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RESEARCH ARTICLE

INFLUENCE OF UV LIGHT EXPOSURE ON SHELF LIFE EXTENSION OF FRESH-CUT FRUITS

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Abstract

The effect of UV-C radiations on the shelf life of fresh cut fruits was studied by comparing the treated fruits with untreated fruit as control sample. A fruit basket was prepared by packing cut fruits into an aluminum box and oxywrap cling film. Comparative study was done by analyzing texture, color, TSS, pH, acidity and moisture during storage at 8^0C. Texture analysis of fresh fruits and UV irradiated fruits was done by TA-XT Plus texture analyzer as well as browning analysis was done by Lovibond RT series Reflectance Tintometer. UV treatment was found effective to control microbial growth and enzymatic browning. There was no any significant change in physicochemical properties of fruits was observed. The firmness of fruits got improved by UV irradiation than control sample. Juice leakage was observed in control sample but fruits were firm after UV treatment till 4^{th} day. Untreated fruits had progressive browning as well as deterioration attend in 2 days storage. Deterioration quality was evaluated by microbial growth on fruits on 4^{th} day of treatment. Change in color value was minimum compared to untreated fruits. The slight decrease in lightness L* during 4 days storage at 8^0 temperature indicates enzymatic browning. Results indicate that quality and shelf life of fresh cut fruits get improved by UV radiation treatment and it is a highly efficient non thermal preservation technique for fresh cut fruits.

INTRODUCTION

The International Fresh-cut produce association (IFPA) defines fresh-cut produce as fruit or vegetables that have been trimmed and/or peeled and/or cut into 100% usable product that is bagged pre-packaged to offer consumers high nutrition convenience and flavor while still maintaining its freshness (Laxmikanra, 2002). In particular, fresh-cut fruits attract consumers because they are fresh, nutritious, low price and ready to eat. As a consequence, a wide assortment of minimally processed fruit has been developed to meet consumer's needs for "quick" and convenient products and to benefit from fruit's healthy image. Minimal processing gives additional value to fresh-cut in terms of convenience and time saving, although several hurdles are encountered due to the difficulty in preserving their freshness during prolonged periods. These products in fact are characterized by a shorter shelf life than their whole counterparts because of higher susceptibility to microbial spoilage, increased respiration rate and ethylene production, which is stimulated by process operation (i.e. cutting, trimming, slicing etc) determine enzymatic browning, texture decay, rapid microbial growth juice leakage, water loss thus reducing shelf life.

Fresh fruits and vegetables treating with Ultra Violet (UV) radiation is a new approach that holds promise for the extension of storage life of fresh horticultural crops (Ben-Yehoshua, 2003). Ultraviolet light (UV-light) technology utilizes radiation with the electro-magnetic spectrum in the range of 100 to 400 nanometers, between visible light and x-rays. It could be further divided into UV-A (320–400 nm), UV-B (280–320 nm) and UV-C (200–280 nm). UV-C is known to have biocidal effects and destroys microorganisms by degrading their cell walls and DNA (Ngadi *et al.,* 2003). For fruit juice and beverage processing, the wavelength of 254 nm is widely used (Guerrero-Beltran *et al.,* 2004). As a non-thermal preservation method, UV-C treatment takes the advantages of no toxic or significant non-toxic by-products being formed during the treatment, very little energy being required when compared to thermal pasteurization processes, and maximum aroma and color of the treated fruits being maintained (Tran *et al.,* 2004). The application of UV-C in minimally processed fruit causes an increase in the concentrations of antioxidants, polyphenols, and flavonoids (Alothman *et al.,* 2009). Thus of application of UV radiation during cutting process could better improve product shelf life.

Texture an important property of food, is measured objectively by the function of mass, time and distance for establishing the physical and mechanical behavior of a food, when processed, consumed and stored. If predicts the product’s quality under certain manufacturing conditions, consumer food habits and performance of accepted food under certain conditions (Bourne, 1982). Establishing the interrelationships among composition, texture and microstructure of food help in predicting its geometric characteristics under various process treatments.

Color of the product is one of the most important quality attributes influencing consumer food choices, perceptions and purchase behavior. Color measurement and analysis is therefore important in the bioprocessing and storage to optimize the quality and value of the product. Color quality will determine whether these products are acceptable to the consumer. By conditioning above, the aim of this research work was to compare effect of UV on cut fruits in terms of textural characteristics and color value with non-UV-treated fruits. Also to prepare a basket of ready to eat fruits that is readily made available to consumers.

MATERIALS AND METHODS

2.1 Fruit basket preparation

Nine matured but firm and popular fruits (apple, banana, pear, guava, oranges, pineapple, grapes, papaya and dates) were purchased from local market of Nagpur. Fruit basket was prepared from aluminum boxes and oxywrap PVC cling film. Surface sanitization of fruits was done by 10 ppm chlorinated water and fruits were subjected to size reduction. Approximately 250 gm of cut fruits were placed in basket. Fruits were cut in cubes or slices. Fruits like pear, apple, guava and pineapple were cut in 1.5cm×2cm×2.3cm sizes. Orange segments kept had 2cm×4cm size. Banana was peeled and sliced in round shape with diameter 2.5 cm and thickness 1cm. whereas grapes and dates were added in basket as it is. Good manufacturing practices and best possible sanitary conditions were strictly adhered during processing and all subsequent handling stages.

2.2 UV treatment on fresh–cut fruits

These fresh-cut fruits were irradiated with UV-C radiations, provided by UV lamp with peak of emission at 253 nm. Irradiation was carried out after size reduction under ambient conditions. The expose time for fruit was 20 min to each side. The lamp was placed at 56 cm above the processing surface. The control and irradiated fruits were then placed in aluminum box, covered with oxywrap PVC cling film. Aseptically both treated and untreated fruits were stored at 8^0C temperature. Untreated fresh fruits were considered as reference. During storage at 8^0C fruits were analyzed for color, texture and physicochemical changes.

2.3 Physicochemical analysis of fruit

Total soluble solid content of a solution was measured by hand Refractometer (Atago Instruments; Range: 0-32). Fruit juice was prepared manually by squeezing. In case of banana, guava and dates 10% fruit juice in distilled water was taken for analysis.

Percent Moisture content was done by AOAC (1990). Where sample was kept at 105^0C till the constant weight attended.

pH of fruit juice was measured by using pH meter (VSI electronics Pvt., Ltd. Mohali. Sr. No: 0302014F). For sample preparation fruit cuts were pressed to squeeze out the juice. In case of fruits like banana, guava and dates one gram of fruit pulp was taken for analysis.

Neutralizable acidity of fruit juices was calculated by the method titrating with 0.01N NaOH (Cornelius *et al.,* 2013). Amount of NaOH required to raise the pH up to 7 was noted for each sample.

Ascorbic acid was determined by titrating fruit juices with 2,6 dichloroendophenol. Dye factor was calculated by titrating 10ml of 0.1 mg/ml standard ascorbic acid solution with dye. The resulted ascorbic acid content was reported in mg/100ml sample.

$$Dye\ factor = \frac{1.0}{titre}$$

$$Ascorbic\ acid\ = \frac{titre \times dye\ factor \times volume\ made\ up \times 100}{aliquot\ of\ extrat\ taken\ for\ estimation \times wt\ or\ vol\ of\ sample\ taken\ for\ estimation}$$

2.4 Color (Browning) analysis

Color change in fruits during storage was determined by Lovibond RT series Reflectance Tintometer. Color measurement were recorded as L*, a*, and b* (L*= lightness, a*= ranging from green to red and b*= ranging from blue to yellow). Lightness was detected by L* value, a* and b* are for color opponent dimensions, based on nonlinearly compressed coordinates. L*,a* and b* values of fruits in which color change takes place due to enzymatic browning like apple, pear and guava are determined and noted. Each measurement was taken at three locations for each sample piece and mean was reported in results. The values of fresh fruits were considered for reference and compared with treated fruits.

2.5 Texture analysis

Texture analysis of fruits was done by using TA-XT Plus (manufactured by Stable micro system, UK) instrument. In this measurement of skin puncture strength of grapes, oranges by penetrating with a 2mm Cylinder Probe (P/2) using 5kg load cell on Heavy Duty Platform (HDP/90) and firmness of fruits like apple, banana, strawberries, papaya, pineapple, pear and guava by shearing by Blade Set (HDP/BS) using 5kg load cell was done.

1.6 Statistical analysis

During study all experiments were performed and parameters were calculated three times (unless indicated otherwise) for one sample. Mean of these three replicates was reported as result. Deviation in these readings was mentioned by calculating standard deviation for each value and represented with results.

RESULTS AND DISCUSSION

3.1 Physicochemical analysis of fruits

The fresh cut fruits were stored at 8^0C temperature in refrigerator. Leakage of juice from untreated fruits was observed during storage. After 24 hours fruits became soft and texture loss was observed. At 2^{nd} day microbial growth on fruit surface was observed. So from this, we can say shelf life of fresh cut fruits without any treatment, at refrigeration temperature is one day. Physicochemical analysis of fresh fruits was carried out while that of UV treated fruits was done on 2^{nd} and 3^{rd} day. The results obtained from the physicochemical analysis of both category fruits is interpreted in table 1.

Table 1 Physicochemical analysis of fruits

Fruits	Parameters	Fresh	UV treated	
			2^{nd} day	3^{rd} day
Banana	TSS(^{0}brix)	2.2±0.16	2.4±0.16	2.4±0.16
	pH	5.02±0.02	5.68±0.02	5.75±0.02
	0.01N NaOH required (ml)	5.5	4.9	4.7
	%Moisture	78.74	77.5	76.5
	VitaminC mg/100gm	0.979	0.90	0.816
Grapes	TSS(^{0}brix)	15.4±0.16	18.83±3.93	19.8±3.08
	pH	3.55±0.02	3.81±0.10	3.94±0.02
	0.01N NaOH required (ml)	8.6	7.8	5.6
	%Moisture	84.17	83.0	82.5
	VitaminC mg/100gm	1.224	1.0613	0.9796
Oranges	TSS(^{0}brix)	11.4±0.16	13.2±0.16	13.6±0.16
	pH	3.34±0.11	3.70±0.01	3.78±0.03
	0.01N NaOH required (ml)	12.5	11.4	10.9
	%Moisture	86.99	74.5	83.8
	VitaminC mg/100gm	16.899	13.388	13.225
Papaya	TSS(^{0}brix)	9.2±0.16	11.93±0.99	13.6±0.16
	pH	5.06±0.04	5.39±0.04	5.46±0.01
	0.01N NaOH required (ml)	4.5	2.8	2.6
	%Moisture	89.40	88.5	86.5
	VitaminC mg/100gm	20.79	20.328	18.858
Guava	TSS(^{0}brix)	1.0±0.16	0.6±0.16	0.8±0.16
	pH	3.46±0.05	4.12±0.03	4.13±0.01
	0.01N NaOH required (ml)	7.5	7.2	7.4
	%Moisture	77.92	76.0	76.5
	VitaminC mg/100gm	21.389	21.552	19.756
Pear	TSS(^{0}brix)	8.8±0.16	12.73±1.87	16.2±0.16
	pH	4.24±0.07	4.25±0.05	4.21±0.01
	0.01N NaOH required (ml)	3.7	2.1	4.1
	%Moisture	87.11	85.0	86.0
	VitaminC mg/100gm	0.653	0.571	0.489
Dates	TSS(^{0}brix)	6.2±0.16	5.0±0.16	6.0±0.16
	pH	5.01±0.14	5.09±0.16	5.17±0.04
	0.01N NaOH required (ml)	5.0	4.8	4.7
	%Moisture	19.86	18.0	19.0
	VitaminC mg/100gm	1.0613	1.142	0.979
Pineapple	TSS(^{0}brix)	14.2±0.16	15.2±0.03	15.6±0.16
	pH	3.38±0.05	3.88±0.02	3.71±0.28
	0.01N NaOH required (ml)	4.7	3.3	3.2
	%Moisture	85.81	82.5	83.85
	VitaminC mg/100gm	9.143	10.205	10.694
Apple	TSS(^{0}brix)	13.2±0.16	12.6±0.16	12.4±0.16
	pH	3.88±0.03	4.16±0.01	4.83±0.47
	0.01N NaOH required (ml)	3.0	3.4	4.1
	%Moisture	85.51	84.0	82.5
	VitaminC mg/100gm	0.898	0.979	0.8164

Values are mean± SD of three replicates

Physicochemical properties of UV treated and untreated fresh fruits are reported in the table 1. The TSS values and the standard deviations are shown in this table. All the tested fruit were enough matured and were in starting phase of ripening. In fresh fruits guava and banana were low in TSS. The mean TSS was lowest for guava (1.0), followed by banana 2.2 and highest for grapes (15.4), and followed by pineapple (14.2). In all above fruits TSS of the UV treated on 2^{nd} day was slightly greater than the untreated fresh fruits and on 3^{rd} day it was found greater than 2^{nd} day. This was mainly due to the ripening changes in fruits. During ripening inversion of sugar takes place and this leads to the increase in total sugar (solid) content. Increase in brix makes the fruit sweeter.

The mean pH of the all UV treated fruits and untreated fresh fruits are shown in the table along with the standard deviations. All untreated fresh fruits were acidic and the pH was well below 5.5. The fruit possessing the lowest pH was orange (3.34), followed by pineapple (3.38) and highest for papaya (5.06), followed by banana (5.02). During storage at 8^0C the increase in pH was observed. At 2^{nd} day of UV treatment the pH of all fruits was slightly increased and continued up to 3^{rd} day in all fruits (except pear). Low pH is the sign of acidity, increase in pH from lower side to higher indicate the decrease in acidity. During ripening of fruits acidity get decreases. Here also decrease in acidity was due to ripening of fruits.

The amount of NaOH base needed to neutralize the acidity of fruit was determined and presented in the table. From this result, oranges required the most base (12.5). While apple needed the least volume of base to rise its pH to 7.0. So from this orange had the highest nutralizable acidity and apple had the lowest nutralizable acidity compared to other fresh untreated fruits. This acidity was lower down during the storage. The values of volume of NaOH required were higher in fresh untreated fruits but that was lower in 2^{nd} day and 3^{rd} day (except pear).

Respiration in fruits is a continuous process. During storage fruits undergo respiration and moisture loss takes place. The packaging material used oxywrap PVC cling film was permeable to oxygen and moisture. Thus suffocation during respiration of fruits was avoided during storage. Initial moisture content of all fresh fruits was high. Fresh untreated papaya was high in moisture content, while dated was reported low moisture content.

Ascorbic acid is very sensitive to temperature and processing. Room temperature at which analysis of fruits was carried out was high compared to storage temperature. Also it is water soluble vitamin. The loss of ascorbic acid noted was due to variation in temperature and moisture loss during storage. All fresh untreated fruits were rich in ascorbic acid. In this, guava had found high ascorbic content and pear was having low ascorbic acid content. On the 2^{nd} day and 3^{rd} day of UV treatment all fruits observed low ascorbic acid values.

In case pear, pH of UV treated fruit at 2^{nd} day was observed higher than fresh untreated fruits. This was due to ripening and inversion of sugar. But at 3^{rd} day pH was found lower than that of 2^{nd} day. This was the indication of increase in acidity of pear. Ultimately amount NaOH required to neutralize the acid was greater than that of fresh and 2^{nd} day of UV treatment. From the observations it was identified that the increase in acidity was due to presence of microbial growth. The difference in pH values was slight and there was no any noticeable growth was observed on the surface of pear at 3^{rd} day.

For shelf life extension of fruits a non thermal preservation technique was used that is UV radiations. Exposure time was 20 min on each side of fruit. UV treated fruits were looked like fresh fruits on 1^{st} day of treatment. On 2^{nd} day slight browning was observed and it was found increasing day by day. On 4^{th} day microbial growth was observed on the surface of fruits.

3.2 Color (Browning) analysis

During storage it was observe that, after cutting the fruits within one hour browning of apple, pear and guava takes place. Color analysis of UV treated and an untreated fruit was done during storage. Color change was identified by using Lovibond RT series Reflectance tintometer. The color measurement was done on three different positions of each fruit surface. Mean of these three values with standard deviations were reported in the table. The analysis was done on 2^{nd}, 3^{rd} and 4^{th} day. L*, a* and b* values are reported in the table 2.

Table 2 Color analysis of fresh fruits and UV treated fruits at 2nd, 3rd and 4th day

Category	Apple			Guava			Pear		
	L*	a*	b*	L*	a*	b*	L*	a*	b*
Fresh	76.81±2.91	0.22±0.33	21.58±2.55	79.29±2.71	-0.78±1.28	18.26±2.36	60.99±1.43	1.24±0.31	16.54±1.22
FF after 24hrs	70.48±2.10	2.73±0.55	33.09±4.31	63.37±3.78	1.75±1.45	24.85±3.06	46.38±3.57	3.94±4.65	26.4±2.54
UVF 2nd day	72.17±1.86	1.58±0.88	30.86±1.69	70.67±3.60	0.53±0.64	24.77±1.74	56.78±3.92	2.66±1.25	16.91±3.33
UVF 3rd day	70.59±2.13	4.04±0.45	32.75±0.69	64.77±5.49	9.00±2.91	27.56±3.44	54.77±2.27	2.99±0.72	24.83±1.83
UVF 4thday	61.54±0.35	4.82±0.73	33.29±1.77	63.80±1.92	10.14±0.19	34.43±1.69	53.03±2.73	4.48±0.25	18.45±6.64

Values are mean± SD of three replicates. FF-Fresh fruits untreated, UVF-UV treated fruits.

The primary pigments imparting color quality are the fat soluble chlorophylls (green) and carotenoids (yellow, orange and red) and the water soluble anthocyanins (red, blue), flavonoids (yellow) and betalains (red). In addition, enzymatic and non-enzymatic browning reactions may result in the formation of water soluble brown, gray and black colored pigments. The enzymes involved in browning reaction include polyphenol oxidase, which catalyzes the oxidation of polyphenolic compounds, phenylalanine ammonialyase, which catalyzes the synthesis of precursor to phenolic substrates.

The above table 2 indicates, in all three fruits L* values decreases from fresh fruit to 4th day of UV treatment. Fresh apple with L* (76.81±2.91) when kept at 8^{0}C after 24 hrs untreated apple gives L* value (72.48±2.10) indicating enzymatic browning. UV treated apple has L* (72.17±1.86) on 2nd day, 3rd (70.59±2.13) and (61.54±0.35) 4th day. The lightness of guava from fresh (79.29±2.71) decreased to (63.80±1.92) after 4th day compared to (63.37±3.78) untreated within 24 hrs. Similarly in case of pear decreasing trend in L* value was observed up to 4th day of storage, indicating browning of pear at slow rate compared to untreated pear having L* (46.38±3.570) after 24 hrs at same temperature. The color change was mainly due to enzymatic browning of fruits. The fruits having lower L* value and higher a* and b* value were influenced by the enzymatic browning compared to fresh cut fruits. UV exposure is an effective non thermal preservation technique. It was found effective on the inactivation of enzymes and reduction of microbial growth. The fruits exposed to UV radiations show decrease in enzymatic browning. Similar results were obtained by khademi *et al.,* 2013.

3.3 Texture analysis

Table 3 Texture analysis of fresh fruits and UV treated fruits

Fruits	Fresh		UV treated	
	Force (gram)	Distance (mm)	Force (gram)	Distance (mm)
Grape	271.296	147.463	431.11	149.352
Orange	87.135	197.517	100.360	147.171
Apple	3053.493	-	3881.273	-
Banana	492.133	-	537.812	-
Guava	2476.712	-	4165.016	-
Pear	4591.131	-	4089.440	
Papaya	1344.475	-	2543.911	-
Pineapple	4164.905	-	4409.193	-

Texture is an important sensory property of all food can be regarded as a manifestation of the rheological properties of food. Texture is a quality of attribute as it affects processing, handling and influencing shelf life as well as consumer acceptance as their food habits. The study of texture is important to establish mechanical behavior of a food when consumed. The characteristics of consumed of perceived texture is determined by different physical and physicochemical properties of food and by the unique as well as complex feature of human sensory system. In case of fresh-cut fruits, texture is an important property as the points of consumer's acceptance and satisfaction (Karadbhajne *et al.,* 2010)

Texture analysis of UV treated fruits was carried out after one day of treatment. Graphical representation of force required and time is shown for both fresh and UV treated in figure 1. Whilst the force applied to the fruit in this test indicates the ripeness. Force (in grams) and distance (in mm only for oranges and grapes) required to fresh untreated fruits and UV treated fruits were reported in table 3. The force and distance indicate the skin strength and elasticity of fruit respectively. Softening due to ripening is a major factor limiting the shelf life of fresh cut produce. It is generally regarded that pectinase enzymes such as pectin methylesterase and polygalacturonese are responsible for texture losses in plant tissue. In case of grapes force required to rupture the skin for UV treated (431.11 gm) was higher than fresh (271.296 gm) shows inactivation of enzyme and improved firmness of fruits. Similar results was observed in orange force required to rupture skin was (100.360) of UV treated compared to fresh (87.135). Also, for apple force requirement to cut the UV treated fruit (3881.273) was greater than untreated fresh apple (3053.493). Similar was observed with banana, guava, papaya and pineapple. Due to delaying of ripening improvements in firmness and texture was observed in all these fruits. The force required to cut the UV treated pear (4591.131) was less compared to fresh fruit (4089.440), which implies softening of UV treated pear.

The texture of the fruits given the UV treatment was firmer as compared to the untreated fresh fruits. Greater the maximum force the firmer is the sample. It means that after UV treatment the fruits remain firm. UV treatment improved the texture of fruits by retaining firmness. The similar results were obtained for fresh–cut cantaloupe melon processed under UV-C by Olusola *et al.*, 2005. In this study output of corrected for distance was approximately 1.18×10^3 µWsec/cm^2. Exposure time for each fruit from the initial cut until the fruit was placed in storage containers was approximately 4 min.

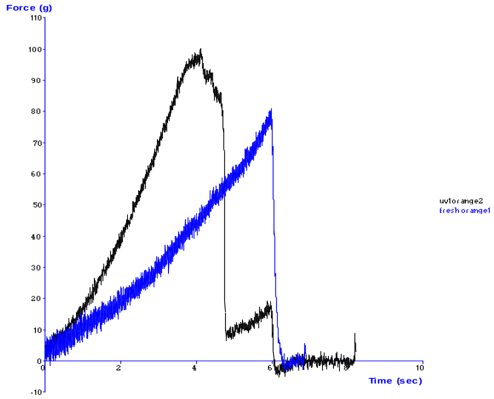

Figure 1.1 Oranges

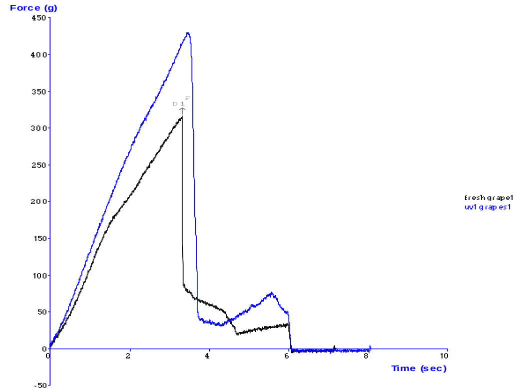

Figure 1.2 Grapes

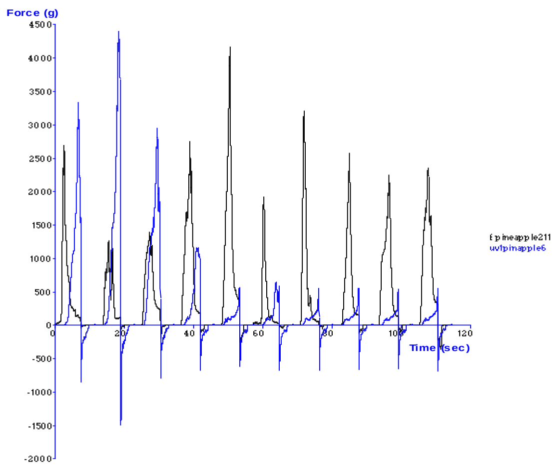

Figure 1.3 Pineapple

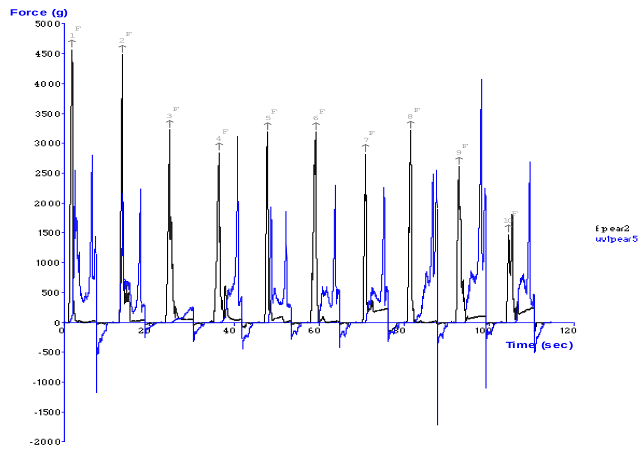

Figure 1.2 Pear

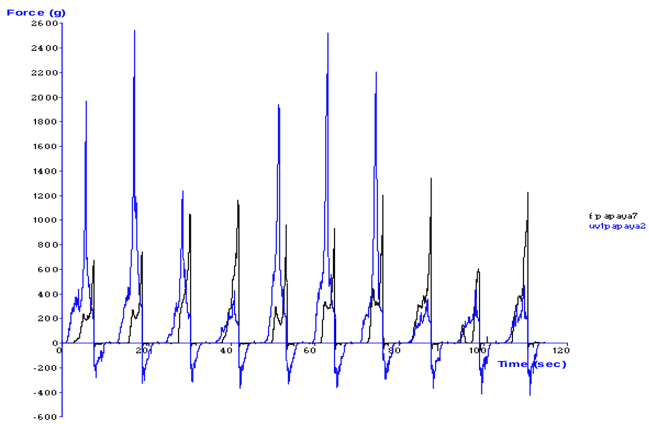

Figure1. 3 Apples

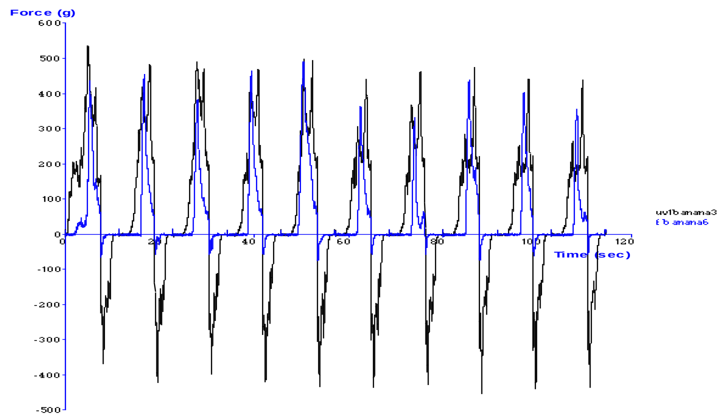

Figure1.6 Banana

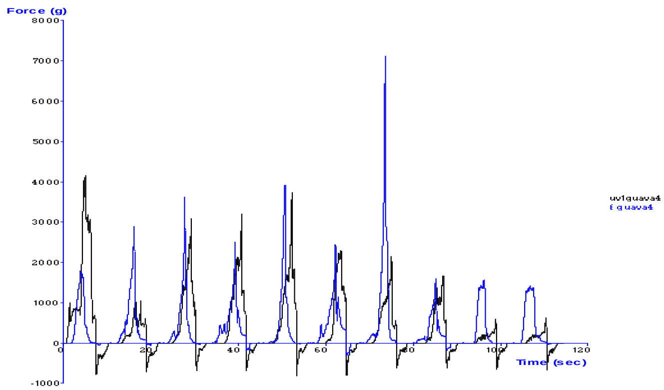

Figure 1.4 Guava

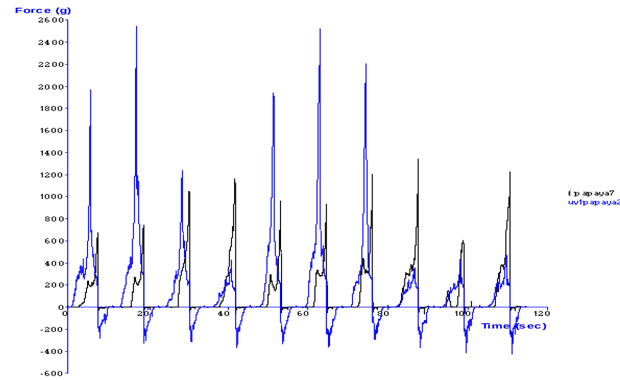

Figure 1.8 Papaya

Fig1 Force Vs time graph of fresh fruits and UV treated fruits texture analysis

4. CONCLUSION

Results indicate that UV-C explosion is a very effective and efficient non thermal technique for the preservation of fresh cut fruits. The inactivation of browning causing enzymes can be done by the UV treatment without noticeable effect on the fruit quality parameters like total soluble solids, acidity etc. According to the importance of firm fresh cut fruits for transportation and marketing the use of UV-C light will be effective. Enzymatic browning can be controlled by this technique. Also, UV light penetrates radiation into the DNA of microorganism and the reproduction of cell gets stopped. This resulting in reduction of microbial spoilage of cut fruits. By using this technique fresh cut fruits can be easily made available to the consumers in ready to eat form.

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