, France). After a centrifugation at room temperature for 10 minutes at 2000g and 4000 rpm using (Benchtop centrifuge, Thermo Fisher scientific, Waltham, USA), the supernatant was used for pH, titratable acidity and total soluble sugar measurement. The pH of mixture was measured using a pH meter (ATAGO, Tokyo, Japan) and titratable acidity by titration with 0.1 N NaOH by colorimetry method using phenolphthalein as indicator. Finaly, a manual ATAGO refractometer (ATAGO, Tokyo,Japan) was used to determine total soluble sugar according to the manufacturer’s instructions. In total, three measurements were carried out on each parameter studied. Also, for this study three harvesting sessions were carried out.

2.3.3. Measurement of weight loss, color, firmness of fruits

For each harvest session and batch, 10 fruits were sampled for weight loss measurement and 3 of them for measurement of color and respiration. Fruit weight was measured for each fruit and at each sampling point. The obtained data was used to calculate the -weight loss between 2 sampling point t0 and t1, using the following formula:

Where: WL is the percentage of weight loss, Wt0 and Wt1 are the weight of fruit at sampling point t0 and t1, respectively.

Fruit color was measured using a Konica Minolta chromameter (Chromameter CR-10 plus, Japan). Measurements were made every three days and directly on three zones previously demarcated at different locations of the fruit. A total of three measures were performed per fruit and treated using the CIE L*a*b* color space. Parameters L* and a* were selected to express color changes in “Klongbo” variety fruits that turn red during ripening, while parameters L* and b* were selected to express color changes in “Gbokouman” variety fruits that turn from white to hard yellow. A total of three fruits per variety were used to measure color parameters.

Firmness was measured using a digital penetrometer (FC GAUGE PCE - FM 200, Milan, Italy) with a penetration force range between 0 and 10 kg and equipped with a 8 mm probe. The maximum force required for an 8 mm diameter tip to penetrate the pulp was recorded and expressed in Newton (N). One measure was performed on each fruit.

2. 3.6. Assessment of fruit-decay rate during postharvest storage

For fruit-decay rate assessment, a batch of were examined visually every two days and the number of infected fruits was determined. Fruit-decay rate was calculated using the formula described by Alvarez [16]:

Where, N.I is the number of infected fruits observed in batch and T.N the total number of fruits of the batch.

2.3.7. Determination of phenolic compounds content

2.3.7.1. Total phenols compounds contents

Total phenolics compounds were extracted twice by homogenizing 1 g of dried fruits powder in 10 mL of 70 % (v/v) methanol buffer following by 10 min of centrifugation at 1000 rpm at room temperature. The supernatant was collected in a 50 ml flask and the volume adjusted with distilled water to the mark. The polyphenols content of the filtered supernatant was measured using a spectrophotometer and Folin-Ciocalteu’s reagent [17]. The absorbance was read at wave length (λ)=760 nm and the results were expressed in mg gallic acid equivalent (GAE)/100 g DM. All experiments were performed in triplicate on all sample including UV-C traited and control.

2.3.7. Antioxidant activity determination

The antioxidant activity was determined according to the technique described [18]. The stable radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) was solubilized in absolute methanol (MeOH) to obtain a solution with a concentration of 0.03 mg/mL. Different concentration ranges (0.0007; 0.0014; 0.001; 0.0036; 0.0129; 0.0714 and 0.1429 mg/ml) of each sample was prepared in the same solvent. The reaction medium was composed of 0.4 mL of extract, 2.4 mL of absolute MeOH and 1.2 mL of methanolic DPPH solution. The absorbance of the mixture was then measured at 517 nm with a spectrophotometer against a blank consisting of 2.8 mL of MeOH and 1.2 mL of DPPH solution for 30 min at regular intervals of 3 min (3 min, 6 min, 9 min, 12 min, 15 min, 18 min, 21 min, 24 min and 30 min). The positive control was ascorbic acid (vitamin C). The DPPH reduction percentages are calculated according to the formula:

While: RP is Reduction percentage, Ab = Absorbance of the methanolic solution of DPPH (3 mM), Ae sample = Absorbance of the DPPH solution reduced by the sample extract.

2. 4. Statistical analysis

Analysis of variance (ANOVA) was used to determine differences between treatments. When a difference was observed, the 5% Duncan multiple range test was performed to separate treatment means. Statistical tests were carried out using STATISTICA software version 7.1.

3. Results

3.1. Change of pH value during storage

Table 1 presents the pH of the two varieties treated with UV-C at different doses and untreated during storage. pH increases from day 0 to day 9 over time, regardless of treatment. However, the pH values of the 1920 Kj m^{-2} treatment were significantly lower during storage and for both varieties, ranging from 5.17 to 5.75 and 5.45 to 5.62 respectively for the “Klongbo” varieties. and “Gbokouman”. Statistical analysis showed a significant difference between the pH values of eggplants treated with 1920 Kj m-2 and those of the other treatments. On the other hand, no significant difference was observed between the pH values of eggplants treated with 960 Kj m^{-2}, 2880 Kj m^{-2} and those of the controls.

UV-C dose	**Storage time (days)**			
	0	3	6	9
Klongbo variety				
0 (Control)	5,15±0,57^{abA}	5.4±0.10^{bB}	5.76±0.01^{bC}	6.01±0.10^{bAB}
960 Kj m^{-2}	5,16±0,05^{abA}	5.38±0.01^{bA}	5.74±0.05^{bBC}	6.04±0.05^{cD}
1920 Kj m^{-2}	5,15±0,01^{abA}	5.17±0.05^{aB}	5.35±0.05^{aC}	5.75±0.01^{aD}
2880 Kj m^{-2}	5,15±0,05^{abB}	5.38±0.01^{bC}	5.75±0.10^{bA}	6.04±0.05^{cB}
Gbokouman variety				
0 (Control)	5,44±0,00^{bcC}	5.55±0.01^{bB}	5.64±0.01^{bA}	6.2±0.00^{bD}
960 Kj m^{-2}	5,42±0,01^{abA}	5.53±0.00^{bC}	5.61±0.02^{bD}	6.18±0.01^{bE}
1920 Kj m^{-2}	5,45±0,00^{bcD}	5.47±0.00^{aB}	5.50±0.01^{aB}	5.62±0.00^{aA}
2880 Kj m^{-2}	5,44±0,01^{bcE}	5.53±0.00^{bC}	5.62±0.00^{bB}	6.18±0.00^{bA}

Table I: Evolution during storage of the pH of eggplant varieties treated at different

doses of UV-C

Values topped by the same lower-case letter in the same column and by the same upper-case letter in the same row are not significantly different at the 5% threshold according to Duncan's test.

3.2. Evolution of titratable acidity

The evolution of titratable acidity of eggplant varieties treated with different doses of UV-C during storage is presented in Table 2. The acidity of eggplant decreased with time, independently of treatment and the variety. However, the acidity values of eggplants treated with 1920 Kj m^{-2} were significantly lower during storage for both varieties, ranging from 5.17 to 5.75 and 5.45 to 5.62 respectively for the varieties “Klongbo” and “Gbokouman”. Statistical analysis showed a significant difference between the acidity values for all treatments over storage time and the “Klongbo” variety was less acidic than the “Gbokouman” variety.

UV-C dose	**Storage time (days)**			
	0	3	6	9
Klongbo variety				
0 (Control)	0.94 ± 0.57^{bA}	0.79 ± 0.10^{Bab}	0.65 ± 0.01^{aB}	0.60 ± 0.10^{aC}
960 Kj m^{-2}	0.90 ± 0.05^{aA}	0.77 ± 0.01^{abB}	0.68 ± 0.05^{bC}	0.62 ± 0.05^{bD}
1920 Kj m^{-2}	0.90 ± 0.01^{aC}	0.88 ± 0.05^{cD}	0.78 ± 0.05^{cA}	0.74 ± 0.01^{cB}
2880 Kj m^{-2}	0.92 ± 0.05^{abB}	0.75 ± 0.01^{aA}	0.66 ± 0.10^{aC}	0.60 ± 0.05^{aD}
Gbokouman variety				
0 (Control)	0.88 ± 0.00^{bB}	0.75 ± 0.01^{aC}	0.62 ± 0.01^{aD}	0.58 ± 0.00^{aA}
960 Kj m^{-2}	0.85 ± 0.01^{aA}	0.77 ± 0.00^{abB}	0.66 ± 0.02^{bC}	0.61 ± 0.01^{bD}
1920 Kj m^{-2}	0.88 ± 0.00^{bAB}	0.82 ± 0.00^{cD}	0.75 ± 0.01^{dE}	0.71 ± 0.00^{dF}
2880 Kj m^{-2}	0.86 ± 0.01^{aC}	0.79 ± 0.00^{bA}	0.68 ± 0.00^{cB}	0.62 ± 0.00^{cD}

Table 2: Titratable acidity of UV-C treated and untreated eggplant varieties “Klongbo” and “Gbokouman” during storage

Values topped by the same lower-case letter in the same column and by the same upper-case letter in the same row are not significantly different at the 5% threshold according to Duncan's test.

3.3 Firmness

Eggplant firmness decreases during storage. From the 3rd to the 9th day of storage, eggplants treated with 1920 Kj m-2 showed significantly higher firmness values than those treated with 920 and 2880 Kj m-2, ranging from 62.54 N to 51.83 N and from 40.38 N to 32.88 N successively for the “Klongbo” and “Gbokouman” varieties. The statistical analysis showed a significant difference between the firmness values of the fruits at the different doses and the control fruits at all times. Moreover, the “Gbokouman” variety was firmer than the “Klongbo” variety. Figures 1 and 2 show the evolution of the firmness of eggplant varieties treated with different doses of UV-C during storage.

Figure 1: Firmness of eggplants of the “Klongbo” variety treated with UV-C and untreated during storage

Figure 2: Firmness of eggplants of the “Gbokouman” variety treated with UV-C and untreated during storage

- **Weight loss**

Whatever the treatment and variety, eggplants lose weight during storage. However, weight loss during storage was relatively higher in untreated (control) samples of the “Klongbo” variety from day 0 to day 6 (30.78%). Then on day 9, it was higher in eggplants treated with 960 Kj m^{-2} with a value of 56.81%. The 1920 Kj m^{-2} dose significantly reduced weight loss by 30% compared with the 960 Kj m^{-2} dose and by 27 % compared with the 2880 Kj m^{-2} dose. For the “Gbokouman” variety, weight loss was highest in the 2880 Kj m-2 treatment during storage, with a loss of 35.36% on day 9. The 1920 Kj m^{-2} dose significantly reduced weight loss by 17.65 % versus 2880 Kj m^{-2} and 10.24 % versus 960 Kj m^{-2} respectively on day 9. Statistical analysis showed no significant difference between the mass loss values of control and 960 Kj m-2-treated eggplants in the two varieties. On the other hand, a significant difference was observed between the values of eggplants treated at 1920 Kj m^{-2} and those at 960 Kj m^{-2} and 2880 Kj m^{-2} as well as the controls. Eggplants of the “Gbokouman” variety showed a much more pronounced loss of mass than those of the “Klongbo” variety. Figures 3 and 4 respectively show the percentage weight loss of “Klongo” and “Gbokouman” varieties treated with different doses of UV-C during storage.

Figure 3: Mass loss of eggplants of the “Klongbo” variety treated with UV-C and untreated during storage

Figure 4: Weight loss of eggplants of the “Gbokouman” variety treated with UV-C and untreated during storage

- **Evolution of the soluble solids content**

The soluble solids content of both eggplant varieties increased during storage. From day 3 to day 9 of storage, the increase in soluble solids values for the two eggplant varieties treated with 1920 Kj m^{-2} was significantly lower than for the same varieties treated with

960 Kj m^{-2} and 2880 Kj m^{-2}, the increase of which has remained high over time. For the “Klongbo” variety, it was 0.41 °brix in fruits treated at 1920 Kj m^{-2} against respectively 0.49 and 0.48 °brix in fruits treated at 960 and 2880 Kj m^{-2} on day 9. For the “Gbokouman” variety, the soluble solids content was 0.57 °brix in fruits treated at 1920 Kj m^{-2}, compared to respectively 0.67 °brix and 0.69 °brix in fruits treated at 960 and 2880 Kj m^{-2} on day 9. No significant differences were observed between the sugar content values of control fruits and fruits treated with 960 Kj m^{-2} and 2880 Kj m^{-2} at any time. On the other hand, a significant difference was observed between the sugar content values of fruits treated at 960 Kj m^{-2}, 2880 Kj m^{-2} and controls with the values of fruits treated at 1920 Kj m^{-2} at all times. Furthermore, the “Gbokouman” variety had a higher sugar content than the “Klongbo” variety during storage. Table 3 shows the evolution of soluble solids during storage of the “Klongbo” and “Gbokouman” eggplant varieties treated with different UV-C doses.

UV-C dose	**Storage time (days)**			
	0	3	6	9
“Klongbo” variety				
0 (Control)	0.30 ± 0.00^{aA}	0.37 ± 0.00^{bAB}	0.43 ± 0.05^{bC}	0.50 ± 0.05^{cD}
960 Kj m^{-2}	0.30 ± 0.00^{aA}	0.37 ± 0.05^{bB}	0.41 ± 0.00^{bC}	0.49 ± 0.06^{bcD}
1920 Kj m^{-2}	0.30 ± 0.00^{aA}	0.31 ± 0.00^{aA}	0.35 ± 0.00^{aB}	0.41 ± 0.05^{aC}
2880 Kj m^{-2}	0.30 ± 0.00^{aA}	0.36 ± 0.00^{bC}	0.41 ± 0.00^{bB}	0.48 ± 0.05^{bBC}
“Gbokouman” variety				
Control	0.50 ± 0.00^{aA}	0.56 ± 0.05^{bB}	0.62 ± 0.09^{bC}	0.68 ± 0.05^{bD}
960 Kj m^{-2}	0.50 ± 0.00^{aA}	0.57 ± 0.05^{bAB}	0.63 ± 0.05^{Bd}	0.69 ± 0.05^{bE}
1920 Kj m^{-2}	0.50 ± 0.00^{aA}	0.52 ± 0.00^{aA}	0.55 ± 0.00^{Aa}	0.57 ± 0.00^{aA}
2880 Kj m^{-2}	0.49 ± 0.00^{aA}	0.56 ± 0.00^{bC}	0.62 ± 0.05^{Bb}	0.67 ± 0.00^{bD}

Table 3: Soluble solids content of UV-C treated and untreated eggplant varieties “Klongbo” and “Gbokouman” during storage

Values topped by the same lower-case letter in the same column and by the same upper-case letter in the same row are not significantly different at the 5% threshold according to Duncan's test.

3.6. Decay

The decay-rate generally increases with storage time and for all eggplant varieties (Figures 5, 6). Regarding the "Gbokouman" variety, eggplants treated at 960 Kj m^{-2} presented a degradation rate of 21.23 % to 92.4 % from the 3rd to the 12th day of storage. Those treated at 2880 Kj m^{-2} showed a percentage of rot ranging from 5 % to 75.6 % over the same 9-day period. As for the eggplants irradiated at a dose of 1920 Kj m^{-2}, they presented the significantly ($P < 0.05$) lowest rate of rot throughout storage with a percentage of rot of 50.3 % on the 12th day, i.e. a reduction in the percentage of rot of 45.13 % compared to the control. For the "Klongbo" variety, eggplants treated at 960 Kj m^{-2} presented a rot rate of 90.3 % on the 12th day. This same percentage was 71 % for fruits treated at a dose of 2880 Kj m^{-2}. As for the eggplants treated at 1960 Kj m^{-2}, they showed a significantly lower percentage of rot of approximately 53 % during storage, a reduction of 40.3 % compared to the controls. The statistical analysis showed that whatever the variety and the time there was no significant difference between the rot rate of the control eggplants and those treated at 960 Kj m^{-2}. Variety "Klongbo" exhibited a significantly higher rot rate in control fruits treated at different doses from day 3 to day 9. From day 12 onwards, no significant difference was observed in the rot rate of fruits of both varieties.

Percentage of rot of both varieties increases during storage regardless of the treatment or variety resulting from the initial loading. However, eggplants treated at the dose of 1920 Kj.m^{-2} have a significantly ($P < 0.05$) higher percentage of rot and the "Klongbo" variety has a higher rate of rot than the "Gbokouman" variety.

Figure 5: Evolution of decay percentage of eggplants of the "Gbokouman" variety treated with UV-C and untreated during storage

Figure 6: Evolution of decay percentage of eggplants of the Klongbo variety treated with UV-C and untreated during storage.

- **Evolution of color parameters of the "Klongbo" variety**

The color index L* decreases over time in both treated and untreated fruits (Figures 7, 8). Eggplants treated at 2880 Kj m^{-2} showed the greatest decrease in L* color index values during storage (from 61.4 to 37.49), followed by eggplants from fruits treated at 960 Kj m-2 (from 60.38 to 45.19). Fruits treated at 1920 Kj m^{-2}, although showing decreasing L* index values as observed with all others, showed a much less pronounced decline with values ranging from 60.33 to 51.01. The statistical analysis showed a significant difference between the different values of the three treatments at all analysis dates. Regarding the color index a*, it increases during storage in all fruits. However, the results showed that the greatest increase in the value of this index was recorded in fruits treated at 2880 Kj m^{-2} (18.4 to 40.91). The treatment of 1920 Kj m^{-2} on the other hand slowed down the increase of this index during storage with values ranging from 18.12 to 25.13. A significant difference between the values of the different treatments was observed from day 3 to day 9 of storage.

Figure 7: Evolution of L*value of eggplants of the "Klongbo" variety treated with UV-C and untreated during storage

Figure 8: Evolution of a*value of eggplants of the "Klongbo" variety treated with UV-C

and untreated during storage

- **Evolution of the parameters L *and b *of the color of the "Gbokouman" variety**

The color indices L* and b* were measured during storage. In general, the L* index gradually decreases during storage in all treated and control fruits while the b* index increases (Figures 9, 10). The dose of 1920 Kj m^{-2} applied to eggplants gave L* values ranging from 64.62 to 54.83. The dose of 2880 Kj m^{-2} caused the fastest drop in L* index values from 61 to 42.9. This same observation was made for fruits treated with the dose of 960 Kj m^{-2} whose values increased from 63.67 to 48.56. Statistical analysis revealed a significant difference ($P < 0.05$) between the values of the different treatments on all dates. As for the color index b*, a strong increase in its value was observed in fruits treated at a dose of 2880 Kj m^{-2} compared to the control with values ranging from 2.03 to 10.55 per day 0 on day 9. The 1920 Kj m^{-2} dose considerably slowed this increase with values from 2.03 to 4.33. Statistical analysis initially showed no significant difference ($P < 0.05$) between the values of the different treatments. But after the 3rd day, a significant difference was observed between the values of the fruits from the three treatments.

Figure 9: Evolution of L *value of eggplants of the "Gbokouman" variety treated with UV-C and untreated during storage

Figure 10: Evolution of b *value of eggplants of the "Gbokouman" variety treated with UV-C and untreated during storage

- **Evolution of the total polyphenol content during storage of the “Klonbgo” and “Gbokouman” eggplant variety treated at an optimal dose of UV-C (1920 Kj m^{-2}).**

The total polyphenol contents of the untreated “Klongbo” and “Gbokouman” varieties increased from 0 to 6 days with respective values ranging from 1937.89 mg EAG/100g DM to 2392.11 mg EAG/100g DM and 1305.62 mg EAG/100g DM at 1459.07 mg EAG/100g DM. Beyond 6 days, the total polyphenol contents of untreated “Klongbo” and “Gbokouman” varieties decreased. Concerning the “Klongbo” and “Gbokouman” varieties treated with UV-C, the total polyphenol contents increased throughout storage with respective values ranging from 1938.40 mg EAG/100g DM to 2656.20 mg EAG/100g DM and 1314, 64 mg EAG/100g DM to 1866.17 mg EAG/100g DM. DM. In addition, the total polyphenol contents of UV-C treated and untreated samples of the “Klongbo” and “Gbokouman” varieties were not significantly different at 0 day. After 0 days, the total polyphenol content of UV-C treated samples increased significantly ($P < 0.05$) compared to untreated samples. Furthermore, eggplants of the “Gbokouman” variety had a significantly ($P < 0.05$) higher total polyphenol content than those of the “Klongbo” variety. Figures 11 and 12 respectively show the total polyphenol contents of “Klongbo” and “Gbokouman” eggplant varieties treated at the optimal dose of UV-C and untreated during storage.

Figure 11: Evolution of the total polyphenol content during storage of the “Klonbgo” eggplant variety treated at the optimal dose of UV-C (1920 Kj m^{-2}).

Figure 12: Evolution of the total polyphenol content during storage of the "Gbokouman" eggplant variety treated at the optimal dose of UV-C (1920 Kj m^{-2}).

- **Evaluation of the antioxidant activity during storage of "Klongbo" and "Gbokouman" eggplant varieties treated at the optimal UV-C dose (1920 Kj m^{-2}).**

The antioxidant activity of untreated eggplants increased during the first 6 days with respective values ranging from 46.22 % to 66.69 % for the "Klongbo" variety and from 60.26 % to 75.42 % for the "Gbokouman" variety. Beyond 6 days, the antioxidant activity of these same fruits decreased to reach 60.38 % and 70.33 % respectively on the 9th day. Concerning the eggplants treated with the UV-C dose, the antioxidant activity increased throughout storage with values ranging from 46.22 % to 88.48 % for the "Klonbgo" variety and from 60.26 % to 95.01 % for the "Gbokouman" variety during the 9 days of storage. Furthermore, the antioxidant activity values of the UV-C treated and untreated samples of the two varieties were significantly different from the 3rd to the 9th day at the threshold of 5 % according to the Duncan test ($P < 0.05$). Also, when they did not undergo any treatment, eggplants of the "Gbokouman" variety had significantly lower antioxidant activity than that of eggplants of the "Klongbo" variety. On the other hand, once treated with UV-C, the eggplants of the "Gbokouman" variety presented a significantly higher antioxidant activity than those of the "Klongbo" variety during storage at the threshold of 5 % according to the Duncan test ($P < 0.05$). The evolution of the antioxidant activity of the "Klongbo" and "Gbokouman" eggplant varieties treated at the optimal dose of UV-C (1920 Kj m^{-2}) and untreated during storage is presented in figures 13 and 14.

Figure 13: Evolution of antioxidant activity during storage of the "Klongbo" eggplant variety treated at the optimal UV-C dose of 1920 Kj $m^{-2.}$

Figure 14: Evolution of antioxidant activity during storage of the “Gbokouman” eggplant variety treated at the optimal UV-C dose of 1920 Kj m^{-2}

- **Discussion**

Market gardening, which is intensive in inputs in Ivory Coast, suffers from enormous post-harvest losses of up to 50% according to speculation. Particularly, eggplants harvested when ripe and stored in ambient conditions have a shelf life limited to a few days. It is therefore to reduce these post-harvest losses that this work was initiated to extend the shelf life of eggplants through the use of UV-C rays.

The use of three doses (960 Kj m^{-2}, 1960 Kj m^{-2}, 2880 Kj m^{-2}) of UV-C influenced the physicochemical parameters of eggplants. Firmness, mass and color are physical parameters which provide information on the quality of fruits and vegetables. Following the treatment of eggplants with different doses of UV-C, the dose of 1920 kJ m-2 made it possible to considerably slow down the loss of firmness, the loss of mass as well as the degradation of color through the color indices L, a* and b*. On the other hand, the dose of 960 Kj m^{-2} did not have a considerable impact on these parameters and that of 2880 kJ m-2 even had a tendency to degrade the quality of the fruits by a rapid drop in clarity, a acceleration of fruit coloring and a sharp drop in firmness of the “Gbokouman” variety during storage. Indeed, the decrease in the L* parameter reflects a drop in clarity, the increase in the a* parameter reflects the change in color towards red, which is the case for the “Klongbo” variety which goes from white to red during maturation. Furthermore, the color parameter b* expresses the change in yellow color, which is observed during the ripening of the fruits of the “Gbokouman” variety which change from white to yellow during ripening.

When it comes to mass loss in fruits and vegetables, it is mainly due to a process by which water is lost through membrane tissues. This process is called transpiration, also known as water loss or evapotranspiration and contributes to the degradation of fruit quality and appearance. The treatment at 1920 Kj m -2 would therefore have strengthened the membrane of the fruits, making them less permeable to water in order to slow down its loss. Conversely, the treatment at 2880 Kj m -2 being stronger would have led to a weakening of the membranes resulting in a greater loss of mass. Indeed, UV-C can generate oxidative stress [18] and the formation of ROS (reactive oxygen species) which can alter membrane lipids [19], pigments, proteins [20] and even plant nucleic acids [20,21]. These results are consistent with those of Karasahin [22] who demonstrated that UV-C treatment of eggplants combined with hot water treatment reduced mass loss by up to 68 %. In this study, the reduction is 69.11 % for the klongbo variety and 76.58% for the Gbokouman variety.

Concerning the firmness of the two varieties of eggplant, it is slowed down by the treatment at 1920 Kj m-2. The dose of 960 Kj m-2 was not sufficient to impact the evolution of firmness and that of 2880 Kj m-2 was too high, thus producing a deleterious effect which is manifested by a greater loss of firmness. The dose of 1920 Kj m-2 would therefore have inhibited the action of enzymes involved in the softening of fruits and vegetables. Indeed, polygalacturonases and pectin-methylesterases contribute to the degradation of cell wall components, which leads to the loss of firmness of fruits and vegetables [23]. Our work corroborates that of Pombo [24]. This author showed that the application of a dose of 4.1 kJ/m² on strawberries-maintained firmness and limited wilting while reducing the expression of a set of genes involved in the degradation of the cell membran.

The eggplants treated at 1920 Kj m -2 showed a slight decrease in acidity and a slight increase in pH during storage unlike the two other treatments (960 Kj m $^{-2}$ and 2880 Kj m $^{-2}$) which did not. had no significant effect on pH and acidity. Which would mean that this dose of treatment would have slowed down the maturation of the eggplants compared to the other two by slowing down the conversion of the organic acids of the eggplant, mainly made up of citric acid and malic acid [25]. These organic acids will subsequently be transformed into sugars through a process called gluconeogenesis [26].

Regarding the infection rate, it remained lower during storage in fruits treated at 1920 Kj m $^{-2}$ compared to fruits treated at 960 Kj m^{-2} and 2880 Kj m $^{-2}$ as well as the controls. Treatment at a dose of 960 Kj m^{-2} did not have a significant effect on the rate of eggplant rot. As for the dose 2880 Kj m $^{-2,}$ it caused a slight reduction in the rate of rot, much less significant than the dose 1920 Kj m $^{-2}$. These results could firstly reflect the fact that the dose of 960 Kj m^{-2} was insufficient to inhibit the activity of pathogenic microorganisms or induce a reaction at the level of defense compounds inside the eggplants. Then the dose of 2880 Kj m $^{-2}$ would have inhibited the action of pathogenic microorganisms while being harmful to the fruits because it was too strong. This is through the rapid degradation of color and reduction in the rate of rot to a lesser extent. Finally, the dose 1920 Kj m $^{-2}$, due to its strong action on reducing the rate of rot, would not only have inhibited the action of pathogenic microorganisms like the dose 2880 Kj m $^{-2}$, but would also have activated the synthesis of compounds of intrinsic defenses of fruits. Indeed, UV-C rays, when induced at a sufficient dose, have a double mechanism of action: a germicidal action which directly destroys the microorganisms on the surface of the fruits and an action to stimulate the synthesis of certain compounds involved. in the defense of fruits against microorganisms [27]. When microorganisms are exposed to sufficient doses of UV-C radiation, their DNA and other cellular components are damaged, resulting in their death or inability to reproduce. This therefore prevents the growth and multiplication of microorganisms on the surface of fruits and vegetables. Also, according to Hua [28] UV-C stimulates the synthesis of secondary metabolites which are phenolic compounds involved in the plant defense mechanism. The result of the evaluation of the optimal dose of 1920 Kj m $^{-2}$ having made it possible to preserve the quality and reduce the rate of rot on total polyphenols and the antioxidant activity of eggplants effectively confirms that this dose has indeed an effect on these compounds. Indeed, the irradiation of eggplants at a dose of 1920 Kj m $^{-2}$ increased their contents of total polyphenols as well as their antioxidant power during storage. This increase in phenolic compounds, associated with the inhibitory effect of the UV-C dose, could be the origin of the strong reduction in losses observed in fruits treated at this dose.

Conclusion

The use of UV-C at the optimal dose made it possible to maintain the quality of eggplants and reduce the infection rate during storage. The fruits of both eggplant varieties remained firmer, the loss of mass and color degradation was slowed during storage. UV-C used at the right dose is therefore an effective means of preserving the two varieties of eggplant studied. This dose also increased the content of phenolic compounds. The rest of this work will consist of identifying and quantifying these phenolic compounds.

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