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Process protocol standardisation and shelf life study of minimally processed fresh cut tender jackfruit

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Abstract
Jackfruit (*Artocarpus heterophyllus* L.) is a tropical fruit having high nutritional value. India is one of the leading producer of jackfruit. As the first largest producer of jackfruit in the world, the Indian jackfruit processing technology is still in developing stage and waste is high in our country. Adoption of preservative technologies like minimal processing will be a possible solution to overcome these problem. But the oxidative stress imparted in fruits and vegetables during cutting and slicing operations remaining as a hurdle in marketing of minimally processed fruits and vegetables. Therefore in present study different preservatives and refrigerated storage conditions are used to improve the shelf life of fresh cut tender jackfruit. The jackfruit slices were steam blanched for 3 min and dip treatment was carried out with varying concentrations of preservatives for 6 minutes duration. The quality of minimally processed jackfruit slices were evaluated with 3 days of interval. The physico-chemical parameters of minimally processed tender jackfruit *viz.*, firmness (12-96.77 N), total colour deviation (ΔE) and colour values in terms of L*(47.82-80.12) a*(-0.08-3.31) b*(11.68-22.88), Ascorbic acid content (13.03-22.35 mg/100g) and pH (4.10-6.97) were measured conferring the standard procedures. From the qualitative analysis the best combination of 1% sodium chloride and 0.05% sodium benzoate stored at refrigerated condition for a period of 9 days was optimised. This research could be beneficial for upgrading the quality standards of minimally processed tender jackfruit with improved the product shelf life.

Keywords: Tender jackfruit, minimal processing, steam blanching, preservatives, shelf life

1. Introduction
Jackfruit (*Artocarpus heterophyllus* L.), known as the state fruit of Kerala which is rich in nutrients, carbohydrate, fiber, minerals and antioxidants (Jagadeesh *et al*, 2007) [4]. It has a distinctive aroma with fibrous flesh that can be eaten in raw or ripe stage in variety of dishes. Jackfruit in its tender form is consumed as a vegetable because of its versatile flavour and meat like texture. In south Asian countries the commercial value for tender jackfruit is very high. However, marketing and handling of jackfruit is very difficult owing to its bulky size and weight. Jackfruit is a popular fruit and ranks third in total annual production. In South India, out of 2.60 lakh tonnes/annum production only 8 tonnes of jackfruit produced is consumed, and the rest is unutilized. In Kerala alone annual wastage of jackfruit accounts for 35 crores *i.e.* 75% of national wastage. (APAARI, 2012) [2]. As the edible portion of jackfruit only makes up 30-35% of the fruits, the jackfruit is profoundly potential for minimal process. The processing activities like washing, sorting, peeling and cutting causes ill effects on quality of fresh cut tender jackfruit by microbial contaminations, excessive tissue softening and browning. As it remains in respiratory condition and physiologically active form the pre-cut fruits lose some of its textural integrity that disintegrates the cell wall.
The market for fresh cut fruits has rapidly grown in recent years. Optimisation of minimal processing technique for the bulky jackfruit in its tender form could be highly advantageous in making the commodity convenient for handling and transport. According to Ramli (2017) [7] minimal processing is a replaceable traditional preservation method as it helps to produce products with good sensorial as well as nutritional quality. The foodservice industries are also focusing on getting more pre-prepared ingredients to minimize handling and to reduce operating cost (Ahvenainen, 1996) [1]. International Fresh-cut Produce Association (IFPA) defines fresh-cut products as fruit or vegetables that have been trimmed and/or peeled and/or cut into 100% usable product that is bagged or pre-packaged to offer consumers high nutrition, convenience, and flavour while still maintaining its freshness (Lamikanra, 2002) [5].
There is a requisite to development of technology or process for jackfruit to grapple with the problems such as browning, flavour loss, colour loss, tissue softening and decaying. In the

present study, different preservatives such as firming and anti-browning agents with refrigerated storage conditions were used for minimally processed jackfruit to improve the shelf life of fresh cut fruit. The objective of current study is to optimize the minimal processing variables *viz;* combination of preservative, storage condition for tender jackfruit and for predicting the effect of treatments on the quality of minimally processed tender jackfruit.

2. Materials and Method

2.1 Sample preparation

Tender '*Koozha*' jackfruits (*Artocarpus heterophyllus* L.) at a harvest maturity of 60 - 70 days after fruit formation were collected from Fruit research station, Kerala Agricultural University, Thrissur, Kerala, India. The jackfruits were washed properly in tap water for the removal of external impurities and surface sanitized with 120 ppm sodium hypochloride solution. Subsequently the surface sanitized fruits were cut and sliced manually using a stainless steel knife. Tender jackfruit slices of uniform size were steam blanched for 3 min and immersed in solutions of different treatments (Table.1) for six minutes. Then the samples were took out from solution, surface dried and packed in 200 gauge LDPE pouches. Preservative treated samples were stored in room temperature and refrigerated condition. Minimally processed and stored tender jackfruit were analysed for quality parameters in a regular interval. Quality parameters considered in the present study were firmness, colour, Vit. C, and pH.

Table 1: Combination of chemical preservatives used for minimal processing of tender jackfruit

Sl. No.	Treatment	
1	TC	Fresh sample
2	T1	$CaCl_2$+SB
3	T2	$CaCl_2$+AA
4	T3	SB+AA
5	T4	$CaCl_2$+SB+AA
6	T5	NaCl+SB
7	T6	NaCl+AA
8	T7	NaCl+AA+SB
9	T8	NaCl

$CaCl_2$: 2% Calcium chloride; SB: 0.05% Sodium benzoate; AA: 0.5% Ascorbic Acid; NaCl: 1% Sodium chloride

2.2 Firmness

Firmness was the maximum force recorded in Newton (N). The firmness of the minimally processed tender jackfruit was measured using a texture analyzer model: TA.XT2 with cylindrical probe operated at specified test conditions (Table 2). The quality of minimally processed tender jackfruit was measured in three days interval expressed as the mean values of three replications.

Table 2: Test settings of the texture analyzer to determine the firmness

Test mode	Return to start
Pre test speed	2.00 mm/s
Test speed	2.00 mm/s
Post test speed	2.00 mm/s
Distance	10 mm
Trigger force	10 g
Load cell	50 kg
Probe	5 mm cylindrical probe

2.3 Colour characteristics

The colour measurements of the minimally processed tender jackfruit were measured under D65 illuminating condition at an observer angle of 10° with a Hunters tri-stimulus colorimeter. Degree of lightness or darkness of the sample was represented by L value on hunter scale. The results were reported as mean values of three replications. The 'L*' coordinate measures the value or luminance of a colour. The 'a*' coordinate measures red when positive and green when negative and 'b*' measures yellow when positive and blue when negative.

In addition, the total colour change (*ΔE*) is the parameter considered for the overall colour change. Fresh tender jackfruit samples (*L**, *a**, *b**) were used as the reference and a low *ΔE* value corresponds to a less colour change from the reference samples.

$$\Delta E = \sqrt{(L-L_0)^2 + (a-a_0)^2 + (b-b_0)^2}$$

The subscript "0" in the equation represents the colour value of fresh sample.

2.4 Ascorbic acid (mg.100g^{-1})

The ascorbic acid content of minimally processed tender jackfruit was determined by visual titration method explained by Ranganna, 1986. Determination of vitamin C content of samples was carried out thrice using the Eq. (1) and the average value was considered as vitamin C content of minimally processed samples.

$$\text{Ascorbic acid (mg.100 g}^{-1}) = \frac{0.5\,(\text{mg}) \times V_2\ (\text{ml}) \times 100\ (\text{ml})}{V_1\ (\text{ml}) \times 5\ (\text{ml}) \times \text{Weight of sample}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

2.5 pH

The pH of minimally processed samples was measured by using digital pH meter.

2.6 Experimental design

Factorial completely randomised design (FCRD) was used to analyse the data. Statistical significance of the terms in the regression equation was examined by analysis of variance (ANOVA) for each response. The p-values were used as a tool to check the significance of each of the coefficients, which, in turn were necessary to understand the pattern of the mutual interactions between the test variables.

3. Results and Discussion

The pre-treatments for minimal process were optimized in terms of experimental variables with respect to different responses during the storage period at ambient and refrigerated conditions. The various physico-biochemical parameters *viz;* textural properties, colour characteristics, pH and ascorbic acid under different combinations were evaluated using analysis of variance. All the responses during the optimization process were found to have significant effect ($P<0.01$) and detailed under the following sessions.

3.1 Influence of chemical treatment and storage condition on quality parameters of minimally processed tender jackfruit slices

3.1.1 Firmness

Firmness is the main textural attribute characterizing the freshness of the minimally processed tender jackfruit. The firmness of the tender jackfruit slices were significantly influenced by preservative treatments, storage period and their interaction. The firmness of the minimally processed slices were recorded as 12.95-85.44 N during 9 days of refrigerated storage (Fig. 1) and 74.8707-96.70 N after 6 days of ambient storage (Fig. 1) for different combinations of treatment. The firmness of all the samples decreased during storage. During the storage period, maximum firmness and storage life was observed in the refrigerated samples compared to the samples stored at ambient temperature. Out of eight treatment combinations, treatment with 1% NaCl and 0.05% sodium chloride found to have a greater and significantly positive effect on firmness of the slices on the third day of storage i.e., 84.55 N. At the same time treatment with 2% $CaCl_2$ and 0.5% Ascorbic acid stored at refrigerated storage showed the firmness value of 84.04 N which was on par with the highest firmness value found in treatment containing 1% NaCl and 0.05% sodium chloride. The combined effect of $CaCl_2$ and Ascorbic acid has been reported to attribute to lower cellular leakage and biochemical activity, thus maintained the better retention of texture (Saxena *et al*. 2009) [9].

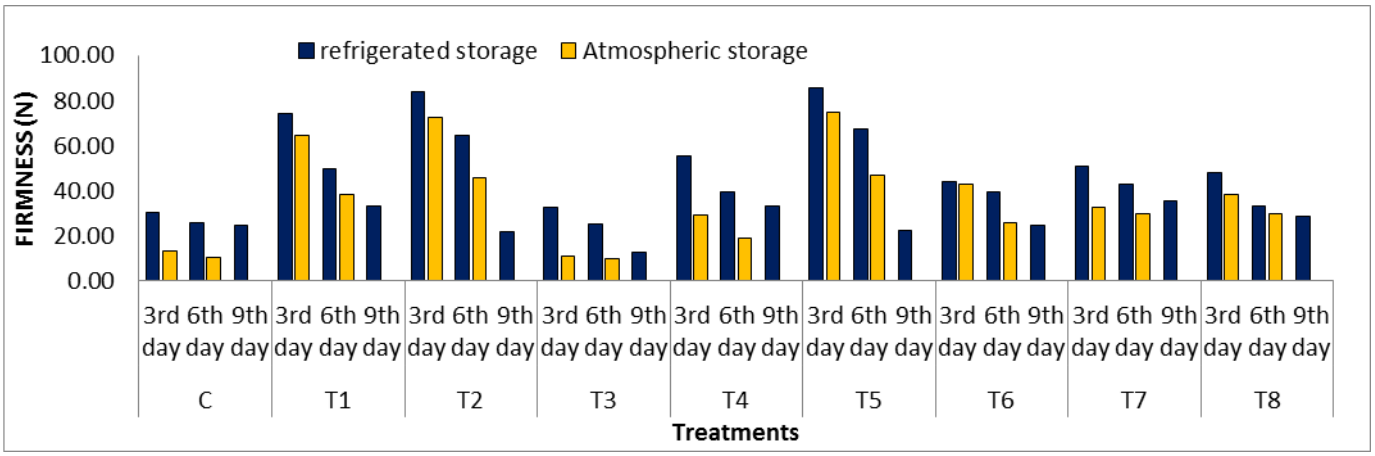

Fig 1: Firmness of minimally processed tender jackfruit in refrigerated and atmospheric storage conditions

3.1.2 Colour characteristics

Total colour change of minimally processed tender jackfruit was analysed in terms of L*, a*and b* values. The L* values of the samples ranged from 80.12 to 47.82 under refrigeration storage after 9 days and 53.52 to 79.12 under atmospheric storage after 6 days (Table 3). The samples kept at refrigerated storage exhibited an appreciable a* value of 0.13 to 3.53 compared to the samples stored at ambient storage condition *ie*, -0.08 to 3.31. During the study the a* value for refrigerated condition of all treatments showed a decreasing trend (Table 4) and the minimum values obtained under refrigerated and ambient conditions were 0.13 and -0.08 for control sample during the 9th and 6th day respectively. The b* values of the samples showed a decreasing trend with storage. The b* values of the samples ranged from 13.54 to 22.88 under refrigeration storage after 9 days (Fig. 2) and 11.68 to 19.87 under atmospheric storage after 6 days (Fig.3). The deviation of colour (ΔE) of minimally processed tender jackfruit calculated from L*, a*and b* values showed highest deviation in samples stored under ambient storage conditions (Fig. 4 and 5).

Ascorbic acid is a reducing agent widely used as an anti-browning agent for processing of fruits and vegetables. The action of calcium chloride might be due to the PPO inhibition by chloride ions. Manolopoulou and Varzakas, 2011 [6] reported that the interaction involving the use of respiratory retardant in the pre-treatment and low temperature storage resulted in minimum O_2 concentration inside the package, low respiration rates, and facilitated maximum retention of colour quality in terms of L*a*b* values in refrigerated samples.

Table 3: L* value of minimally processed tender jackfruit slices

Treatments	Atmospheric storage			Refrigerated storage		
	3rd day	6th day	9th day	3rd day	6th day	9th day
C	69.81	53.52	spoiled	70.81	69.52	66.48
T1	75.79	66.90	spoiled	77.79	70.69	54.09
T2	65.68	60.55	spoiled	66.68	61.55	53.83
T3	72.26	63.86	spoiled	72.26	71.26	62.20
T4	73.03	67.80	spoiled	73.93	67.80	56.56
T5	76.25	68.02	spoiled	78.25	76.02	64.53
T6	79.12	70.60	spoiled	80.12	77.60	64.60
T7	60.47	59.97	spoiled	62.47	62.17	47.82
T8	70.92	67.06	spoiled	73.32	70.76	61.80

Table 4: a* value of minimally processed tender jackfruit slices

Treatments	Atmospheric storage			Refrigerated storage		
	3rd day	6th day	9th day	3rd day	6th day	9th day
C	0.15	-0.08	spoiled	2.21	2.02	1.84
T1	0.39	0.72	spoiled	0.81	0.72	0.65
T2	0.55	1.31	spoiled	1.50	1.34	1.13
T3	1.70	0.96	spoiled	1.70	1.45	0.99
T4	2.10	1.23	spoiled	2.27	1.89	1.21
T5	3.31	1.92	spoiled	3.36	3.02	2.22
T6	0.21	0.11	spoiled	0.50	0.21	0.13
T7	3.19	1.67	spoiled	3.53	3.00	3.12
T8	1.38	0.95	spoiled	1.71	1.40	1.29

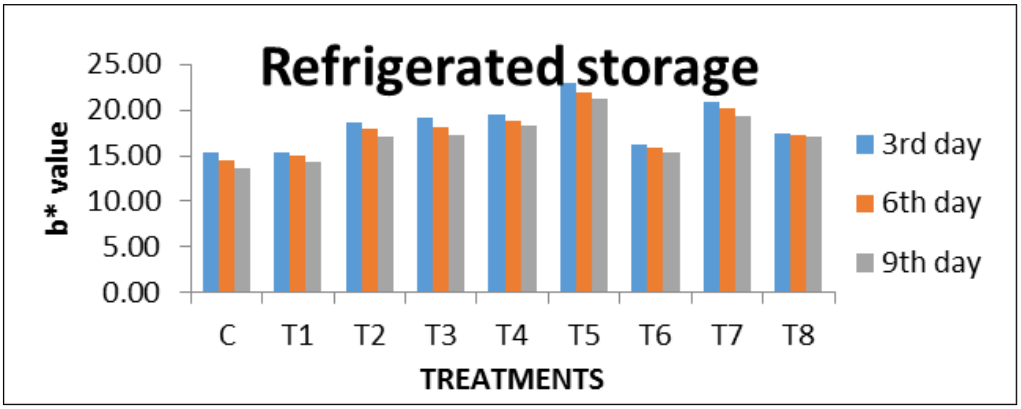

Fig 2: b* value of minimally processed tender jack stored under refrigerated condition

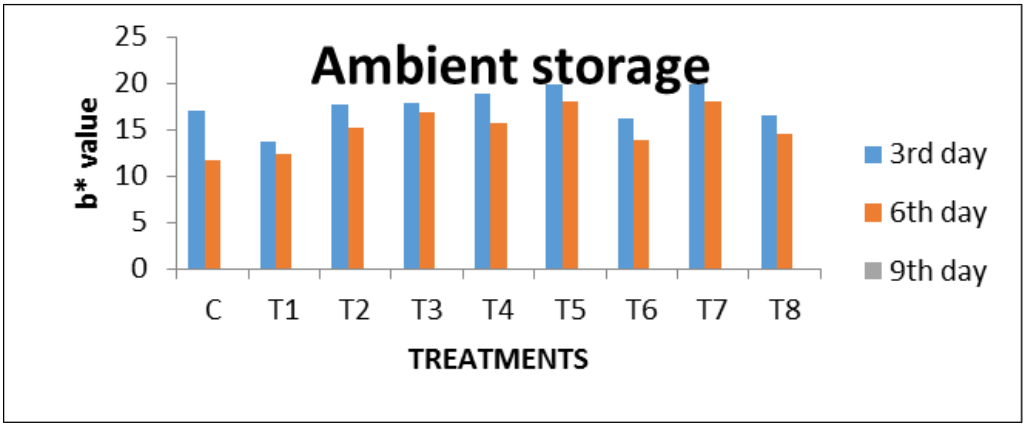

Fig 3: b* value of minimally processed tender jack stored under ambient condition

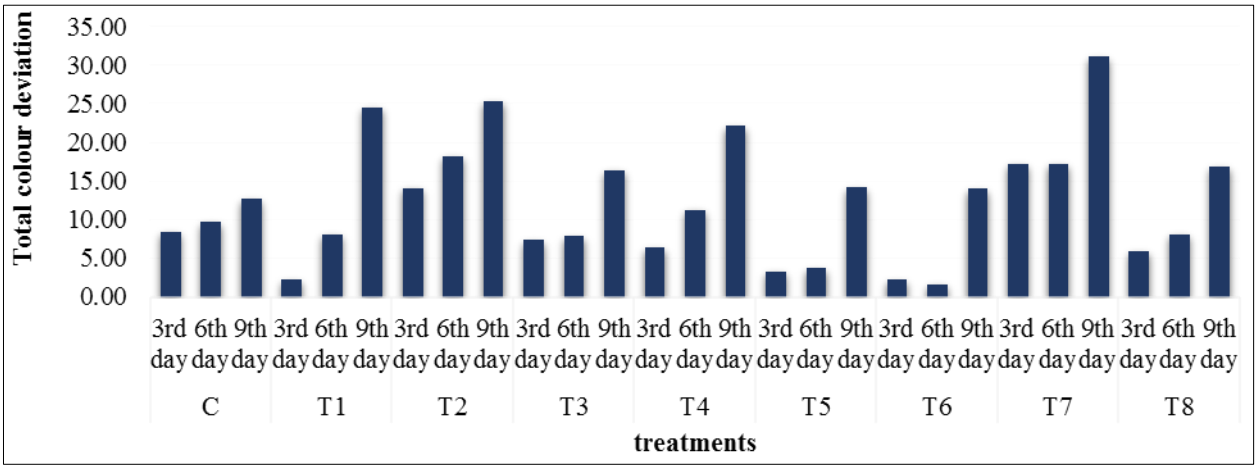

Fig 4: Total colour deviation of minimally processed tender jackfruit at refrigerated storage

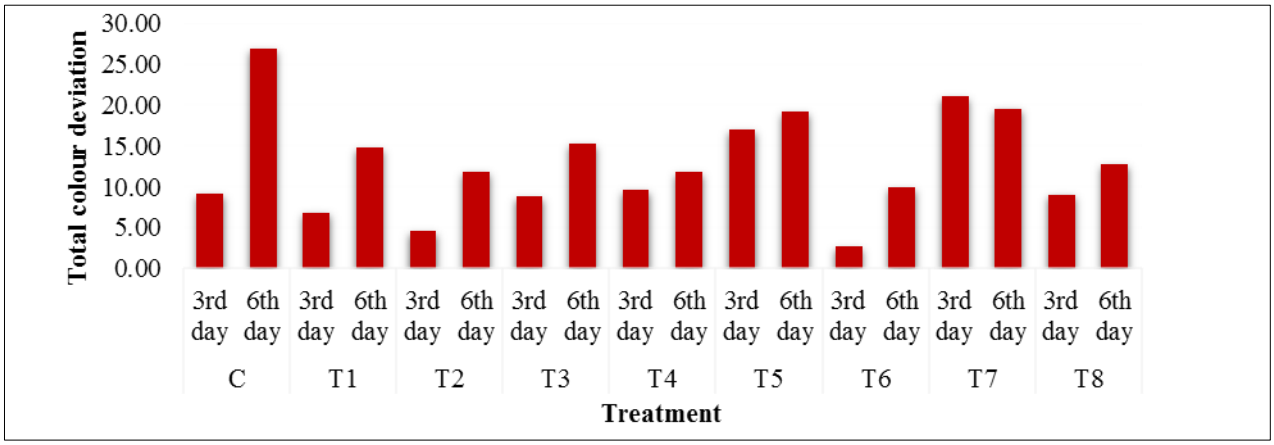

Fig 5: Total colour deviation of minimally processed tender jackfruit at atmospheric storage

3.1.3 Ascorbic acid (mg.100g^{-1})

Ascorbic acid (AA) has an important role as a phyto-chemical, due to its functionality as an antioxidant besides its vitamin C activity. Significant differences were observed amongst the different treatments in respect of the ascorbic acid content and after 9 days of refrigeration storage, samples had significantly higher retention of ascorbic acid (16.69-22.35 mg/100g), against 9.04-22.35 mg/100g in the case of samples stored at ambient condition (Table. 5). Lower respiratory activity under refrigerated conditions could be attributed to the higher retention of ascorbic acid content due to restriction in enzymatic oxidation of ascorbic acid. The maximum ascorbic acid retention was recorded in samples treated with sodium chloride and sodium benzoate at refrigerated storage and atmospheric storage.

Table 5: Ascorbic acid content in minimally processed tender jackfruit (mg/100g)

Treatments	Refrigerated storage condition			Ambient storage condition		
	3rd day	6th day	9th day	3rd day	6th day	9th day
C	22.35	20.77	16.69	22.35	9.04	spoiled
T1	20.36	19.95	17.00	20.30	12.51	spoiled
T2	21.46	20.02	19.47	17.13	13.02	spoiled
T3	19.50	19.15	16.56	19.16	15.48	spoiled
T4	16.66	16.27	15.07	16.66	10.83	spoiled
T5	21.92	21.90	20.96	21.66	13.10	spoiled
T6	20.99	19.06	19.06	20.32	18.96	spoiled
T7	20.79	18.00	17.18	19.12	10.45	spoiled
T8	20.01	19.50	19.05	20.03	14.96	spoiled

3.1.4 pH

Minimally processed jackfruits were tested for its pH according to the standard methodology. The results of the pH values of the minimally processed tender jackfruit slices during storage are presented in Table 6. Results indicated that there was an increase in pH values of the samples during its storage period. According to Corbo *et al.*, 2010 [3] 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. The treatment T8 exhibited higher pH of 6.97 at 9th day of refrigerated storage.

Table 6: pH of minimally processed tender jackfruit at different storage conditions

Treatments	Refrigerated condition			Ambient condition		
	3rd day	6th day	9th day	3rd day	6th day	9th day
C	5.21	5.98	6.10	5.01	5.28	spoiled
T1	5.40	5.70	5.86	5.64	5.70	spoiled
T2	4.30	5.45	5.98	4.10	4.45	spoiled
T3	5.00	5.34	5.50	5.34	5.64	spoiled
T4	4.98	5.40	5.60	4.80	4.94	spoiled
T5	6.40	6.80	6.86	5.40	5.80	spoiled
T6	5.87	6.08	6.23	5.07	5.35	spoiled
T7	5.76	5.88	6.43	5.70	5.78	spoiled
T8	6.87	6.94	6.97	6.44	6.71	spoiled

4. Conclusion

Tender jackfruit is a potential vegetable which has a huge market potential. Process protocol standardisation of minimally processed fresh cut tender jackfruit was carried out under different storage conditions by dipping treatment using different preservatives. Fresh cut tender Jackfruit slices were processed by using the independent parameters such as concentration of preservatives and storage condition and the response variables were firmness, colour characteristics, Ascorbic acid content and pH after the treatment. From the response variables the best combination of independent variables was resulted as 1% concentration of $NaCl_2$ and

0.05% concentration of sodium benzoate for refrigerated storage of 9 days. The optimised conditions for minimally processed fresh cut tender jackfruit ensure maximum retention of quality and longer shelf life. The output from this study could be prove a boon for the industries which deals with processing and packaging of fresh cut tender jackfruit. Further studies under different packaging and prolonged storage need to be carried out to enhance the better results.

5. Acknowledgement

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