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INFLUENCE OF VACUUM PACKAGING AND STORAGE TEMPERATURE ON POSTHARVEST SHELF-LIFE AND QUALITY OF MINIMALLY PROCESSED JACKFRUIT BULBS

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ABSTRACT
The study on influence of vacuum packaging in minimally processed jackfruit bulbs of five different clones were carried out with and without vacuum packaging in polypropylene (300 gauge) and stored in refrigeration (3-5^{0}C) and deep freeze (-12^{0}C). There was no detectable total loss in weight (0.18% to 0.45%) in samples under two storage conditions. Vacuum packed samples under deep freeze condition had higher retention of ascorbic acid content of 7.82, 8.37, 8.64, 8.16 and 8.40 mg/100 g for clone1, clone 2, clone 3, clone 4 and clone 5, respectively (ranged from 7.90 to 8.70 mg/100g before packaging) over conventional storage (3-5^{0}C).TSS was found at acceptable levels (ranging from 24.2^{0}B to 27^{0}B)in samples under deep freeze conditions with vacuum packaging after four weeks of storage over samples under refrigerated conventional packaging (TSS of 26.01 ^{0}B to 28^{0}B) atsecond week of storage itself. The rate of decrease in titrable acidity was slower under deep freeze conditionwith vacuum packaging (0.35% to 0.44%). Higher sensory scores were recorded in vacuum packaged samples under deep freeze as they sustained the quality and fresh-like parameters of jackfruit bulbs. Thus deep freeze storage retarded deteriorative changes and enhanced the shelf-life of jackfruit bulbs.

INTRODUCTION

Jackfruit is a nutritious fruit, rich in vitamins A, B and C, potassium, calcium, iron, proteins and carbohydrates. The value of its versatility is enhanced by its availability during the monsoon period, when the supply of other fruits and vegetables is small (Singh, 1986). It is therefore commonly referred to as the poor man's fruit (Samaddar, 1985; Jagtap *et al*., 2010). There are peak seasons during which the fruit mainly rots away in the gardens or in the markets due to its perishable nature. Post-harvest losses of fruits in Indiais reported to be as high as 30% (Verma and Joshi, 2001) with loss of potential income and nourishment. Since the edible fleshy pericarp amounts to only 35% of the whole fruit, which is often prone to flavor loss, tissue softening, cut-surface browning and post-harvest decay (Narasimham, 1990), it is desirable to develop suitable processing and storage protocols for the pitted and pre-cut bulbs. Jackfruit bulbs in pre-cut form can provide convenience for consumers and an appropriatepost-harvest technology for shelf-life extension may facilitate its transportation from production site to remote location.Storage of fresh-cut or minimally processed fruits and vegetables along with low temperature storage conditions have gained rapid popularity due to growing consumer preference towards ready-to eat and quality produce for convenience (Shah and Nath, 2006).

The safety and effectiveness of minimal processing depends on the use of novel preservation technologies (Ohlsson and Bengtsson, 2002).There is need to diversify utilization and reduce losses through appropriate processing into a variety of convenient and relatively shelf-stable and acceptable products like minimally processed jackfruit bulbs.Changing lifestyles dictate the need for food that offers convenience to the consumer in a myriad of ways such as minimizing preparation time while also offering high quality through an extended shelf-life (Blakistone, 1999). As a result, consumers are increasingly demanding convenient, ready-to-use and ready-to-eat fruits with a fresh-like quality, containing only natural ingredients (Lund, 1989; Rocha and Morais, 2007). In response to these needs, one of the most important recent developments in the food industry has been the development of minimal processing technologies designed to limit the impact of processing on the nutritional and sensory quality and to preserve food without the use of synthetic additives. The increasing demand for these minimally processed products represents a challenge for researchers and processers to make them shelf-stable and safe. All food producers and processors have an obligation to produce food that is both safe and of high quality.There is need to reduce losses through appropriate processing into a variety of convenient and relatively shelf-stable and acceptable products like minimally processed jackfruit bulbs. The safety and effectiveness of minimal processing depends on the use of novel preservation technologies (Ohlsson and Bengtsson, 2002).

In view of the above factors, an investigation was undertaken to study the influence of vacuum packaging in enhancing the post harvest shelf-life and quality of minimally processed jackfruit bulbs of five different clones.

MATERIALS AND METHODS

To study the influence of vacuum packaging on shelf-life and quality of minimally processed jackfruit bulbs, fresh, well matured, uniformly sized and good quality ripened jackfruits from five different elite clones were procured from in and around Doddaballapur taluk, Bangalore Rural District, Karnataka State and used for the study. Bulbs (deseeded) were packed in polypropylene (PP) packages of 300 gauge with and without vacuum packaged with 70% vacuum and stored in refrigeration (3-5ºC) and deep freeze (-12ºC) temperatures for a period of 2 weeks and 4 weeks, respectively. The details of the experimental treatments are as shown below.

Vacuum packaging was done in polypropylene bags of 300 gauge using a laboratory model vacuum packaging machine (Reepack- RV 50, Italy). The bulbs were packed at 70% vacuum and thermally sealed. Observations pertaining to pH, titrable acidity, total soluble solids (TSS), ascorbic acid and sensory evaluation scores were taken at weekly intervals during the course of the storage of the minimally processed and packaged jackfruit bulbs. The procedures followed in taking these observations are detailed below.

Total loss in weight

The total loss in weight of the minimally processed jackfruit bulbs inside the package was determined by weighing on a digital electronic balance DS-450 (Essae-Teraoka Ltd., India) at periodic intervals during the storage period (Mandhare, 2008). The difference in sample weight expressed as percentage, was computed from the first day of storage to the subsequent week.

Ascorbic acid content

The ascorbic acid content of jackfruit bulbs was determined by 2, 6-dichlorophenol indophenol visual titration method.A 2 to 5 g of pulp of minimally processed jackfruit bulbs was taken in a 100 ml volumetric flask and thoroughly mixed with 50 ml of 4 percent oxalic acid. The mixture was filtered through a thin cloth and the filtrate volume made up to 100 ml using 4 percent oxalic acid. A 10 ml of filtered sample and 5 ml of 4% oxalic acid were taken in a conical flask and titrated against the 2, 6 dichlorophenol indophenol dye solution in a burette. The end point was light pink colour that persisted for 5-10 seconds.

$$\text{Ascorbic acid, mg/100g} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Volume taken for titration} \times \text{Weight of pulp sample}} \times 100$$

pH and TSS

Juice extracted from 100 g of sample of minimally processed jackfruit bulbs of each treatment was used to determine the pH and TSS. The pH was estimated using a litmus paper. TSS was assessed with a hand refractometer (Erma Optical Works Ltd., Tokyo, Japan).

Titratable acidity

The titratable acidity of jackfruit bulb samples was determined by the visual titration method. A 10 g sample of pulp was taken in a 100 ml beaker and a little quantity of distilled water was added to it. The mixture was then gently boiled in a water bath for 1 hour with occasional stirring and frequently replacing water which was lost due to evaporation. After cooling, the mixture was transferred to 100 ml volumetric flask and the volume made up with distilled water. This was then filtered through Whatman No. 4 filter paper and the filtrate was used for analysis.A 10 ml of filtrate was taken in a conical flask and titrated against 0.1N NaOH solution in a burette using 1 or 2 drops of phenolphthalein indicator. Formation of pink colour was reckoned at the end point of titration. The titration was repeated till consistent titre values were obtained.

$$\text{Titratable acidity (\%)} = \frac{\text{Titre value} \times \text{N of NaOH} \times \text{Volume made up} \times \text{Equivalent weight of citric acid}}{\text{Aliquot taken for titration} \times \text{weight of sample} \times 1000} \text{X } 100$$

Sensory Evaluation

The criteria used to judge the appearance were freshness, aroma, flavour, sweetness, bitterness, cut surface browning, discoloration and marketability, etc. The products were scored for appearance, texture and shelf life on a numerical scoring method. The nine point "Hedonic scale" was employed.

Statistical analysis

The experimental data was subjected to analysis of variance (ANOVA) using the SAS system at 5% level of significance.

RESULTS AND DISCUSSION

The results on influence of vacuum packaging in enhancing the post harvest shelf-life and quality of minimally processed jackfruit bulbs of five different clones are presented below.

Total loss in weight

There was no detectable total loss in weight in the samples of all five clones under deep freeze storage and refrigeration storage (Under refrigeration storage temperature, the control samples recorded total loss in weight of 0.37%, 0.30%, 0.18%, 0.45% and 0.20% in PP bags of clone 1, clone 2, clone 3, clone 4 and clone 5, respectively during second week) (Table 1). In contrast to present result, study on litchi storage showed that PLW (Physiological Loss in Weight) of fruits increased with the increase in duration of storage irrespective of treatments (Monica *et al.*, 2013). Packaging of products modifies the atmosphere (O_2 and CO_2 levels) inside the package to levels required to alleviate respiratory activity and also maintains a high humidity environment inside the package. As the product tissues are still alive, moisture is lost due to respiration resulting in total loss in weight (Naglaa, 2010).

Ascorbic acid

The rate of decline in ascorbic acid content was slower (non significant difference) under deep freeze storage than under refrigeration storage. The ascorbic acid content of five different clones varied from 7.90 mg/100g (clone 1) to 8.70 mg/100g (clone 3) before packaging. The ascorbic acid content retention under refrigeration storage was 7.75 (clone 1), 8.36 (clone 2), 8.56 (clone 3), 8.05 (clone 4) and 8.25 mg/100 g

Table 1: Influence of vacuum packaging on total loss in weight of minimally processed jackfruit bulbs of five different clones under different storage conditions

Clone	Vacuum %	Total loss in weight (%) Storage period (weeks) Refrigeration storage(3-5°C)			Deep freeze storage(-12°C)				
		0	1	2	0	1	2	3	4
Clone 1	control	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00
	70%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clone 2	control	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
	70%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clone 3	control	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00
	70%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clone 4	control	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00
	70%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clone 5	control	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
	70%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S.Em±	-	-	-	-	-	-	-	-	
CD @ 5%		NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Influence of vacuum packaging on the ascorbic acid content (mg/100g) of minimally processed jackfruit bulbs of different clones under different storage conditions

Clone	Vacuum %	Ascorbic acid content (mg/100g) Storage period (weeks) Refrigeration storage (3-5°C)			Deep freeze storage (-12°C)				
		0	1	2	0	1	2	3	4
Clone 1	Control	7.90	7.85	7.75	7.90	7.86	7.78	7.60	7.58
	70%	7.90	7.88	7.80	7.90	7.88	7.86	7.86	7.82
Clone 2	Control	8.50	8.40	8.36	8.50	8.42	8.35	8.30	8.28
	70%	8.50	8.48	8.44	8.50	8.50	8.41	8.38	8.37
Clone 3	Control	8.70	8.61	8.56	8.70	8.63	8.58	8.54	8.50
	70%	8.70	8.68	8.60	8.70	8.69	8.66	8.64	8.64
Clone 4	Control	8.20	8.14	8.05	8.20	8.15	7.92	7.88	7.87
	70%	8.20	8.18	8.14	8.20	8.20	8.18	8.16	8.16
Clone 5	Control	8.50	8.38	8.25	8.50	8.40	8.32	8.28	8.26
	70%	8.50	8.45	8.44	8.50	8.47	8.46	8.42	8.40
S.Em±		-	-	-	-	-	-	-	-
CD @ 5%		NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Influence of vacuum packaging on TSS (°B) of minimally processed jackfruit bulbs of five different clones under different storage conditions

Clone	Vacuum %	TSS (°B) Storage period (weeks) Refrigeration storage (3-5°C)			Deep freeze storage (-12°C)				
		0	1	2	0	1	2	3	4
Clone 1	control	26.20	27.30	28.00	26.20	27.40	28.20	28.36	28.40
	70%	26.20	26.80	27.00	26.20	26.40	26.60	26.70	27.00
Clone 2	control	25.50	26.90	27.20	25.50	26.40	26.50	26.80	26.80
	70%	25.50	25.70	26.10	25.50	25.60	25.80	26.00	26.20
Clone 3	control	25.00	26.60	26.80	25.00	26.70	26.90	27.00	27.20
	70%	25.00	26.10	26.80	25.00	26.30	26.50	26.80	26.80
Clone 4	control	22.50	25.60	26.01	22.50	25.78	25.82	25.91	25.95
	70%	22.50	23.01	24.50	22.50	23.01	23.45	23.50	24.22
Clone 5	control	23.50	26.50	26.58	23.50	26.01	27.12	27.42	27.47
	70%	23.50	25.52	25.63	23.50	25.01	25.22	25.47	25.58
SEm ±	-	-	-	-	-	-	-	-	
CD @5%		NS	NS	NS	NS	NS	NS	NS	NS

(clone 5) during second week under conventional packaging. Under deep freeze condition, ascorbic acid retention was found to be 7.82, 8.37, 8.64, 8.16 and 8.40 mg/100 g for clone1, clone 2, clone 3, clone 4 and clone 5, respectively under vacuum packaging (Table 2). Vitamin C is probably the most unstable vitamin and it is readily oxidized by many non-enzymatic processes. Although frozen storage temperatures between -18 and -28°C result in satisfactory vitamin C retention

Table 4: Influence of vacuum packaging on titratable acidity (%) of minimally processed jackfruit bulbs of five different clones under different storage conditions

Clone no.	Vacuum %	Titratable acidity (%) Storage period (weeks) Refrigeration storage (3-5°c)			Deep freeze storage (-12 °C)				
		0	1	2	0	1	2	3	4
Clone 1	Control	0.52	0.45	0.40	0.52	0.50	0.46	0.40	0.38
	70%	0.52	0.48	0.44	0.52	0.50	0.48	0.48	0.46
Clone 2	Control	0.56	0.48	0.38	0.56	0.53	0.48	0.44	0.40
	70%	0.56	0.54	0.46	0.56	0.52	0.50	0.48	0.44
Clone 3	Control	0.48	0.42	0.35	0.48	0.45	0.42	0.38	0.34
	70%	0.48	0.44	0.36	0.48	0.46	0.44	0.42	0.38
Clone 4	Control	0.58	0.46	0.39	0.58	0.52	0.49	0.42	0.38
	70%	0.58	0.50	0.46	0.58	0.53	0.50	0.47	0.44
Clone 5	Control	0.50	0.40	0.32	0.50	0.47	0.45	0.35	0.32
	70%	0.50	0.44	0.36	0.50	0.48	0.43	0.38	0.35
SEm±	-	-	-	-	-	-	-	-	
CD @ 5%		NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Influence of vacuum packaging on pH of minimally processed jackfruit bulbs of five different clones under different storage conditions

Clone no.	Vacuum %	pH Storage period (weeks) Refrigeration storage (3-5°C)			Deep freeze storage (-12°C)				
		0	1	2	0	1	2	3	4
Clone 1	Control	5.40	5.38	5.53	5.40	5.36	5.46	5.50	5.52
	70%	5.40	4.35	4.60	5.40	4.39	4.56	4.59	4.61
Clone 2	Control	5.30	5.27	5.42	5.30	5.28	5.37	5.40	5.42
	70%	5.30	4.23	4.50	5.30	4.26	4.48	4.49	4.52
Clone 3	Control	5.40	5.36	5.51	5.40	5.34	5.42	5.48	5.50
	70%	5.40	4.37	4.63	5.40	4.39	4.55	4.60	4.61
Clone 4	Control	5.22	5.00	5.28	5.22	5.17	5.28	5.36	5.48
	70%	5.22	4.20	4.49	5.22	4.16	4.38	4.40	4.43
Clone 5	Control	5.80	5.68	5.70	5.80	5.77	5.86	5.88	5.93
	70%	5.80	4.80	4.98	5.80	4.79	4.91	4.93	5.03
SEm±	-	-	-	-	0.020	0.020	0.019	0.019	
CD @ 5%	NS	NS	NS	NS	0.034	0.034	0.034	0.033	

Table 6: Influence of vacuum packaging on the overall acceptability scores of minimally processed jackfruit bulbs of different clones under different storage conditions

Clone no.	Vacuum %	Overall acceptability scores Storage period (weeks) Refrigeration storage (3-5°c)			Deep freeze storage (-12 °C)				
		0	1	2	0	1	2	3	4
Clone 1	Control	9.00	7.70	7.50	9.00	8.80	8.60	8.40	8.30
	70%	9.00	8.50	8.40	9.00	9.00	8.90	8.80	8.70
Clone 2	Control	9.00	7.50	7.30	9.00	8.80	8.60	8.30	8.10
	70%	9.00	8.50	7.90	9.00	8.90	8.80	8.70	8.50
Clone 3	Control	8.80	7.60	7.30	8.80	8.70	8.50	8.30	8.20
	70%	8.80	8.40	8.20	8.80	9.00	8.80	8.70	8.60
Clone 4	Control	8.50	7.60	7.40	8.50	8.80	8.60	8.30	8.10
	70%	8.50	8.50	8.10	8.50	8.90	8.80	8.70	8.50
Clone 5	Control	8.50	8.40	8.20	8.50	8.30	8.50	8.30	7.90
	70%	8.50	8.50	8.40	8.50	8.40	8.70	8.60	8.50
Upper score: 10									

levels in fruits during storage, at temperatures above 10°C, it is easily oxidized and will be drastically reduced in a short period of time (Lozano, 2006). Ascorbic acid has an important role as a phytochemical, due to its functionality as an antioxidant besides its vitamin C activity (Saxena *et al.,* 2008).

Total soluble solids (TSS) and titrable acidity (TA)

The TSS of fresh jackfruit ripe bulbs among five different clones varied from 22.5° B to 26.2° B for clone 4 and clone 1 respectively. The rate of increase in TSS was much slower under vacuum packaging with deep freeze (ranging from

24.22 °B for clone 4 to 27 °B for clone 4) during fourth week of storage than that observed under the conventional packaging technique under refrigeration (ranging from 26.01 °B for clone 4 to 28°B for clone 4) during second week of storage(Table 3). Samples with vacuum packaging at 70% was credited for the increase in titrable acidity of the samples against the control. At the end of the fourth week of the deep freeze storage, the control samples in PP packaging recorded the titrable acidity values in between 0.32% (clone 5) and 0.40% (clone 2), while the samples with vacuum packaging in PP bags had the values in between 0.35% (clone 5)and 0.44% (clone 2). Under refrigeration, vacuum packaged samples had the values ranging from 0.36% (clone 5) to 0.46% (clone 4 and 2) after two weeks of storage while the control had values in between 0.32% and 0.40% for clone 5 and clone, respectively (Table 4). The rate of decrease in titrable acidity was slower under deep freeze storage, indicating the influence of storage temperature in the ripening process.

The faster the rate of increase in TSS, the faster the ripening process and therefore the senescence. The increase in TSS with the advancement of storage period might be due to conversion of reserved starch and other polysaccharides into soluble form of sugar (Gohlani and Bisen, 2012). Vacuum packaging delayed the occurrence of ripening and as such, senescence in minimally processed jackfruit bulbs. Ripening index (RI), which is the ratio of TSS/acidity was observed to increase in the minimally processed jackfruit bulbs during storage. The increase in RI could be due to the degradation of available starch during storage into simple sugars (Saxena *et al.*, 2008) which might be the reason for the decreased acidity and increased sweetness of the minimally processed jackfruit bulbs as observed during sensory evaluation. Lower values of ripening index are preferred as they are indicative of a longer shelf-life and better flavour of the fruit. As the ripening process is influenced by temperature and amount of O_2 in the package headspace, the rate of increase in ripening index was higher under refrigeration storage and conventional packaging technique compared to deep freeze storage temperature and vacuum packaging technique.

pH

The samples with vacuum packaging had significantly ($p<0.05$) lower pH values than the control samples under both refrigeration and deep freeze storage. During the course of storage, there was an increase in the pH values of the control samples in PP packages. Significant changes in pH was observed among the clones during first to fourth week of storage between packaging in deep freeze condition. No significant ($p<0.05$) differences were observed among clones between vacuum packaging under refrigeration condition (Table 5). Spoilage of fresh-cut fruits caused by specific moulds and yeasts which utilize organic acids, could have led to further reduced acidity and increased pH (Corbo *et al.,* 2010). This indicated the positive influence of vacuum packaging in controlling the rise in pH of the minimally processed jackfruit bulbs. There were no significant changes in pH among five clones under vacuum packaging.

Sensory evaluation

Samples under vacuum packaging under deep freeze conditions had higher sensory scores compared to samples under conventional packaging techniques as these samples maintained freshness in terms of colour, flavour and appearance (Tables 6). Sensory attributes of pre-cut jackfruit bulbs showed better preference by the judges for the samples kept under vacuum packaging due to better maintenance on colour, flavor and texture compared to conventional packaging.The samples under refrigeration in PP packages (without vacuum) had the lower acceptability scores, which may be the result of anaerobic fermentation (Saxena *et al.*, 2008).

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