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SHELF LIFE EXTENSION OF PAPAYA (*CARICA PAPAYA* L.) PACKAGED IN CUSTOMIZED CORRUGATED FIBRE BOARD (CFB) BOX AFTER SUBJECTING TO VIBRATION AND DROP TESTS

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Abstract

Papaya cv: Red lady harvested at two streak stage, packaged in customized Corrugated Fibre Board box of size 450×300×300mm, 5ply rate, 20 kg/cm² bursting strength with inbuilt cushioning papaya withstood vibration and drop test as compared to those packaged in CFB boxes of 18 kg/cm² bursting strength. The fruits packaged in these boxes and stored at 18°C had less weight loss (3.75%), more firmness (2.38kg/cm²) less spoilage (14.27%), TSS (12°Brix), Acidity (0.16%) and carotenoids content (1.13mg/100g) in subsequent storage compared to those other packages. The papaya fruits had a shelf life and marketability of 12 days at low temperature storage (18°C, 80% RH) and 6 days at ambient storage condition (28-30°C, 55% RH).

Key words : Papaya, Customised CFB box, inbuilt cushioning, drop and vibration test, shelf life, firmness.

Introduction

Papaya (*Carica papaya* L) is a tropical fruit. It is highly perishable and reduce the marketability which include bruising damage and mechanical damage such as abrasion and puncture injuries, which are more during handling and transportation of papaya. By simple technological interventions losses could be reduced and storage life could be extended. At present there is no proper package for transporting of papaya for domestic market. Mostly papaya fruits are being transported by individually wrapping in newsprint paper and directly loading into the trucks, which leads to more loss due to damage during transportation (Bhuvaneswari and Narayana, 2013). Farmers often select the cheapest and the most readily available packages. Other packaging materials like mesh bags, sacks or baskets are unacceptable for papaya transport due to high susceptibility to bruising. In bulk transport, fruits are piled one on top of another without any padding materials. It has been seen that use of suitable containers alone would reduce the losses and maintain the quality of fruits and vegetables during transportation.

The impact and vibration during transportation are the main reasons to cause packages to be damaged. The fruits and vegetables packages come under impact, vibration, dropping, swinging, static pressure and many other factors in storage and transportation with the result of damaged fruits and vegetables. In order to prevent the papaya from bruising damage in the transportation and storage process, packaging with proper cushioning is needed.

Corrugated fibre boxes as packaging material have many advantages such as light weight, low cost, are easy to design, process and print and reduces mechanical damage. The empty box can be folded up, compact and is easy to be transported and stored and also they are easy to recycle, non-polluting and reusable.

Cushioning plays a very important role in any packaging. The cushioning material should be energy absorbing. For loose filled fibre board cartons, bruising injury is caused by flexing of carton base during shock and vibration loading. Individual wrapping of fruit serves to minimise the bruising injury, but if the wrapping material is of low friction type then the injury is unavoidable. Cushioning material is a must to reduce fruit bruising damage by careful handling and proper packaging with top cushioning material. Package and packing

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configuration affected the bruising of mangoes and other sensitive fruits during shipping and handling (Chonhenchob and Singh, 2003). Lining the carton with polyethylene as cushioning has been found to beneficial (Ayman *et al*., 2013).

A transportation packaging test is important to determine the highest normal strains that will occur during a transport. The test conducted the structure and quality of a corrugated board are essential to ensure the protection of the product during dropping. During storage and transportation, products can fall onto the floor resulting in damage, and a drop test is used to determine the box's ability to retain and protect its contents under a shock due to a free fall (Djilali Hammou *et al*., 2012).

During transportation, fruit and vegetables move randomly in the boxes. Deterioration of fruits and vegetables was determined by the duration and intensity of vibration related to the extent of the repeated force and displacement (Çakmak *et al*., 2010).

The present study was undertaken with an objective to evaluate the suitability of Corrugated Fibre Board (CFB) boxes provided with inbuilt cushioning and its ability to withstand vibration and drop test, in retaining the fruit quality after vibration and drop test and subsequent storage.

Materials and Methods

Papaya : cv. Red lady was harvested at two streak stage from the farmers field, cleaned and taken for packaging and storage studies.

Box characteristics	:	Corrugated fibre board box
Size	:	450×300×300mm,
Capacity	:	11 kg
Thickness	:	5 ply rate
Kraft paper thickness	:	200Gsm
Flute	:	B flute

CFB boxes with bursting strength 18kg/cm^2, 20 kg/cm^2 and 22 kg/cm^2 were tested for its suitability. Bursting strength is the most widely used strength parameter for kraft paper. It indicates the resistance of paper to bursting forces encountered in transit or in storage. B flute is the most popular profile. It is used in three ply as well as five ply construction. The flute can effectively withstand the pressure of plate during printing operation. The B flute has spacing sufficient enough to provide reasonable flat surface of top liner. It can also effectively withstand beating during transportation. Better printability coupled with reasonable flat crush strength makes it extremely suitable for small sized three ply boxes. It is also put on outside of the five ply box.

Cushioning

Cushioning plays an important role in reducing fruit bruising damage. Corrugated fibre board boxes were provided with in-built cushioning using polystyrene foam (2 mm) thick pasted to the inner wall layer of all the four sides (fig. 1).

Fig. 1 : Papaya in customised corrugated fibreboard box in low temperature storage (18°C, 80% RH).

Drop test : The test simulates actual shocks by dropping the package and its content freely against a rigid plane surface from a predetermined height. For example, a drop test can be conducted so that the package hits the surface diagonally against one corner (ISO 2248).

Vibration test : Various forms of transportation vibrations can be simulated in a laboratory through a vibration test. The test-bench was made to swing and vibrate in upwards and downwards for 30min to simulate the transportation of 200-500km (ISO 2247 and 8318).

Puncture resistance : Reflects the strength of paper. It is more relevant in case of 5-ply and 7-ply. It determines the resistance of corrugated boards to external forces (IS 13228:2006).

Cobb value : A measure of how much water the paper will absorb in given time, say, one minute. This property gives the extent of loss of strength of corrugated fibre board box due to high humidity especially in low temperature storage (IS 13228:2006).

$$Weight\ of\ water = \frac{g}{m^2} = final\ weight(g) - conditioned\ weight\ (g)$$

Storage studies

The papaya fruits packaged in CFB boxes after subjecting to transport simulation studies were stored in ambient condition (28-30°C, 55% RH) and low temperature storage (18°C, 80% RH). The papaya samples in storage (both ambient and low temperature) were subjected to the quality analysis as follows.

Weight loss

Weight loss of fruits was calculated from the initial weight papaya fruit per treatment and at each storage interval of 2 days during the 12 days storage period.

Firmness

The firmness index, which is force per unit deformation of papaya was measured by using Instron (model FT 011; 0–11 lbs). Each fruit was placed on the table, and the plunger vertically moved down at a speed of 100m/min pressed in to the flesh. The average readings (kg cm^{-2}) were recorded for firmness determination.

Total soluble solids

The total soluble solids (TSS) were determined by placing an aliquot of the juice, which was obtained from the the flesh of papaya and was homogenized in a laboratory blender. Two drops of clear juice was placed on the prism of digital hand held refractrometer (ERMA™) with a range of 0 to 32°Brix.

Titrable acidity

For titratable acidity (TA) determination, papaya juice was extracted from the sample with a juice extractor and filtered with filter paper. Clear juice was used for the analysis of TA as the methods described by Ranganna (2000). The TA expressed as percent citric acid, was obtained by titrating 10 ml of papaya juice to pH 8.2 with 0.1 N NaOH.

Ascorbic acid

The ascorbic acid (AA) content of papaya was determined by the 2, 6-dichlorophenol indophenol method (AOAC, 2010). An aliquot of 10 g papaya puree was diluted to 50 ml with 3% metaphosphoric acid in a 50 ml volumetric flask. The aliquot was then centrifuged for 15 min and titrated with 2, 6-dichlorophenol indo-phenol dye to a pink endpoint (persisting for 15s).

Reducing and total sugars

Reducing and total sugars were estimated by Lane and Eynon method. The sugar content in the fruit sample is estimated by determining the volume of the sugar solution (unknown) required to completely reduce a measured volume of Fehlings solution (Ranganna, 2000).

Carotenoids

The carotenoids content in papaya were estimated by the procedure described by Sadhasivam and Manickam (1996). The carotenoids in the sample are extracted in acetone and then taken up in petroleum ether. The absorbance of the solution is determined with a spectrophotometer at 436nm.

Statistical analysis

Difference between the treatments was determined by analysis of variance (ANOVA) in completely randomized design with three replications using WASP 2.0 statistical software. (Bhuvaneswari and Narayana, 2013).

Results and Discussion

CFB box characteristics

Physical properties of Corrugated Fibre board boxes for papaya packaging

From the table 1, the cobb value is higher for the CFB box with 18BF strength compared to 20 and 22 BF strength. This shows that the CFB box of 18BF strength has more water absorption capacity than with 20 and 22BF strength.

Weight loss of papaya during storage

From the tables 2 and 3, it was found that weight loss values varied between 1.33 and 4.07% in the low temperature storage (18ºC, RH 80%) and from 1.58 and 5.14% under ambient condition (28-30°C, RH 55%). The highest weight loss (PLW(%)) was recorded for the papaya fruits packaged in CFB box of 18BF strength stored under ambient conditions, whereas the lowest was for fruits packaged in CFB boxes of 22BF bursting strength.

In general, weight loss of papaya fruits progressively increased during the storage period both under the low temperature storage and ambient storage conditions. The papaya fruits packaged in CFB box of 22BF strength had about 33% lower weight loss at low temperature storage and 30% lower in ambient storage compared to the weight loss in CFB box of 18BF strength (tables 2 & 3). Fruits packaged in CFB box of 20BF strength and stored had a relatively higher weight loss 44% at ambient conditions and 36% at low temperature storage as compared to those packaged in 18BF strength.

After day 7, nearly all papaya fruits stored at ambient conditions were unmarketable while those fruits in low temperature storage was marketable upto 12 days. Generally, the weight loss of papaya fruits was higher under ambient storage condition than in the low temperature storage. The weight loss differences may be due to differences in temperature and relative humidity among the storage environments. About 10.0% physiological loss in weight is considered as an index of termination of shelf life (threshold level) of commodities (Paull *et al*., 1997). According to Proulx *et al*. (2005), loss of about 8.0% of weight from papaya results in unmarketable fruit as a result of rubbery and low-gloss appearance.

The loss of weight, loss of glossy appearance, shrivelling, softness and dryness of the peel, in papaya fruits are greatly influenced by the relative humidity and temperature of the storage. High storage temperature leads to accelerated water loss and subsequently to shrivelling and softening of the fruit (Proulx *et al*., 2005). In the present study, the average temperature and RH of the low temperature storage were 18°C and 80%, respectively, compared to 28°C and 55% at the ambient condition. This might have contributed to the high weight loss of papayas in the later storage condition, which is associated with faster ripening and metabolism at higher temperature. Furthermore, lower weight loss of fruits in the package could be due to slow rate of ripening and prevention of excessive moisture loss.

Spoilage

Spoilage percentage was less (14.40-21.43%) in papaya stored in low temperature storage than at ambient condition (20.00-21.42%) (tables 2 and 3). The percentage marketability of papaya stored in low temperature storage was higher than those stored under ambient condition.

Firmness

Firmness of papaya fruits during the storage period varied between 1.85 and 2.76 kg cm^{+2} (tables 2 and 3). The storage environment affected firmness of papaya fruits. The fruits stored in low temperature storage were firmer (2.05-2.76%) compared to those stored at ambient conditions (1.85-2.30%).

The relatively higher firmness of fruits in low temperature storage might be due to the presence of higher relative humidity and lower temperature which will retard the respiration and transpiration rate of the fruits. The rapid loss in firmness of papaya during ripening at ambient (25°C) temperature is associated closely with increase in activity of polygalacturonase, pectin methyl esterase and β-galactosidase as well as with depolymerisation of cell wall pectin (Lazan *et al*., 1993).

The fruits packed in 18 BF strength had less firmness compared to those packaged in 20 and 22BF strength both in low temperature storage and ambient storage conditions. This may be due to the reason that fruits packaged in CFB boxes of higher bursting strength withstood the vibration and drop test and the fruits kept inside were not subjected to any bruising damage, hence fruits were firmer compared to those kept in 18 BF strength box. These effects of packaging materials may be attributed to their retardation effects of ripening and reduction of water loss (Yamashital *et al*., 2002)

Table 1 : Physical properties of Corrugated Fibre board boxes used for papaya packaging.

Box dimension (mm)	Box strength (BF)	Thickness (ply rate)	Cobb value (g/m²)	Puncture Resistance (J)
450×300×300	18	5	15.52	3.61
450×300×300	20	5	14.24	3.55
450×300×300	22	5	12.42	3.50

Table 2 : Physiological changes of papaya in CFB boxes of different bursting strength during ambient condition (28-30°C, RH 55±2%) storage.

Treatments	PLW (%)	Firmness Kg/cm²	Spoilage (%)
CFB box (18BF strength)	5.14	2.30	21.42
CFB box (20BF strength)	3.59	2.31	20.00
CFB box (22BF strength)	1.58	1.85	20.00
CD(1%)	0.77	NS	NS

BF-Bursting strength of CFB Box.

Table 3 : Physiological changes of papaya in CFB boxes of different bursting strength during low temperature (18°C, RH 80%) storage.

Treatments	PLW (%)	Firmness Kg/cm²	Spoilage (%)
CFB box (18BF strength)	4.07	2.05	21.43
CFB box (20BF strength)	3.75	2.38	14.27
CFB box (22BF strength)	1.33	2.76	14.40
CD (1%)	0.34	NS	0.153

Generally, there was softening of fruits as the storage time progressed which could be due to texture modification through degradation of polysaccharides such as pectin, cellulose and hemicelluloses that take place during ripening (Irtwange, 2006). According to Manrique and Lajolo(2004) texture changes in fruits are consequences of modifications by component polysaccharides that, in turn, give rise to disassembly of primary cell wall and middle lamella structures due to enzyme activity on carbohydrate polymers

Shelf life

The shelf life of papaya in ambient storage condition was 6 days. The termination of shelf life of papayas stored at ambient environment was determined by shrivelling,

Table 4 : Nutritional quality of papaya packaged in telescopic customized CFB box with inbuilt cushioning at ambient condition (28-30°C, RH 55±2%) at the end of the storage period.

Treatment	TSS(°Brix)	Acidity(%)	Reducing sugar (%)	Total sugar (%)	Carotenoids (mg/100g)	Moisture content (%)
T_1 (18BF)	11.9	0.24	5.59	7.20	0.88	88.28
T_2 (20BF)	12.0	0.16	6.16	7.58	1.13	89.08
T_3 (22BF)	12.3	0.18	6.82	7.40	1.31	85.06
Control	12.9	0.22	6.51	8.12	1.29	89.02
CD (1%)	0.21	0.10	0.51	0.75	0.06	NS

BF-Bursting strength of CFB Box.

Table 5 : Nutritional quality of papaya packaged in telescopic customized CFB box with inbuilt cushioning at low temperature storage (18°C, 80% RH) at the end of the storage period.

Treatment	TSS(°Brix)	Acidity(%)	Reducing sugar (%)	Total sugar (%)	Carotenoids (mg/100g)	Moisture content (%)
T_1 (18BF)	11	0.31	6.27	7.11	1.09	82.84
T_2 (20BF)	12.8	0.19	6.11	8.49	1.67	83.41
T_3 (22BF)	11.9	0.23	6.59	8.92	1.36	81.41
Control	12.7	0.24	6.90	8.31	1.44	78.07
CD(1%)	0.22	0.09	0.14	0.65	0.43	0.58

BF-Bursting strength of CFB Box.

over ripening, discoloration and mould growth. Faster transpiration rate at relatively higher temperature may result in shrivelling of papaya fruits in ambient storage condition. Furthermore, higher respiration rate at higher temperature may lead to senescence because the stored food reserve which provides energy could be exhausted (Paull, 1993).

Papayas stored in the low temperature storage remained fresh and firm upto 12 days of storage. The ripening rate was also delayed in low temperature storage. They looked shiny and had attractive color compared to those stored at ambient conditions. This might be attributed to reduced rate of respiration and transpiration of fruits due to relatively lower temperature and higher RH inside the low temperature storage. Since a higher rate of respiration decreases shelf life (Lee *et al*., 1995), the use of low temperature is indicated to be the most important means of extending the storage life of postharvest produce (Exama *et al*.,1993).

Total soluble solids

The changes in total soluble solids (TSS) content of papaya fruits during the storage both in low temperature storage and ambient condition is given in tables 4 and 5. The TSS values of fruits varied between 11 and 12.8° Brix in the low temperature storage and from 11.9–12.3°Brix under ambient conditions. Wills and Widjanarko (1995) reported a range of 8–12°Brix for papayas, which is in agreement with the present result.

The fruits stored in CFB box of 18BF strength had lower TSS content compared to those in 20BF and 22BF strength in both storage conditions. However, the TSS of papaya fruits was maintained at lower level in the low temperature storage than under ambient storage. According to Irtwange (2006), this may be partly attributed to lower temperature and higher relative humidity maintained in the low temperature storage that could have resulted in slow conversion of starch in to water soluble sugars.

Titratable acidity

The effect of CFB box packaging and storage environment had significant effect on the titrable acidity of papaya fruits. In this study, the titrable acidity value varied from 0.19-0.31 in the low temperature storage and 0.16-0.24% under ambient storage conditions, respectively (tables 4 and 5). These results are similar to titrable acidity values of papaya fruits with a range varying from 0.20% to 1.0% those reported by Azene *et al.* (2011).

Reducing sugars

The effect of storage condition and CFB box packaging material on reducing sugar content of papaya fruit at the end of the storage period is given in tables 4 and 5. The reducing sugar concentration varied from 5.59-6.82 (%) of fresh weight for papaya stored in ambient condition whereas the concentration varied from 6.11-6.90 (%) for those stored in low temperature storage.

Fruits stored in the low temperature storage had significantly higher reducing sugar content than those stored under ambient conditions. Similar results were presented by Azene *et al.* (2011). This could be as a result of reduced temperature in the low temperature storage that reduces fruit metabolism, particularly respiratory activity which delays the ripening process and increasing fruit shelf life.

Total sugars

The effect of storage condition and CFB box packaging material on total sugar content of papaya fruit at the end of the storage period is given in tables 4 and 5. The total sugar content varied from 5.40-6.20(%) of fresh weight for papaya stored in ambient condition whereas the total sugar content varied from 6.31-7.11(%) for those stored in low temperature storage.

Packaging had significant effect on total sugars concentration of papaya fruits. The total sugar content of the fruits packaged in 18BF strength had higher sugar content both reducing and total sugars when compared to those packaged in 20 and 22BF strength. Storage conditions significantly affected the total sugar content of papaya fruits during the storage period. The total sugar content of the fruits at low temperature storage was higher than the total sugar content of papayas stored in ambient condition. This could be associated with the higher rates of respiration and metabolic activity resulting in rapid hydrolysis of sugar under ambient temperature (Ramakrishnan *et al*.,2010).

Carotenoids

The effect of storage condition and CFB box packaging material on carotenoids content of papaya fruit at the end of the storage period is given in tables 4 and 5. The carotenoid content varied from 0.88-1.31 mg/100g of fresh weight for papaya stored in ambient condition whereas the carotenoid content varied from 1.09-1.67 mg/100g for those stored in low temperature storage. Fruits stored in the low temperature storage had significantly higher carotenoids content than those stored under ambient conditions.

Conclusion

Packaging and storage environments had significant effects on the shelf life and physiological and chemical qualities of papaya fruits. In this experiment, papaya packaged in CFB boxes of size 450×300×300mm, 5ply rate with 20BF bursting strength and maintained at temperature 18°C and relative humidity 80% RH is found to be suitable for storage of papaya. The fruits packaged in these boxes withstood vibration and drop test, had less weight loss, less spoilage and had a shelf life and marketability of 12 days.

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