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(Research Article)

Improvement of the shelf life and physico-chemical parameters of papaya fruits (*Carica papaya* L., cv. solo 8) by hexanal pre-harvest application

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Abstract

Papaya (*Carica papaya* L.), is a plant native to the Americas, belonging to the Caricaceae family, whose fruit has extraordinary nutritional properties. It is a climacteric fruit, and its ethylene production and respiratory activity increase during ripening. It is therefore important to find a process for delaying ripening before harvesting in order to extend its post-harvest shelf life and make it more accessible on the market. Field experiments were carried out to study the effect of hexanal (0.02%) spraying on papaya fruit (*Carica papaya* L. cv. solo 8) 90 days after anthesis. Papaya fruits received hexanal application once a week for six weeks (90 T6) and every fortnight for six weeks (90 T3) compared to control (90 NT). The fruit was analysed at weekly intervals for nine weeks during ripening period to assess physico-chemical characteristics. Papaya fruits sprayed once a week for six weeks (90 T6) and once every fortnight for six weeks (90 T3) delayed fruit ripening time for five (5) and four (4) weeks longer respectively than the control. Physico-chemical parameters such as firmness (71.29-4.23 N) and vitamin C (78.33-51.2 g/100 FM) decreased in the control after four weeks, whereas they increased in fruit treated six times (90 T6) up to nine weeks, with values of 76.05-78.05 N to 67.16-78.2 g/100 FM and eight weeks for fruit treated three times (90 T3) (72.63-71.1 N; 79.18-74.4 g/100 FM).

Keywords: Carica papaya fruit; Hexanal spraying; Maturation; Ripening period; Physico-chemical properties

1. Introduction

Fruits are commercially important and nutritionally essential food products. They play a vital role in human nutrition by providing the growth factors necessary to maintain health [1]. Nutritionally, they are known for their high energy content provided by fibre, minerals, vitamins (B complex, C and K), β-carotene (pro-vitamin A) and phenolic acids (antioxidants). Fruits are widely distributed in nature and are classified as tropical, subtropical and temperate fruits [2]. For most countries in Africa, Caribbean and Pacific, fruit and vegetables are a vital economic sector [3]. Among fruits, papaya (*Carica papaya* L.) is one of the predominant vital plants in tropical Africa. In West Africa, Côte d'Ivoire has been identified as the 2nd largest producer in Africa after Ghana. They are the main suppliers of papaya to the European Union (EU) markets [4]. Several varieties exist, but in Côte d'Ivoire the Bluestem, Solo N°8, Sunrise, Sunset, Waimanolo and Golden varieties are much more widely used by local growers. However, the Solo N°8 variety is still the most widely grown, with a yield of 14 tonnes per hectare.

Papaya (*Carica papaya* L.) is a fruit of an economic and nutritional potential due to the richness in vitamins (A, C, E thiamine and riboflavin) and in minerals (calcium, iron, potassium, magnesium and sodium) [5, 6]. The nutritional importance of papaya mainly due to its richness in vitamins A and C [7, 6]. Papaya is also a well-known source of natural antioxidants thanks to its high lycopene and vitamin C content [8]. The presence of antioxidants in papaya contributes

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very effectively to the body's defence against infections [9]. Despite this nutritional advantage, papaya fruit (*Carica papaya* L.) have a limited storage time due to the rapid softening of the pulp and fungal growth. It is a climacteric fruit whose respiratory rate and ethylene production increase considerably after harvesting. In tropical climates, papaya rapidly loses its quality and storage is limited to four to seven days [10].

To increase papaya fruit (*Carica papaya* L.) availability, a major step is to prevent the loss of the fruit between harvest and consumption. Current fruit storage facilities use refrigeration alone or coupled with controlled or modified atmospheres, in which O_2 is kept at a low level and CO_2 at a high level. But, these techniques are expensive and cause damage in fruit during storage [2]. Fruit ripening and senescence have shown that the softening process is accompanied by the initiation of membrane damage, possibly involving phospholipase D (PLD). One of the recent, promising and innovative methods for fruit preservation is the use of hexanal [11, 12]. Hexanal is a natural substance synthesised by plants via the lipoxygenase pathway after tissue damage or stress.

Several studies have shown that as well as being a powerful inhibitor of phospholipase D activity, hexanal improves several beneficial qualities of fruit and vegetables, including colour, firmness and volatile substances. The application of hexanic formulations before or after harvest extended the shelf life of fruits such as bananas, apples, grapes, strawberries and sweet cherries, pears, tomatoes, broccoli, carnations, roses and chrysanthemums [13]. No data exist in Ivory Coast in the use of hexanal before or after harvest to improve the self-life of papaya (*Carica papaya* L.). So this study was undertaken to investigate the effect of pre-harvest application of the hexanic formulation on papaya fruits quality during ripening.

2. Material and methods

2.1. Plant material

The plant material consisted of the fruit of papaya cv. solo 8 (*Carica papaya* L.) from 90 days after anthesis.

2.2. Experimental design

The plant material was collected in experimental plantation located in Azaguié (Abidjan, Côte d'Ivoire). This experimental plot was divided into 3 blocks (A, B and C) of 110 m², 5 m apart and bounded by a 3 m firewall. Each block consisted of three (3) ridges of thirty (30) plants. The rows were spaced 2.5 m apart within the blocks. Ninety (90) papaya plants were selected immediately after anthesis (first flowering stage). These plants were marked and monitored until physiological maturity.

2.3. Pre-harvest treatment of papaya fruit

Ninety (90) days after anthesis, the 0.02% (v/v) hexanal-based formulation was applied as a pre-harvest spray once a week and once every fortnight to papaya fruit for six consecutive weeks. This work required three types of treatment, including a control (untreated papaya fruit), a hexanal treatment every week for six weeks (90 T6) and a hexanal treatment every fortnight for six weeks (90 T3).

For each treatment, twenty (20) papaya trees located in different parts of the orchard per block (A, B and C) were randomly selected for the study. Ten (10) papaya fruits per block were then harvested once a week and sent to the Tropical Products Biochemistry and Processing Laboratory for analysis during the study. Fruit samples were selected in the absence of mechanical damage and according to size and shape (same size and shape). The fruits were analysed once a week from the first spraying for 9 weeks, i.e. until physiological maturity.

The hexanal solution was obtained using hexanal (1%), tween 20 (10%) dissolved in ethanol (10% v/v) as described by Paliyath et *al.* (2008). The stock solution was mixed in water to provide a final 0.02% solution and sprayed at a rate of 150 mL per papaya plant directed upwards onto the papaya fruit using a sprayer.

2.4. Analysis of fruits quality parameters

Moisture content was measured by drying the sample at 105 °C for 24 h [14]. pH was determined using a digital pH-meter (model MP220, Mettler-Toledo). Titratable acidity was determined using the [14]. This was carried out by neutralising the total titratable acidity with NaOH (0.1 N) using a phenolphthalein indicator and expressed as % citric acid. The soluble dry extract (°Bx) was measured with a refractometer (model FG103 / 113, Milan, Italy). Firmness was measured with a digital penetrometer (model FC Gauge, PCE-FM 200). The ascorbic acid content of the samples was estimated by the titration method using 2,6 dichlorophenol indophenol as an indicator according to the method described by [15] (1971). The colour of the pulp was determined longitudinally at four points on each flat side of the fruit using a high-quality 3 nh colorimeter (NH 310). The value (L *) represented the brightness of the fruit, where 0 = black and 100 = white but the value (a *) varied from negative (green) to positive (red) and the value (b *) varied from negative (blue) to positive (yellow), [16] The hue angle (h), a relative ratio of yellow intensity to red intensity expressed as [tan - 1 (b / a)].

2.5. Statistical analysis

All experiments were performed in triplicate. A one-way ANOVA was used, followed by Duncan's multiple comparison test to analyse significant differences between treatments at the 95% confidence level ($p<0.05$). This statistical analysis was performed using Statistica 7.1 software.

3. Results

3.1. Fruit colour parameters

Tables 1 and 2 show the colour properties of harvested papaya from the first spraying to the physiological maturity of the papaya. Hexanal treatment and mode of application revealed a significant difference ($P<0.05$) in the colour of papaya pulp and epicarp (Table 2), as indicated by the 'hue' values. Papaya epicarp hue gradually and uniformly dropped as epicarp (skin) colour changed from green to lime to yellow to amber over 153 (S9) days. Control fruit had a faster rate of colour change from day 125 (S5) compared to papaya treated with 0.02% hexanal. The colour of the epicarp and the pulp of papaya fruits treated with hexanal increased slowly with an angular value of 96° to 68° for fruits treated once every fortnight for six weeks (90 T3) and 95° to 81° for fruits treated once a week for six weeks (90 T6). However, for untreated fruit (90 NT), a constant decrease in hue angle over a narrow range from 96° (unripe) to 51° (ripe) was observed.

Table 1 Effect of the hexanal pre-harvest treatment on the colour of papaya epicarp

Treatments	Epicarp									
	Tint angle (h°)									
	S0	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
90NT	129.65 ±1.9 j	115.48 ±1.3 hi	113.09 ±1.2 ghi	111.3 ±0.9 fghi	111.09 ±0.7 fghi	106.6 ±1.2 bcdefg	ND	ND	ND	ND
90 T_3	116.22 ±0.4 i	111.34 ±3.0 fghi	110.46 ±1.0 efghi	110.33 ±1.5 defghi	109.99 ±0,9 cdefghi	109.83 ±1.3 cdefghi	109.12 ±0.9 bcdefghi	108.64 ±0.9 bcdefgh	103.66 ±0.6 bcde	102.92 ±0.4 bc
90 T_6	113.53 ±2.1 ghi	111.8 ±4.1 ghi	111.54 ±4.1 fghi	110.26 ±1.2 cdefghi	109.83 ±1.3 cdefghi	108.94 ±1.2 bcdefghi	108.27 ±3.6 bcdefgh	104.17 ±1.6 bcdef	103.12 ±0.4 bcd	103.1 ±0.4 bcde

Values followed by the same letter in the same column and on the same line are not significantly different at the 5% threshold according to the Duncan test.

90 NT: Untreated papayas; **90 T_3:** Papayas treated with hexanal once every fortnight for six weeks (T_3); **90T_6:** Papayas treated with hexanal once a week for six weeks (T_6); **S:** week; **ND**: Not determined.

Table 2 Effect of the hexanal pre-harvest treatment on the colour of papaya pulp

Treatments	Pulp									
	Tint angle (h°)									
	S0	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
90NT	96.4 ±1.1 k	94.7 ±0.5 jk	90.01	85.3 ±0.1 defgh	72.89 ±7.8 bc	52.84 ±1.90 a	ND	ND	ND	ND

			±2.1 efghijk							
90 T3	95.33 ±1.8 k	94.41 ±2.1ijk	92.43 ±0.4ghijk	89.64 ±1.1efghijk	87.64 ±0.4efghijk	86.26 ±2.4defghij	85.17 ±0.7defg	83.37 ±2.7def	68.52 ±3.4b	67.59 ±2.8b
90 T6	92.2 ±1.7 fghijk	94.26 ±5.2hijk	92.72 ±2.5ghijk	92.43 ±0.4ghijk	91.02 ±2.1fghijk	89.73 ±1.7efghijk	88.37 ±0.4efghijk	85.59 ±6.4defghi	81.23 ±2.1de	78.84 ±1.4cd

Values followed by the same letter in the same column and on the same line are not significantly different at the 5% threshold according to the Duncan test.

90 NT: Untreated papayas; **90 T3:** Papayas treated with hexanal once every fortnight for six weeks (T3); **90T6:** Papayas treated with hexanal once a week for six weeks (T6); **S:** week; **ND:** Not determined.

3.2. Fruit firmness

The firmness of papaya fruit harvested from hexanal-sprayed plants (90 T3 and 90 T6) was significantly (P <0.05) higher than the firmness of fruit from unsprayed plants (90 NT). Fruit firmness was almost similar in all treatments when harvested after one week (Table 3). Fruit firmness values increased progressively in treated papayas (90 T3 and 90 T6). However, the values were always higher for fruit treated once a week (90 T6) than those treated once every fortnight (90 T3) for six weeks. The firmness values of untreated papayas (90 NT) decreased from the 118th (S4) day after anthesis (4 weeks after anthesis) and those of fruits treated once every fortnight (90 T3) from the 153 rd (S9) day after anthesis (9 weeks after anthesis).

Table 3 Effect of the hexanal-based formulation on papaya firmness

Treatments	**Firmness (Newton)**									
	Days of ripening									
	S0	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
90NT	70.2 ±1.8cdef	70.35 ±0.0 cdef	70.9 ±3.8 cdefg	71.15 ±2.9 cdefg	71.29 ±0.8 cdefgh	64.96 ±0.2 c	ND	ND	ND	ND
90 T3	68.06 ±0.0cd	68.83 ±0.0cde	71.18 ±0.9 cdefg	71.47 ±0.0 cdefghi	72.63 ±2.1defghi	75.11 ±2.9defghi	76.77 ±4.6fghi	76.8 ±4.10fghi	77.38 ±0.9 fghi	71.1 ±2.0 cdefg
90 T6	68.13 ±0.0cd	70.66 ±0.5cdef	72.23 ±2.5defghi	74.68 ±4.4defghi	76.05 ±3.4efghi	77.13 ±0.4 fghi	78.06 ±0.0ghi	78.5 ±0.5hi	78.6 ±0.2i	78.7 ±0.1i

Values followed by the same letter in the same column and on the same line are not significantly different at the 5% threshold according to the Duncan test.

90 NT: Untreated papayas; **90 T3:** Papayas treated with hexanal once every fortnight for six weeks (T_3); **90T6:** Papayas treated with hexanal once a week for six weeks (T_6); **S:** week; **ND**: Not determined.

3.3. Soluble dry extract (°Bx)

The results showed that the hexanal-treated fruits had lower soluble dry extract values than the control fruits. However, the soluble dry extract values of the untreated (90 NT), treated (90 T3 and 90 T6) papayas increased progressively respectively for 5 and 9 weeks (Table 4). The 90 T3 (5.06-7.66 °Bx) and 90 T6 (5.11-7.06 °Bx) fruits harvested after 9 weeks of hexanal spraying showed significantly lower soluble solids contents than the control fruits (5.31-13.36 °Bx).

Table 4 Effect of spraying the hexanal-based formulation on the soluble dry extract of papaya

Treatments	**Soluble dry extract (°Bx)**
	Days of ripening

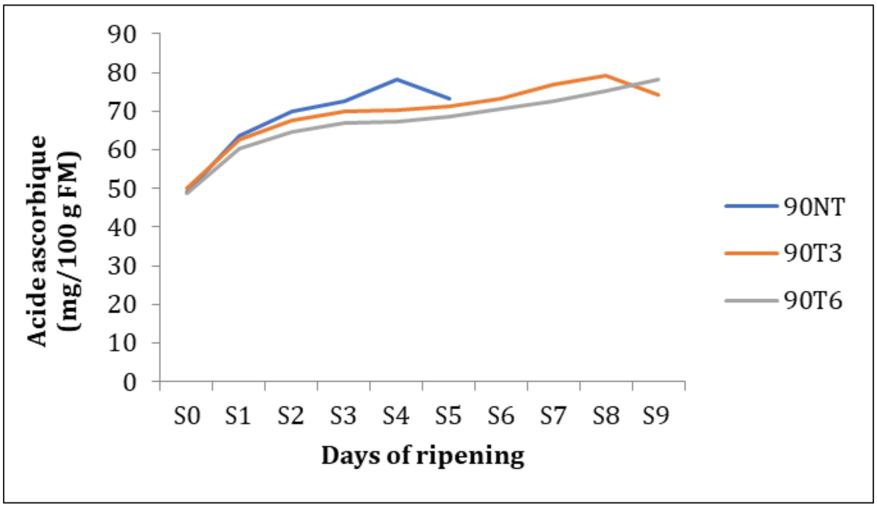
	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
90NT	5.31 ±0.0 abcd	5.43 ±0.3 bcde	6.06 ±0.1 h	6.10 ±0.0h	7.73 ±0.1l	9.46 ±0.2m	ND	ND	ND	ND
90 T_3	5.06 ±0.0a	5.2 ±0.0 ab	5.3 ±00 abc	5.53 ±0.03 cdef	5.56 ±0.03def	5.76 ±0.2fg	6.13 ±0.1h	7.26 ±0.1 jk	7.50 ±0.1 kl	7.66 ±0.1l
90 T_6	5.11 ±0.0a	5.13 ±0.1a	5.26 ±0.0ab	5.33 ±0.1 abcd	5.60 ±0.0ef	5.73 ±0.0fg	5.76 ±0.16 fg	5.96 ±0.03 gh	6.80 ±0.2 i	7.06 ±0.1 j

Values followed by the same letter in the same column and on the same line are not significantly different at the 5% threshold according to the Duncan test.

90 NT: Untreated papayas; **90 T_3:** Papayas treated with hexanal once every fortnight for six weeks (T_3); **90T_6:** Papayas treated with hexanal once a week for six weeks (T_6); **S:** week; **ND**: Not determined.

3.4. Ascorbic acid

Ascorbic acid levels are shown in figure 1. Hexanal treatment of papaya fruit showed a significant difference (P <0.005) in the ascorbic acid values recorded between control (90 NT) and treated fruit. The fruits showed a downward trend in ascorbic acid levels from 118 (S5) days after anthesis (4 weeks after anthesis) (78.33-51.2 mg / 100 g FM) for fruits not treated with hexanal. Fruit treated with hexanal spray showed a progressive and significant increase in ascorbic acid levels in papaya up to day 146 (8 weeks after anthesis) and day 153 (9 weeks after anthesis) respectively for fruit treated with T3 and T6.

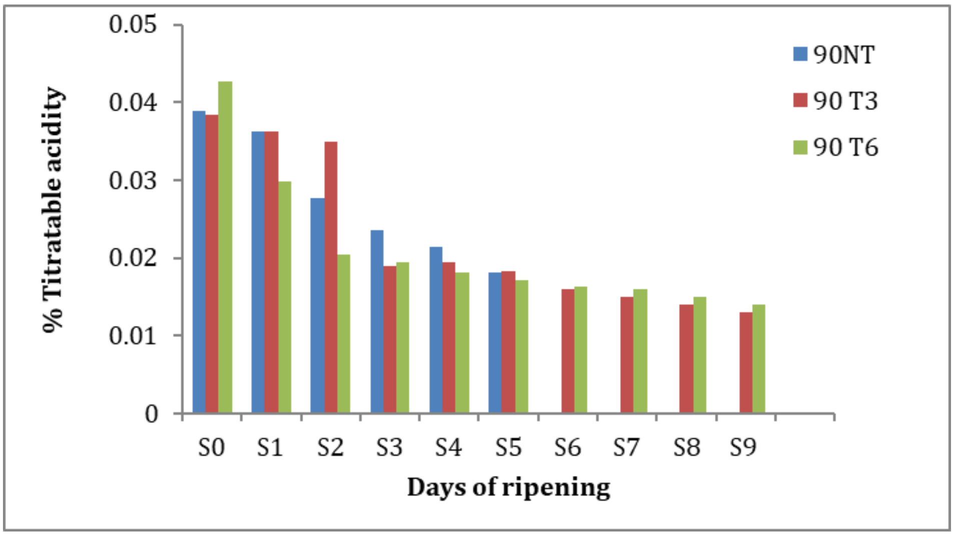


90 NT: Untreated papayas; **90 T_3:** Papayas treated with hexanal once every fortnight for six weeks (T_3); **90T_6:** Papayas treated with hexanal once a week for six weeks (T_6)**; S:** week.

Figure 1 Effect of spraying the hexanal-based formulation on ascorbic acid in papaya

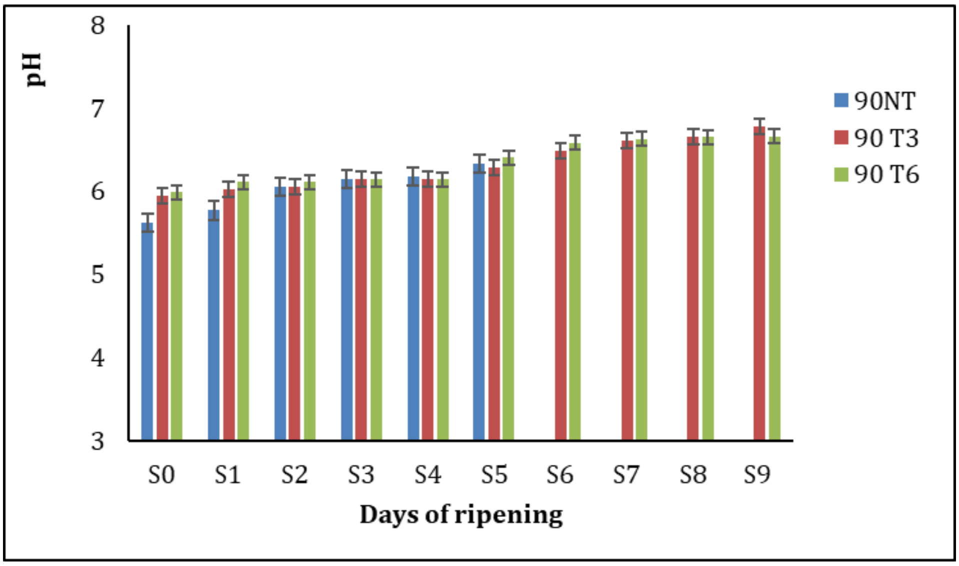
3.5. Titratable acidity and pH

The results for titratable acidity and pH are shown in Figure 2 and Figure 3 respectively. The titratable acidity of untreated (90 NT) and treated (90 T3 and 90 T6) papaya fruit decreased during the experiment while pH increased. Statistical analysis showed that there was no significant difference between the pH values of treated and untreated fruit at the 5% threshold. The pH of the fruit ranged from 5.61 to 6.77 and the citric acid content from 0.01 to 0.042%.



90 NT: Untreated papayas; **90 T_3:** Papayas treated with hexanal once every fortnight for six weeks (T_3); **90T_6:** Papayas treated with hexanal once a week for six weeks (T_6); **S:** week.

Figure 2 Effect of spraying the hexanal-based formulation on the titratable acidity of papaya

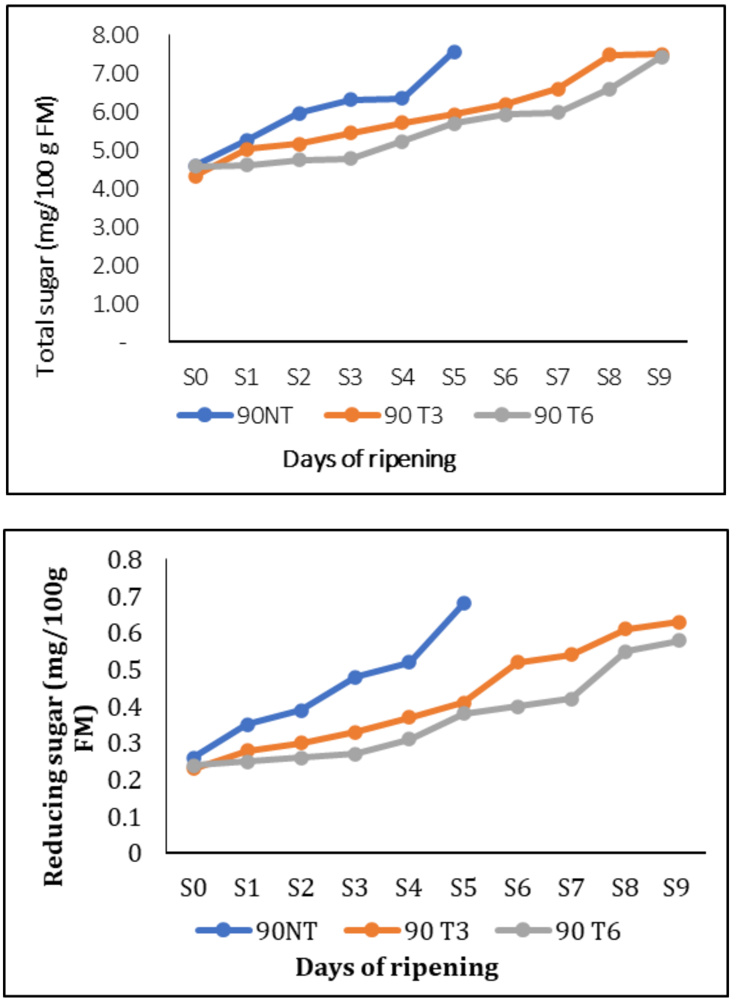


90 NT: Untreated papayas; **90 T_3:** Papayas treated with hexanal once every fortnight for six weeks (T_3); **90T_6:** Papayas treated with hexanal once a week for six weeks (T_6); **S:** week.

Figure 3 Effect of spraying the hexanal-based formulation on the pH of papaya

3.6. Total and reducing sugars

The total sugar content of fruit treated once every fortnight for 6 weeks (90 T3) and fruit treated once every week for 6 weeks (90 T6) increased progressively with the duration of the experiment (Figure 4). However, statistical analysis revealed a significant difference at the 5% threshold between the sugar values of the untreated fruit and those of the treated fruit. The total sugar content recorded in untreated papaya fruit (90 NT) and papaya treated three times (90 T3) and six times (90 T6) was 4.6-8.13 mg / 100g, 4.32-7.51 mg / 100 g and 4.58-7.44 mg / 100g respectively. Fruit harvested from papaya plants treated once every fortnight (90 T3) and those treated once a week (90 T6) had maintained lower values for 9 weeks compared with untreated fruit (90 NT). Statistical analysis showed that hexanal treatment had an influence on papaya sugar levels. Reducing sugar in treated and untreated fruit showed similar trends, but the difference between T3, T6 and NT treated fruit was negligible.



90 NT: Untreated papayas; **90 T$_3$:** Papayas treated with hexanal once every fortnight for six weeks (T$_3$); **90T$_6$:** Papayas treated with hexanal once a week for six weeks (T$_6$); **S:** week.

Figure 4 Effect of spraying the hexanal-based formulation on the total and reducing sugar content of papaya

3.7. Moisture content (%)

Table 5 Effect of hexanal-based formulation spraying on papaya moisture content

Treatments	**Moisture content (%)**									
	Days of ripening									
	S0	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
90NT	87.63 ±0.56^{a}	88.15 ±2.04^{ab}	88.86 ±0.58^{ab}	89.39 ±0.05^{ab}	90.83 ±0.63^{bc}	93.4 ±0.30^{cde}	ND	ND	ND	ND
90 T$_3$	88.1 ±1.14^{ab}	88.5 ±0.28^{ab}	88.80 ±0.6^{ab}	89.88 ±2.51^{ab}	89.93 ±0.59^{ab}	90.1 ±0.54^{ab}	90.17 ±0.66^{ab}	90.33 ±0.51^{ab}	90.73 ±0.57^{bc}	91.03 ±1.14^{bcd}
90 T$_6$	87.95 ±1.14^{ab}	88.11 ±1.16^{ab}	88.76 ±1.52^{ab}	89.56 ±0.65^{ab}	89.73 ±0.57^{ab}	90.01 ±0.57^{ab}	90.05 ±0.57 ^{ab}	90.13 ±0.01^{ab}	90.24 ±0.58^{ab}	90.43 ±0.19^{ab}

Values followed by the same letter in the same column and on the same line are not significantly different at the 5% threshold according to the Duncan test; **90 NT:** Untreated papayas; **90 T$_3$:** Papayas treated with hexanal once every fortnight for six weeks (T$_3$); **90T$_6$:** Papayas treated with hexanal once a week for six weeks (T$_6$); **S:** week; **ND**: Not determined

Table 5 shows the moisture content of the papayas. Statistical analysis at the 5% threshold showed a significant difference between the moisture values of the control fruit (90 NT) and those of the treated fruit (90 T3 and 90 T6). Moisture content increases during ripening of papaya fruit. The moisture content of the papaya ranged from 87.63 to 94.05%, 88.1 to 91.03% and 87.95 to 90.43% in NT, T3 and T6 fruit respectively. The highest moisture content was observed in untreated fruit.

4. Discussion

The application of hexanal-based formulation is a relatively new technology that has been shown to be effective in extending the ripening time and quality of several fruits such as mango, banana and guava [18, 19, 20].

The colour of the epicarp (peel) is a very important visual parameter widely used in fruits as an index of ripeness and allows subjective judgement of fruit taste/preference by consumers. A study of the colour of the different parts (epicarp and pulp) of the papaya showed that the pulp of treated papayas took four to five weeks to change colour (traces of yellow) after the pulp of untreated papayas. The pulp turned orange 125 days (S5) after anthesis for the papaya not treated with hexanal. For the papayas treated with hexanal, the colour began to change 139 days (S7) after anthesis. This would mean that the hexanal treatment effectively delayed the ripening of the papaya fruit. The change in fruit colour is associated with the enzymatic degradation of chlorophyll in the epicarp (skin) and the concentration of carotenoids in the epicarp and pulp that give the fruit its characteristic colour. In addition, it was observed that the hue angles decreased steadily as the a* and b* values increased during ripening, ensuring a uniform colour break in the epicarp and an intense orange colour concentration in the pulp. It was noted that the hue angle of hexanal-treated papaya shifted from green to lime to yellow and amber as the chlorophyll continued to degrade.

The moisture content of papaya is an indicator of the level of ripeness and maturity of the fruit. In fact, dry matter content decreases with ripening, which is the opposite effect of moisture content [21]. The results showed that fruit treated with hexanal once every fortnight for six weeks (90 T3) or those treated with hexanal once a week for six weeks (90 T6) had a lower moisture content and increased over the 9 weeks (S9) of analysis, unlike untreated fruit (90 NT) whose moisture content increased rapidly from the 118th day (S4) after anthesis. The increase in water content during ripening would probably be due to the use of the water contained in these fruits in the various metabolic activities during the ripening process. In addition, the fruit stops growing from 90 days after anthesis, which could also explain the low change in moisture content in papayas treated with hexanal. Hexanal treatment would therefore have delayed papaya ripening for 4 (S4) to 5(S5) weeks (days 118-153).

Pre-harvest sprays of hexanal formulation helped the fruit retain its firmness during ripening. Fruit firmness is generally defined as an essential mechanical response to fruit structure that is influenced by physiological development, ripeness, damage and turgidity and is an attribute that must be maintained during handling, storage and processing [22]. Firmness is one of the most important quality parameters of papaya and is closely associated with ripeness and shelf life. Pre-harvest applications of 0.02% hexanal (once a week and once every fortnight) for six weeks on papaya resulted in higher fruit firmness than the control fruit. The firmness values of the untreated papaya (NT) decreased from day 118 onwards (S4). The possible cause of this loss of papaya firmness may be the result of an increase in the rate of skin lesions after a respiratory and climacteric peak [23]. Our results corroborate those obtained by [18, 24] in their respective work concerning hexanal treatments of papaya and mango.

Pre-harvest treatments with hexanal did not result in any major differences in pH and acidity. The acidity of treated and untreated papayas decreased, leading to an increase in pH to around 6. During ripening, this relative decrease in acidity and increase in pH could result from the conversion of these organic acids into sugars by a process called gluconeogenesis [25].

As for vitamin C content, it rises sharply in treated and untreated papayas, reaching a peak and then falling. However, it fell from day 118 (S4) for the untreated papayas and then from day 146 (S7)and 153 (S9) respectively for the papayas treated once every fortnight and once every week. This observation confirms that hexanal treatment delays papaya fruit ripening by at least 4 weeks. Furthermore, these results are in agreement with those of [26] who observed that vitamin C levels increase during papaya ripening. Recently, [27] also observed an increase in vitamin C content in tomatoes in response to pre-harvest spray application of hexanal-based formulation.

Total and reducing sugars and soluble dry extract levels increased overall during the study. This accumulation of soluble sugars is due to their synthesis by sucrose phosphate synthase from galactose released by hydrolytic enzymes in the cell wall [28].

The soluble solids of treated and untreated papaya fruit increased continuously as the fruit ripened. The increase in soluble solids as the fruit ripened could be explained by the hydrolysis of starch to sugars as the fruit ripened [29]. Hexanal-treated fruit showed a slight increase in sugar, unlike control (untreated) fruit. However, the levels of soluble dry extract, total sugars and reducing sugars varied slightly for papayas treated once a week for six weeks in hexanal. Hexanal treatment therefore had an inhibitory effect on the action of the enzymes responsible for hydrolysing starch into sugars, which would explain the low sugar content of the fruit treated with hexanal. These results are confirmed by the work of [18] who showed that mangoes that had been treated with hexanal had lower soluble solids and total sugars than mangoes that had not been treated with hexanal. These results are also confirmed by the work of [30] who showed that sugars increased with the level of ripening of papayas.

5. Conclusion

This study on the fruits of Carica papaya cv solo 8 revealed that treatment of papaya fruits with hexanal from the 90th day after anthesis delayed ripening of papayas on the tree for a period of 4 to 5 weeks. In addition, treatment with hexanal, once a week for six weeks (90 T6) from the 90th day after anthesis, proved to delay papaya ripening on the papaya tree the most (5 weeks). In fact, the physico-chemical parameters used to measure fruit ripening (vitamin C, firmness, sugars and moisture) showed that the fruit from this treatment (T6) were the least ripe at all harvest dates. Hexanal treatment therefore delays the ripening of papayas. However, it would be interesting to determine the effect of hexanal on these same fruits (papayas) during post-harvest storage.

The use of this technology will have the advantage for growers of enabling them to plan their harvests perfectly and to obtain better prices on the markets.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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