Studies on refrigerated storage of minimally processed papaya (*Carica papaya* L.)

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Abstract: Experiments were conducted in completely randomized design in order to assess the shelf-life and quality of minimally processed papaya stored under refrigerated condition (5°C±1°C and 95% RH). Before minimal processing, the semi ripe whole papaya was divided into two lots: control (untreated) and mild heat pretreated. The mild heat pretreatment (MHPT) of 45°C constant temperature for different exposure time (15, 30 and 45 min) was given to whole papaya followed by 24 h conditioning in cold room (1°C and 95% RH). Both the untreated and mild heat pretreated samples were packed in four different packaging materials i.e. polyethylene film (LDPE), polypropylene (PP), cling film and open tray. The stored samples were examined for its quality attributes i.e. physical loss in weight (PLW), color, texture (firmness), acidity, TSS and overall acceptability (%) at regular intervals. The results revealed that the packaging material and MHPT exposure time significantly affected the quality attributes. The 30 minutes as well as 45 minutes MHPT exposed samples when packed in LDPE witnessed minor change in color, texture, acidity and better retention of quality in terms of overall acceptability. Overall, the minimally processed papaya when MHPT for 45 min and packed in LDPE can be stored safely for 8 d under refrigerated condition.

Keywords: minimal processing, mild heat pretreatment, papaya, packaging, storage

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1 Introduction

Papaya (*Carica papaya* L.) fruit is rapidly becoming important commodity worldwide, both as a fresh fruit and as processed products (Sankat and Maharaj, 1997). Papaya is a very healthy fruit, and is appreciated because of its attractive pulp color, flavor, succulence, and characteristic aroma. Main varieties used for production are Pusa delicious, Pusa dwarf, Punjab sweet and honey dew (Anon, 2004).

In India, in spite of a good production of papaya, there is no primary processing at the farm level or at the wholesale/retailer level. These are marketed immediately after harvesting without any proper packaging. Peeling, removal of the seeds and slicing before consumption is a time consuming and effort-consuming activity. Minimally processed fruits and vegetables have become increasingly popular, due to their convenience to the consumer and the human health benefits associated with eating these foods. Minimal processing of raw fruits and vegetables is intended for keeping the freshness of the products, yet supplying it in a convenient form without losing its nutritional quality (Javier et al., 2005; Oliu et al., 2008). Desiccation is a major problem with cutting papaya pieces and this can be partially reduced with plastic wrap (Siripanich, 1993).

Heat treatment has been used for many years to control fungal spores and insect infestations in fruits and vegetables (Lurie, 1998). Mild heat treatment has been reported to improve the quality and shelf life of many horticultural produce. The beneficial effect of heat

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treatment has been attributed to the synthesis of heat shock proteins (Wang et al., 2001). Cell wall degrading enzymes and ethylene production were frequently disrupted or sometimes delayed following heating (Wang et al., 2001). Vicente et al. (2002) reported better storage and firmness of mild heat treated strawberries in comparison to untreated fruits.

Investigations conducted in papaya fruit were primarily focused on shelf-life extension of whole papaya fruit by controlling post harvest decay using heat treatments (Chan, 1986) or as a quarantine treatment to combat fungi rots or fruit fly pests (Couey and Hayes, 1986; Conway et al., 1999). Limited information has been reported on quality changes of fresh cut papaya (Paul and Chen, 1997). No attempt has been made on quality and shelf life enhancement of minimally processed papaya through mild heat pre-treatment in combination with different types of packaging material. The purpose of the present work was to study the effect of mild heat pre-treatment exposure time and packaging material on physico-chemical quality and shelf life of minimally processed papaya stored under refrigerated condition.

2 Materials and methods

Semi ripe (3/4 yellow) papaya (Variety: Punjab sweet) fruit obtained from a wholesale market in Ludhiana, Punjab were used for this study. Fruit were sorted based on the uniform size, color and physical damage. The papaya was thoroughly washed with water containing 200 ppm of active chlorine and air dried.

2.1 Mild heat pretreatment (MHPT)

The whole papaya fruit was divided into two lots: control (untreated, UT) and mild heat pretreated (MHPT) samples. For MHPT pretreatment, the whole fruit was tied in the muslin cloth and immersed in the hot water (constant temperature of 45^{o}C) for different holding time (15, 30 and 45 min). The temperature of water is controlled by using water bath. The treated samples were then kept in cold chamber (1^{o}C and 95% RH) for 24 h before giving minimal processing treatment.

2.2 Preparation of fruit sample

The MHPT treated and untreated samples were then peeled, deseeded and cut into cube shaped pieces using a sharp, sterilized knife. The minimally processed papaya samples were then dipped in 100 ppm sodium hypochlorite solution for 30 s followed by 6 h dipping in 4.0% calcium hydroxide solution. The excess water was whipped off with clean cloth after taking out from the solution and packed in different packaging material. Four types of packaging films commercially available in the market viz low density polyethylene film (LDPE), polypropylene (PP), cling film and open tray were used for packaging of minimally processed papaya. Each sample weighing 120 g was packed in selected packaging films and the films were sealed by using sealing machine. After packaging four pin holes were made in all the packs for proper gas exchange and to prevent condensation of water vapor inside the packages. The samples were then kept in refrigerated conditions (temperature variation 5^{o}C ±1^{o}C, relative humidity 95%). The stored papaya was then analyzed for its physio-chemical changes after regular intervals.

2.3 Quality parameters

The percent physiological loss in weight was calculated on fresh weight basis. Texture (firmness) of the fresh as well as stored samples was determined with the help of Texture Analyzer (TA-Hdi). Samples were compressed by an aluminium plate of 75 mm diameter to 75% strain (Kumar et al., 2009). The pre and post compression speed were set at 5 mm s^{-1} whereas; test speed was 1 mm s^{-1} as recommended by Bourne (1982). The height of the force peak during compression cycle was defined as firmness (kgf).

Colour is the most important parameter for the acceptability of the product. The colour properties of the fresh and stored samples were measured by using Miniscan XE plus Hunter Lab Colorimeter (USA), Model No. 45/0-L. Color was recorded using the (CIE-Lab), where L indicates lightness, a indicates chromaticity on a green (-) to red (+) axis, and b indicates chromaticity on a blue (-) to yellow (+) axis. The desired function color change (ΔE) was calculated from the 'L', 'a' and 'b' readings using expression $\Delta E = \sqrt{[(L-L_0)^2 + (a-a_0)^2 + (b-b_0)^2]}$; where, L_0, a_0 and b_0 represent the respective readings of fresh sample (Gnanasekharan et al., 1992).

Acidity was determined using reagents i.e. 90% alcohol, 0.1 N NaOH solution and phenolphthalein indicator. The percentage titratable acidity was calculated as per AOAC (2000). The TSS was determined with the help of 0°-32°Brix Erma Hand Refractrometer. One or two drops of papaya juice were put on the sample plate and the reading of total soluble solids on the scale was noted. The overall acceptability in percentage was evaluated using 9-point hedonic scale and was taken as an average of color, appearance, taste, flavor and texture score according to the method explained by BIS (1971).

2.4 Statistical analysis

The values of all quality parameters were expressed in percentage on the basis of fresh sample and three replications of each experiment were conducted. The data were statistically analyzed using factorial experiment in completely randomized design (CRD) by using computer software package (Cheema and Singh, 1990). Factor means values and least significant difference (LSD) was calculated at 5% level of significance (p=0.05).

3 Results and discussion

3.1 Physiological loss in weight (PLW %)

The statistically factor mean values of PLW based on the triplicate measurements for the selected packaging material, pretreatment and storage period are presented in Table 1. The PLW% increased significantly with the increase in storage period irrespective of the MHPT holding time and packaging material whereas, the packaging material as an individual followed by the interaction term of packaging material and storage period had significantly higher effect (p=0.05) than other parameters. According to Mir and Beaudry (2004), plant tissues tended to lose moisture when RH was below 99%-99.5%. Since the storage RH was around 95%, thus the higher PLW was noticed for the untreated minimally processed samples. The highest weight loss observed in control sample placed in the open tray. Kays (1991) reported water loss of more than 4%-6% (of the total fresh weight) of most commodities. The minimum change in PLW% was observed in 30 min MHPT sample packed in LDPE package.

Table 1 Quality attributes of minimally processed papaya stored under refrigerated condition

Parameter	Packaging material (A)				Pretreatment (B) UT MHPT holding time/min				Storage period/d (C)		
	LDPE	PP	Cling film	Open tray	-	15	30	45	4	8	12
PLW*[a] (%)	3.57	2.64	7.15	30.13	10.48	10.31	9.92	12.78	10.10	15.25	18.14
LSD (p=0.05)	A=0.0873; B=0.0873; C=0.0873; AB=0.175; AC=0.175; BC=0.175; ABC=0.349										
Firmness*	-27.02	-36.23	-28.25	-36.17	-36.74	-33.08	-27.33	-30.51	-16.83	-44.68	-66.16
LSD (p=0.05)	A=0.0899; B=0.0899; C=0.0899; AB=0.179; AC=0.179; BC=0.179; ABC=0.359										
Color Change*[a]	7.87	8.38	8.55	7.39	7.76	10.84	8.19	5.39	8.03	10.80	13.36
LSD (p=0.05)	A=0.0881; B=0.0881; C=0.0881; AB=0.176; AC=0.176; BC=0.176; ABC=0.353										
Titratable Acidity*	-32.50	-22.50	-29.68	-29.37	-33.75	-22.50	-25.00	-22.81	-12.50	-35.31	-56.25
LSD (p=0.05)	A=0.0898; B=0.0898; C=0.0898; AB=0.180; AC=0.180; BC=0.180; ABC=0.359										
TSS*	-16.49	-23.09	-14.05	-3.86	-5.36	-13.98	-23.39	-14.76	-21.73	-14.58	-21.18
LSD (p=0.05)	A=0.0878; B=0.0878; C=0.0878; AB=0.176; AC=0.176; BC=0.176; ABC=0.351										
Overall acceptability*[a] (%)	68.20	58.41	65.06	63.36	60.81	63.13	64.98	66.12	82.08	50.35	22.59
LSD (p=0.05)	A=0.552; B=0.552; C=0.552; AB=1.104; AC=1.104; BC=1.104; ABC=2.208										

Note: data with negative sign shows decrease and positive sign shows increase, except for parameters with superscript a; Factor means values; LDPE= low density polyethylene; PP= polypropylene; UT= untreated; MHPT= mild heat pretreatment; PLW= physiological loss in weight; LSD= least significant difference; AB, AC, BC, ABC represents the interaction of different treatments.

3.2 Texture (firmness)

The texture (firmness) of fresh cut papaya was 3.543 kgf. From Table 1, it is clear that there is a significant % decrease in the texture of minimally processed papya samples with the increase in storage period irrespective of MHPT holding time and packaging material whereas, the storage period has significantly higher effect on firmness (p=0.05). Similar trend of decrease in firmness of oranges with storage period was reported by Tabatabaekoloor (2012). Gonzalez-Aguilar et al. (2004a)

reported that the decrease in firmness during storage could be related with the development of fungal growth and the increases in the metabolism, which increased the enzymatic activity. The minimum change in firmness was observed for 30 min MHPT pretreated papaya packed in LDPE and cling film where as the maximum was observed for untreated with open tray sample. O'Connor-Shaw et al. (1994) reported that fresh-cut papaya texture declined significantly after 2 d of storage at 13°C.

3.3 Color change

The initial color values of fruit were L = 35.54 ±1.0; a = 33.73±0.5, b = 18.45±0.5 and changes in color of fresh-cut papaya were studied throughout storage period at regular period. The significant change in color was observed with storage period irrespective of packaging material (p = 0.05). Among the selected packaging material, the LDPE packed samples witnessed minimum change in colour throughout storage period (Figure 1). It is clear from Table 1 that with the increase in MHPT exposure time there is a decrease in colour change and the minimum color change is observed for 45 minutes MHPT sample which may be due to inactivation of peroxidase enzyme. Similar results were observed for fresh-cut 'Smooth Cayenne' pineapple when stored at 10°C, reporting small changes in L* and b* values due to the browning reactions caused by polyphenol oxidase (PPO) activity (González-Aguilar et al., 2004b).

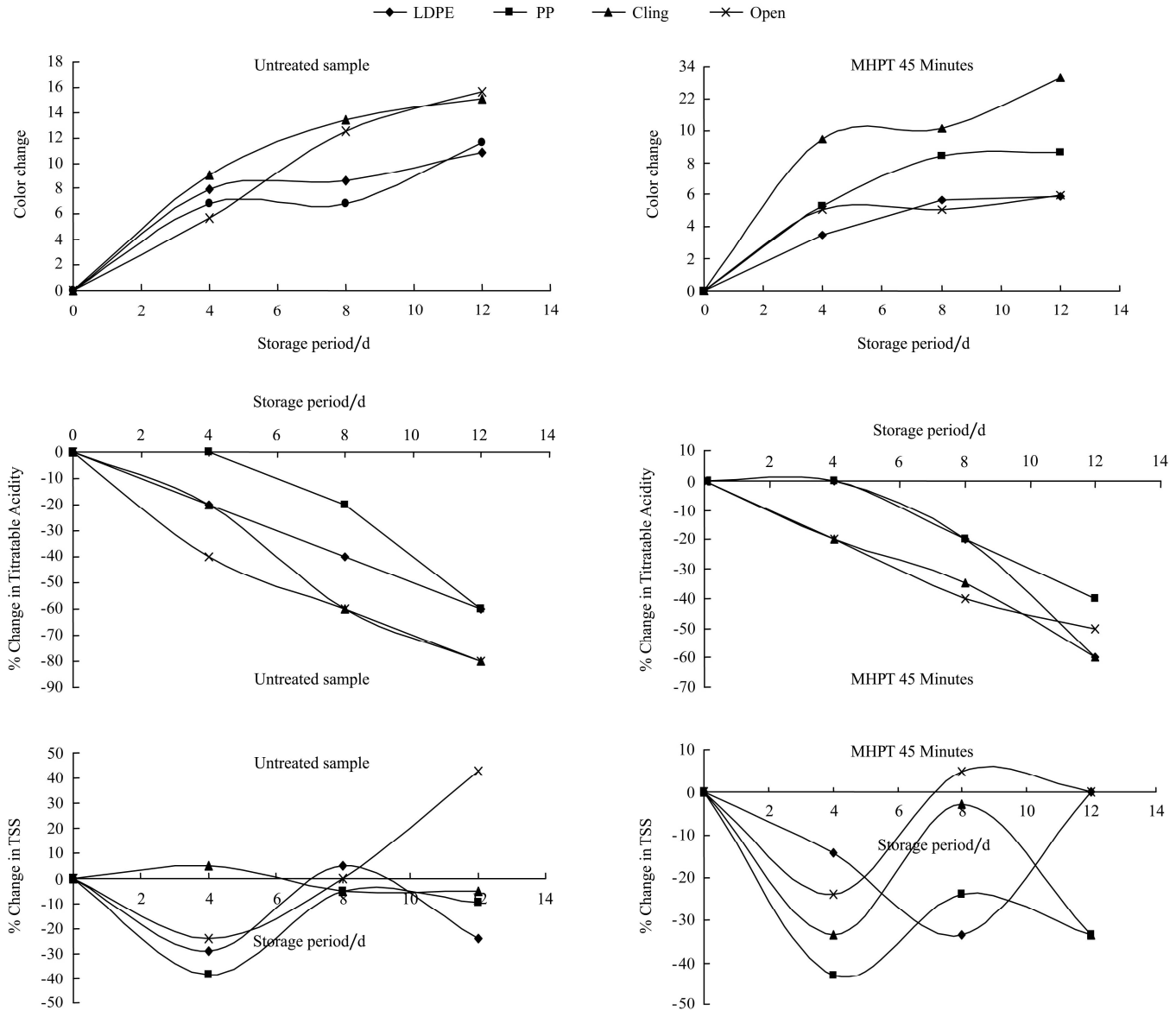

Figure 1 Effect of packaging material, MHPT and storage period on color change, changes in titratable acidity and TSS of minimally processed papaya stored under refrigerated condition

3.4 Titratable acidity

The titratable acidity of fresh cut papaya was 0.33%. The titratable acidity of the minimally processed papaya packed under polythene films showed a linear declining trend with the advancement of storage period (Figure 1). In comparison to individual term, the interactive terms of packaging material, MHPT holding time and storage period witnessed higher affect on titratable acidity (p=0.05). The MHPT samples had better retention of acidity as compared to untreated sample and the MHPT holding time had similar effect on titratable acidity. The packaging films also helped in better retention of acidity. The maintenance of higher acidity in the treated samples packed in films may be due to the decreased hydrolysis of organic acids and subsequent accumulation of organic acids which were oxidized at slow rate because of decreased respiration. Film wrapping is also known to maintain cellular integrity by controlling membrane permeability as a result of which free H^+ ions are unable to break away from the cytosol, thus maintaining higher levels of acidity. The 15 min MHPT samples packed in LDPE packages witnessed maximum decrease in titratable acidity (Table 1).

3.5 Total soluble solids (TSS)

The fresh cut papaya has TSS of 10.5^{o}Brix. Packaging material, pretreatment, storage period and their interactions significantly (p=0.05) affected the TSS (Table 1). It was observed that the % change in the TSS content of the stored samples showed an initial decrease followed by an increase with storage period (Figure 1). The delayed increase in TSS in the film wrapped samples might be attributed to the sole reason that the films retarded ripening and senescence processes and simultaneously reduced the conversion of starch into sugars. The reason for the increase in TSS could be attributed to the water loss and hydrolysis of starch and other polysaccharides to soluble form of sugar. The highest % change in TSS content was observed for 30 min MHPT samples packed in PP film whereas, the minimum change was observed for untreated sample kept in open tray (Table 1).

3.6 Overall acceptability

Overall acceptability of minimally processed papaya decreased continuously with the increase of storage period irrespective of packaging material and pretreatments. The microbial population or colonies were clearly visible after nine days of the storage. Gil et al. (2002) reported that quality of tomato slices was not directly affected by temperature (7-10 d at 0^o-5^{o}C) but depended on the film used. The packaging material, pretreatment, storage period and their interactions significantly (p=0.05) affected the overall acceptability of the stored samples, however the interaction term showed comparatively higher affect on overall acceptability (Table 1). Among packaging material, the maximum overall acceptability was observed for LDPE packed samples (Table 1). The pretreatment, MHPT holding time also showed significant effect on overall acceptability of minimally processed papaya as the microbial proliferation was retarded and the keeping quality was prolonged for 8 days (Table 1).

4 Conclusions

Shelf-life of minimally processed papaya could be prolonged for 8 d when stored at 5^{o}C temperature. The mild heat pretreatment (MHPT) prolonged the keeping quality of minimally processed papaya. LDPE packed papaya had a better shelf-life in terms of quality attributes when compared to open samples as well as PP, cling film packed samples. Among the mild heat pretreatment, the 30 min and 45 min exposed samples were at par. Overall, the MHPT 45 min exposed samples when packed in LDPE witnessed better retention of quality in terms of overall acceptability.

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