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Physicochemical qualities of stored fresh cut EVIARC sweet jackfruit (*Artocarpus heterophyllus* Lam.) pulp as influenced by deseeding, packaging method and storage condition

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ABSTRACT

Processing method plays a significant role in the physicochemical property of food products. This study evaluated the effects of deseeding, packaging method, and storage condition on the physicochemical properties of fresh-cut jackfruit during the 8-day storage period. A 2x2x2 factorial experiment was used in the study with a total of 8 treatments. All of the treatments were subjected to physicochemical analysis following standard protocols. Data were subjected to single factorial Analysis of Variance (ANOVA) and multi-factorial ANOVA for the interaction of dependent variables. Jackfruit pulps which were deseeded have shown significant decrease in the physicochemical attributes of the product which is an indicator for product quality. Deseeded products had much faster deterioration compared to treatments with intact seeds. Treatments stored in chilling (4-6°C) condition exhibited lesser variation in TA, TSS, pH, browning and firmness during the storage period compared to those stored at ambient temperature. Chilled treatments packed in vacuum had slower deterioration compared to treatments which were conventionally packed.

Keywords: EVIARC sweet jackfruit, minimally processed, jackfruit, quality evaluation, low-temperature storage, vacuum packed

INTRODUCTION

Jackfruit is a huge fruit of about 50kg (Coronel1983) that is becoming more popular in the market due to its unique flavor and health benefits. EVIARC Sweet jackfruit variety contains phenolics, tannins, reducing sugar, sulfur and antioxidants (Galvez & Dizon 2017), which have functional properties for human health. One way

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of producing a high value product from this fruit is through minimal processing, which can also reduce its weight.

Freshcut products are highly perishable due to the disruption of tissue and cell integrity with a concomitant increase in the enzymatic, respiratory and microbiological activity, leading to reduction of the shelf life of these products (Olusola 2002 as cited by Fagundes et al 2013). These products generally have higher respiration rates than the corresponding intact products. Higher respiration rates indicate a more active metabolism and usually a faster deterioration rate. In addition, higher respiration rates can result in more rapid loss of acids, sugars and other components that determine flavor quality and nutritive value (Cantwell & Suslow 2002).

In general, freshcut fruits are rinsed just after cutting with cold (0 to 1°C, 32 to 34°F) chlorinated water at pH7.0. This may help extend product shelf life by reducing microbial load, removing cellular juices at cut surfaces that may promote cut surface discoloration, and actually inhibiting the enzymatic reactions involved in fruit browning (Brecht et al 1993, Hurst 1995). However, post-cut washing or dipping may have negative consequences such as increased water activity and "washing away" of desirable flavor attributes.

Cantwell and Suslow (2013) also mentioned that the physical damage or wounding caused by preparation increases respiration and ethylene production within minutes, with associated increase in rates of other biochemical reactions responsible for changes in color (including browning), flavor, texture, and nutritional quality (sugar, acid and vitamin content). The degree of processing and the quality of the equipment significantly affect wounding response.

Strict temperature control is required to minimize increased respiration rates of freshcut products. Low temperature storage is also essential to retard microbial spoilage on cut surfaces. Cantwell and Suslow (2013) cited that the increased oxygen demand due to the higher respiration rates of freshcut products dictates that packaging films maintain sufficient permeability to prevent fermentation and off-odors. Hence, this study was conducted to investigate the relationship of deseeding, packaging method and storage condition to the physicochemical properties of minimally processed jackfruit.

MATERIALS AND METHODS

Procurement of Materials

EVIARC Sweet jackfruit was procured from the farm of Job Abuyabor in Mahaplag, Leyte, Philippines. The chemicals, namely; sodium hypochlorite, calcium chloride and ascorbic acid, as well as other materials were procured from commercial sources in Cebu City, Philippines. Packaging materials were bought in Baybay City, Leyte.

Preparation and Processing of Fresh-Cut Jackfruit

The jackfruit was washed with soap and water, scrubbed until visually clean from adhering organic matter (leaves, soil, stems). The whole fruit was sanitized with chlorine solution of 100ppm concentration equivalent to 0.01% solution and

was sliced longitudinally. The pith was removed and fruit pulps were segregated from the seeds and other jackfruit byproducts. The jackfruit pulps were trimmed and only those undamaged were used. A combination of food grade sodium hypochlorite (NaOCl=0.04374%w/v), calcium chloride ($CaCl_2$=0.74%w/v) and ascorbic acid solution (0.65%w/v) were prepared as pretreatment solution (Patindol 2016) with little modification. A total of 20L of pretreatment solution was prepared. The pulps, about 10kg, were soaked into the pretreatment solution (20L) for 2min. Product was put into sanitized hanging baskets to remove excess water.

After draining off the liquid, treatments were packed in respective containers. Each pack contained 200g of jackfruit pulp. For vacuum packaging, polyethylene bags with 0.003mm thickness were used. The product was vacuumed for 25 seconds and sealed at medium heat for 3 seconds. For conventional packaging, plastic tray and cling wrap was used. Treatments 1, 3, 5, and 7 were stored at chilled condition (crisper) (4-6°C), and the remaining treatments (2, 4, 6 & 8) were stored at ambient condition (30°C) (Table 1). Chilled refrigerator temperature was monitored using a thermometer for cold storage. A controlled air-conditioned room set at 30°C was used for the storage of products at ambient condition. The vacuum-packed samples were placed on the sanitized trays on the sanitized table in the air-conditioned room.

Experimental Design

A 2x2x2 factorial design was employed to compare the different responses of physicochemical properties to the variables. Table 1 shows the different treatments with their corresponding variables.

Table 1. Experimental combinations of jackfruit pulp preparation, packaging method and storage condition in preparation of the treatments

Treatment	Jackfruit Pulp Preparation	Packaging Method	Storage Condition
T1	With seed	Vacuum Packed	Chilled
T2	With seed	Vacuum packed	Ambient
T3	With seed	Conventionally packed	Chilled
T4	With seed	Conventionally packed	Ambient
T5	Without seed	Vacuum packed	Chilled
T6	Without seed	Vacuum packed	Ambient
T7	Without seed	Conventionally packed	Chilled
T8	Without seed	Conventionally packed	Ambient

Physicochemical Analysis

Evaluation of all physicochemical properties of freshcut jackfruit was done on the first until the 8th day of storage for every packaging method and storage condition.

Total Soluble Solids (TSS). The total soluble solids were measured using a hand refractometer (Atago ATC-IE model Japan). It was calibrated by placing a drop of distilled water on the prism of the refractometer. After calibrating, a drop of pure

squeezed juice sample was placed on the prism of the hand refractometer. Then the reading was taken and recorded.

Titratable Acidity (TA). The TA was determined by employing the standard titration method using a standardized 0.1N NaOH solution. Five grams of the blended sample was diluted with 25mL distilled water in a Florence flask. Then, 2-3 drops of phenolphthalein indicator was added. It was titrated with the standardized 0.1N NaOH solution until stable pink color was observed. This acidity was calculated according to the following formula:

$$\%TA\ (\text{citric acid}) = V \times N \times M / W \times 100$$

Where:

V = volume of NaOH added, mL
N = concentration (N) of NaOH,
M = milliequivalent weight (meq/g) of predominant acid,
W=weight (g) equivalent of aliquot, g

$$W = \frac{\text{weight of sample (g)}}{\text{vol.aliquot}} \times \text{vol.of water added}$$

pH. The pH of sample was determined using a calibrated digital pH meter (pH-Pen PT-70). The pH of the sample was determined by dipping the pH meter electrode into a 5g pureed sample. Pureed samples were prepared by blending 20g pulp with 50mL water in an osterizer, Three replications were done.

Color Measurement. For color measurement, colorimeter (Lovibond Colorimeter) was used to determine the color of all the treatments. Hunters *L* and *b value* were measured. *Hunters L* represents the lightness of the color. The *b* value represents the yellow/blue opponent where blue was at negative *b* values and yellow is at positive *b* values.

Degree of Browning. The modified method proposed by Baloch et al (1973) as cited in Mahayothee et al (2009) was used to evaluate the accumulation of the formation of brown pigments. The chopped sample (5g) was soaked in 50mL of 2% (v/v) acetic acid solution for 2h. Subsequently, the sample was placed in the plastic centrifuge tubes (50mL capacity) then centrifuged at 3,000ppm for 1hr. The supernatant was obtained and the absorbance was read at 420nm with UV-Vis double beam spectrophotometer (Genesys™ 10S, USA). Two percent acetic acid was used as a blank. Three readings were taken and the results were expressed as absorbance per weight of sample in dry basis.

Firmness Measurement. Firmness was measured using a fruit penetrometer to get the numerical rating of the pulps. Flat tip plunger was used. The sample was put in leveled surface to ensure stability of both the sample and the reading. The penetrometer was tared to zero, slowly plunged into the sample until it touched the very surface of the sample. The plunger was slowly pressed into the sample until a consistently firmness value appeared on the screen. The values were reported in

kg/cm^2 force. Five readings were obtained and the mean was used in reporting the result.

Statistical Analysis

Data gathered from the physicochemical analysis were subjected to single factorial Analysis of Variance (ANOVA) for the readings of each treatment per day and Multi-factorial ANOVA to determine the interaction of dependent or response variables on the physicochemical properties of freshcut jackfruit. Interval as well as interaction plots were generated through factorial plots and time series plots using Minitab Express Software.

RESULTS AND DISCUSSION

Physico-Chemical Quality

Total soluble solids

The initial Total Soluble Solids of the product during day 0 has a mean of 25±1 ^{o}Brix. It was observed that there is no significant difference ($p \leq 0.05$) on the TSS readings between treatments during 1st and the 2nd day, but apparent changes occurred during Day 3 onwards. The analysis of variance of the TSS of treatments during the 8th day storage period indicates that observed changes were mainly due to the storage temperature since it has the higher percentage of variance explanation (Table 2).

Table 2. Analysis of variance of TSS of fresh-cut jackfruit stored for 8 days

	Storage Period (Day)							
Main Effects	1	2	3	4	5	6	7	8
A: preparation	0.00	0.11	0.01	0.07	0.10	0.04	0.09	0.09
B: packaging method	0.73	0.06	0.49	0.34	1.19	29.75**	0.28	0.19
C: storage condition	1.11	4.32	5.95*	61.04**	54.64**	92.99***	22.48**	11.04*
Interaction								
A x B	0.72	0.17	0.55	0.04	0.14	0.06	0.09	0.28
A x C	1.91	18.91**	3.89	0.28	0.05	0.01	0.13	0.47
B x C	0.04	0.24	0.37	11.35*	6.30	19.17*	4.53	3.53

*,**,***Significant to $p \leq 0.05$, 0.01 and 0.001, respectively.

Ambient temperatures caused increase in biochemical reactions in pulps. Fruit pulps which have living tissues continue the respiration process, consuming sugars and varying TSS levels, as mentioned by Lamikanra et al (2000). Cantwell and Suslow (2013) mentioned high respiration rates indicate a more active metabolism and usually a faster deterioration rate in fruit tissues. Higher respiration rates can result in more rapid loss of acids, sugars and other components that determine flavor quality and nutritive value (Cantwell & Suslow 2013). Another observation noted was treatments with pulps with seed and stored at chilled condition also exhibit increase in their TSS at the early stage of storage (Figure 1).

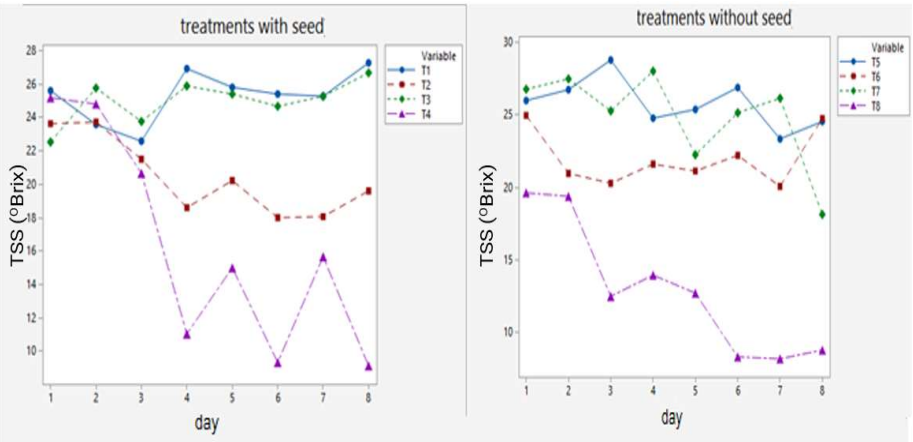

Figure 1. TSS (°Brix) of different treatments at different storage periods (T1-with seed, vacuumed and chilled, T2-with seed, vacuumed and ambient, T3- with seed, without vacuum and chilled, T4-with seed, without vacuum and ambient, T5-without seed, vacuum and chilled, T6-without seed, vacuum and ambient, T7- without seed, without vacuum and chilled, T8- without seed, without vacuum and ambient)

Table 3. TSS reading of each treatment during the 8-day storage period

Treatments	D1	D2	D3	D4	D5	D6	D7	D8	Mean
1	25.6	23.58	22.58	26.92	25.8	25.4	25.26	27.26	24.60
2	23.6	23.72	21.5	18.6	20.22	18	18.06	19.6	20.26
3	22.52	25.76	23.76	25.88	25.4	24.66	25.26	26.66	24.32
4	25.17	24.8	20.66	11.04	15	9.33	15.66	9.13	16.64
5	25.97	26.72	28.76	24.76	25.36	26.86	23.33	24.53	25.03
6	24.95	20.96	20.28	21.6	21.12	22.2	20.06	24.73	21.66
7	26.75	27.46	25.26	28	22.24	25.13	26.13	18.13	24.23
8	19.62	19.38	12.5	13.96	12.72	8.33	8.2	8.8	13.61

During storage, it was observed that TSS of the product is affected by storage condition and preparation method. Treatments stored in chilling (4-6°C) condition exhibited lesser variation in the mean TSS reading during the 8-day storage period (T1=24.6, T3=24.32, T5=25.03 and T7=24.23) compared to those stored at ambient temperature (T2=20.26, T4=16.64, T6=21.66, and T8=13.61) (Table 3). It was observed that with longer storage time within treatments with the same type of preparation and packaging method the mean TSS decreased to minimum values after 8 days, with differences among them, and with significant differences from the initial TSS (Table 3). It was further observed that treatments which have intact fruit pulps (with seed) that were chilled have slight decrease in TSS during the 3-day storage period (±1.84) compared to treatments which are deseeded that shows abrupt decrease in TSS (±2.79). This can be explained by the fact that as a fruit tissue is ruptured, the rate of biochemical reactions increases thus consuming sugars in the process (Cantwell & Suslow 2002). Freshcut processing increases

respiration rates and causes major tissue disruption as enzymes and substrates normally sequestered within the vacuole, become mixed with other cytoplasmic and nucleic substrates and enzymes (Cantwell & Suslow 2002). Processing also increases wound-induced ethylene, water activity and surface area per unit volume, which may accelerate loss and enhance microbial growth since sugars also become readily available (King & Bolin 1989, Watada et al 1990, Wiley 1994, Watada & Qi 1999).This drop in TSS content might also be explained by the fact that this early period (after minimal processing) would be characterized by an intensive respiration during which this sugar would be rapidly used as substrate in the metabolic process. The increase of TSS at the early stages of the chilled treatments might be due to metabolism of the cell wall polysaccharides producing sugars (Fennema 1985).

Titratable Acidity

The increase in TA as storage period increases may be affected by the fermentation in the product due to increased microbial activity. In a study of Aneja et al (2014), fresh fruit juices were spoiled due to high levels of molds and yeast attributable to the increase in acidity of the product. The presence of microorganisms especially yeast can cause fermentation which converts sugars into organic acids.

In Figure 2 fermentation in the product is evident as the packaging materials bloat (vacuum packed treatments) as storage period increases especially those stored at ambient storage condition. It was also observed that T1 (with seed at chilled storage condition) has maintained its vacuum throughout the storage period.

Figure 2. Vacuum packed freshcut jackfruit at (a) chilled and (b) ambient storage for 3 days

Table 4. TA reading of each treatment during the 8-day storage period

Treatments	D1	D2	D3	D4	D5	D6	D7	D8	D1
1	0.004226	0.002871	0.0027 18	0.002351	0.002847	0.0020 71	0.0027 26	0.0096 92	0.004226
2	0.002094	0.004273	0.0090 33	0.007988	0.00787	0.0086 23	0.0099 53	0.0103 47	0.002094
3	0.002392	0.002576	0.0025 4	0.003095	0.003262	0.0026 05	0.0026 59	0.0021 54	0.002392
4	0.003251	0.002417	0.0042 88	0.004454	0.007135	0.0041 5	0.0061 74	0.0028 53	0.003251
5	0.003304	0.002758	0.0033 74	0.002791	0.002236	0.0024 69	0.0037 43	0.0045 32	0.003304
6	0.003855	0.006072	0.0083 35	0.009684	0.00903	0.0094 95	0.0092 17	0.0099 66	0.003855
7	0.002384	0.002621	0.0027 53	0.003796	0.002908	0.0022 77	0.0038 46	0.0027 78	0.002384
8	0.004525	0.005569	0.0042 7	0.00544	0.006329	0.0043 25	0.0020 85	0.0099 82	0.004525

An increase in TA was observed in all treatments as storage time increased (Figure 3). It was observed that treatments stored at ambient temperature established a higher increase in TA relative to the initial TA reading (0.0016 ±0.50%). TA and TSS reading established a relationship. As initial TSS decreased by ≤10.23 during storage period, TA also increased by ≤0.007888 (Table 3 & Table 4). Table 5 shows the ANOVA of TA during the 8-day storage. It was observed that storage condition as well as packaging method greatly affected the TA of the product. And the interaction of factors: packaging method and storage temperature was highly significant starting Day 3.

This rapid increase in TA at treatments stored at ambient condition may be contributed to the fast respiration rate as well as increased microbial activity in the product. With the presence of fermentative microorganisms such as yeast and bacteria, fermentation takes place thus converts sugars into acid thus increasing %TA. As mentioned by Cantwell and Suslow (2013), low temperatures minimize differences in respiration and ethylene production rates between the fresh-cut and the intact product. Low temperatures are also essential to retard microbial spoilage on cut surfaces.

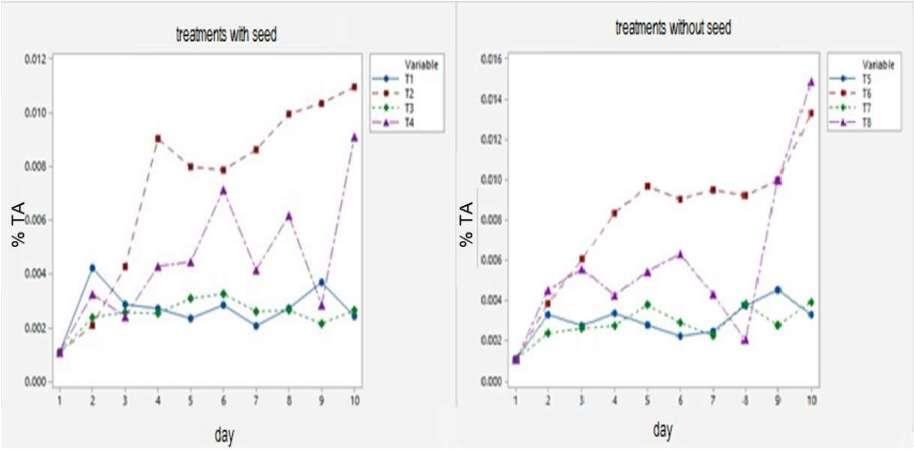

Figure 3.TA (%TA as citric acid) of different treatments for 8-day storage period (T1-with seed, vacuum and chilled, T2-with seed, vacuum and ambient, T3- with seed, without vacuum and chilled, T4- with seed, without vacuum and ambient, T5-without seed, vacuum and chilled, T6-without seed, vacuum and ambient, T7- without seed, without vacuum and chilled, T8- without seed, without vacuum and ambient)

Table 5. Analysis of variance of TA of fresh-cut jackfruit stored for 8 days

	Storage Period (Day)							
Main Effects	1	2	3	4	5	6	7	8
A: preparations	0.44	1.10	0.00	0.17	2.21	0.01	0.07	0.06
B: packaging method	0.08	0.36	95.84***	8.01*	0.06	81.86***	1.21	3.42
C: storage condition	0.36	14.80	219.39***	53.20**	146.43***	279.08***	10.60*	2.51
Interaction								
A x B^{ns}	0.02	0.11	0.00	0.00	0.03	0.02	0.10	2.15
A x C	2.62	6.62*	0.06	0.07	0.21	0.02	0.76	1.10
B x C	3.77	0.28	66.59***	20.02*	8.20*	94.39***	6.08	0.04

,*Significant to $p \leq 0.05$, 0.01 and 0.001, respectively.

pH

As expected, general trend in pH readings showed that during the 8-day storage period, pH decreased at different treatment by ≤1.4 (Table 6). The decrease in pH corresponds to the increase in TA during the storage period. As mentioned by Lea (1991), the pH is a logarithmic measure of the concentration of free hydrogen ions in a chemical or biological system, while titratable acid is a simple measure of the (related) amount of acid 'anions' in a juice. There is no direct relationship between titratable acidity and pH, although generally the pH goes up as the acid goes down and vice-versa. The exact relationship differs from sample to sample and depends on esoteric concepts like 'buffering capacity' which will vary for a whole host of reasons. In general, titratable acid (TA) relates well to the 'acid taste' of a juice while pH relates more to microbial stability and susceptibility to mold and bacterial spoilage.

Table 6. pH reading of each treatment during the 8-day storage period

Treatments	D1	D2	D3	D4	D5	D6	D7	D8	Mean
1	4.5	4.88	5.14	5.16	5.36	4.02	4.27	4.98	4.79
2	4.53	4.46	4.02	5.2	3.88	4.02	4.03	3.86	4.25
3	5.1	5.06	4.88	5.24	6.02	4.72	4.71	4.79	5.07
4	4.78	5.26	4.92	5.5	5.6	4.18	4.19	4.61	4.88
5	5.1	4.84	5.14	5.74	6.48	4.51	4.50	4.26	5.07
6	5.08	4.54	4.68	5.68	4.62	3.89	3.89	3.83	4.53
7	5.13	5.3	5.22	5.72	6.32	4.6	4.6	4.35	5.15
8	4.55	4.96	4.88	5.76	4.96	4.36	4.36	3.95	4.72

Figure 4 shows that treatments stored at ambient condition had higher decrease in pH compared to treatments stored at chilled conditions. As per mentioned in the previous statement, pH change is also an indicator of microbial quality. It was expected that treatments stored at ambient conditions would exhibit increase in fermentation rate because the environment of the microorganism was very favorable for microbial activity and growth. Period of handling of the pulps may have also contributed to microbial contamination thus deseeded samples (T_1-T_4) exhibited lower pH reading compared to sample with intact pulps (T_5-T_8) during the last day of storage period.

Table 7 shows the multifactorial ANOVA of pH readings. It was observed that interaction between factors is not significantly different, while preparation method is significant during Day 4, packaging during Day 2 and storage condition during Day 5 and Day 7. It was observed that treatments which were deseeded had more decrease in pH compared to intact fruit pulps (Figure 4). As the fruit tissue ruptures, surface area of the pulp increases thus contributed to the higher respiration rate of the product. When cells are ruptured by cutting during minimal processing, wound-induced biochemical reactions are initiated that shorten storage life (Cantwell & Suslow 2013).

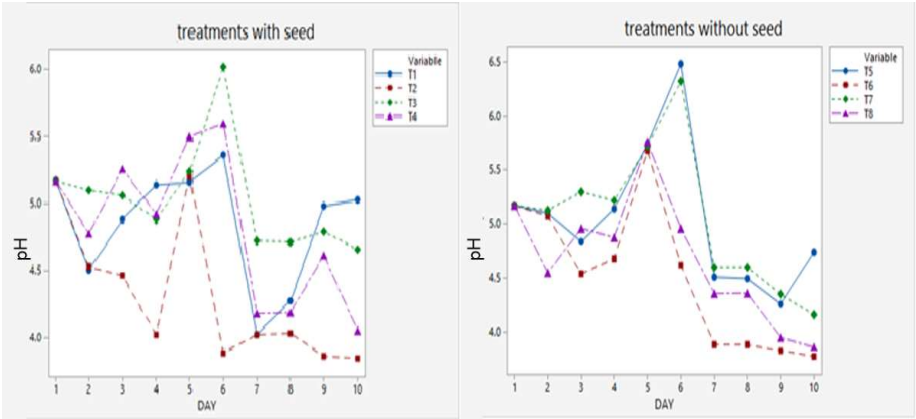

Figure 4 pH of different treatments for 8-day storage period (T1-with seed, vacuum and chilled, T2-with seed, vacuum and ambient, T3- with seed, without vacuum and chilled, T4- with seed, without vacuum and ambient, T5-without seed, vacuum and chilled, T6-without seed, vacuum and ambient, T7- without seed, without vacuum and chilled, T8- without seed, without vacuum and ambient)

Table 7. Analysis of variance of pH of fresh-cut jackfruit stored for 8 days

	Storage Period (Day)							
Main Effects	1	2	3	4	5	6	7	8
A: preparation	2.06	0.00	0.58	43.55**	0.30	0.24	0.03	2.05
B: packaging	0.28	22.23**	0.53	2.60	0.85	2.75	12.05*	0.37
C: storage con.	1.13	0.70	6.39	0.09	11.39*	6.45	22.59**	4.02
Interaction								
A x B	4.17	0.02	0.08	1.38	0.63	0.12	0.00	0.07
A x C	0.13	0.17	0.08	0.99	0.49	0.14	00.91	0.54
B x C	1.13	2.16	2.96	0.12	1.06	0.08	0.07	0.84

*,**,***Significant to p≤0.05, 0.01 and 0.001, respectively.

Packaging method does not directly affect the pH of the product. According to Aneja et al (2014) fruit juices have pH in the acidic range (<4.5) serving as important barrier for microbial growth thus even at different packaging condition, change in pH is dictated by the natural physicochemical properties of the fruit as well the method of how it's handled.

Color Evaluation

The analysis of variance of the color parameters (Tables 8 & 9) shows that the interaction of the three factors was significant for lightness (Hunter *L** value), and only packaging method and storage condition interaction was significant for yellowness (Hunter b*value). As observed, the percentage of variance explanation is very low at all parameters due to the fact that even though the product has undergone fermentation and other quality degradation, the yellow color of the fruit is retained. According to Chichester et al (1965), the stability of various carotenoid pigments is a function of their association with cellular proteins and other substances. Thus, 3-carotene in commodities are relatively stable pigments which persist through prolonged storage.

Table 8. Analysis of variance for color parameter (L*) of fresh-cut jackfruit for 8-day storage period

Main Effects	Storage Period (Day)							
	1	2	3	4	5	6	7	8
A: preparation	2.53	0.26	0.02	0.00	0.01	1.84	0.13	6.38*
B: packaging method	2.79	6.26*	2.53	7.19*	0.41	1.83	11.15**	5.21*
C: storage condition	2.31	8.80**	0.09	26.45***	0.00	0.50	11.88**	3.43
Interaction								
A x B	1.46	0.70	5.65*	0.69	1.80	2.82	0.19	0.00
A x C	0.44	3.87	0.04	3.64	0.94	5.20*	0.21	0.04
B x C	4.75	2.14	3.20	3.64	5.59*	2.12	43.88***	10.68**

*,**,***Significant to p≤0.05, 0.01 and 0.001, respectively.

Table 9. Analysis of variance for color parameter (b*) of fresh-cut jackfruit

Main Effects	Storage Period (Day)							
	1	2	3	4	5	6	7	8
A: preparation	1.95	0.04	0.05	0.05	0.37	0.05	0.00	0.03
B:packaging method	0.27	1.78	0.04	1.35	1.12	10.27*	5.77	1.42
C:storage condition	1.19	3.30	1.45	1.88	2.84	3.65	0.06	19.45*
Interaction								
A x B	0.47	0.80	0.23	2.03	0.08	0.02	0.15	0.02
A x C	0.66	1.17	1.52	0.17	0.33	0.38	0.30	0.22
B x C	0.54	4.37	6.29	8.85	6.19	6.34	0.39	35.38**

,**,***Significant to P≤0.05, 0.01 and 0.001, respectively.

Figure 5 shows the Hunter b*. Positive b* indicates yellowness of the product. Generally, it can be observed that treatments stored in ambient conditions (T_4, T_6 & T_8) have observable lower b* than those stored at chilled conditions (T_3, T_5 & T_7) except T_1. It can also be observed that deseeded pulp have lower Hunter b* during the late day of storage compared to intact samples. This may be due to the browning of the pulps as tissues deteriorated during storage. This is in agreement with the findings of Galvez (2015) with dehydrated jackfruit pulps. Wounding increases rates of water loss, softening, and browning. Using very sharp tools to peel fruits and cut their flesh limits cellular damage and reduces leakage of cellular contents and enzymatic browning mediated by the enzymes polyphenol oxidase and phenol oxidase (Kader 2008).

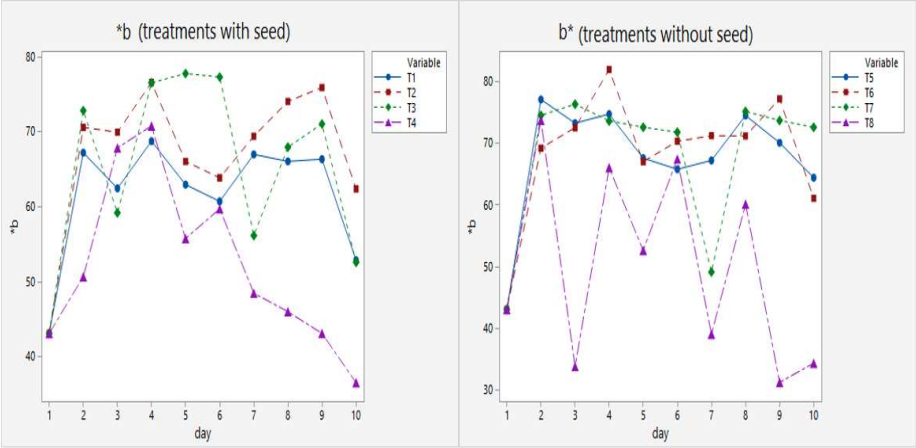

Figure 5. Hunter b*of different treatments at different storage periods (T1-with seed, vacuum and chilled, T2-with seed, vacuum and ambient, T3- with seed, without vacuum and chilled, T4- with seed, without vacuum and ambient, T5- without seed, vacuum and chilled, T6- without seed, vacuum and ambient, T7- without seed, without vacuum and chilled, T8- without seed, without vacuum and ambient)

Degree of Browning

Accumulation of the formed brown pigments will dictate the degree of how physical property of the pulp has deteriorated in terms of firmness and color. As shown in the plots in Figure 6, deseeded pulp has a very evident increase in absorbance compared to intact pulps. As cited by Watada et al (1990), the practice of fresh-cut processing causes wounding, increases metabolic activities, and decompartmentalizes enzymes and substrates. This may cause browning, softening, decay, and off-flavor development.

Storage temperature greatly affects the degree of browning (Table 10). Treatments stored at room temperature have higher degree of Browning compared to those chilled (Figure 6). Biochemical reactions such as respiration speed up at higher temperatures. The increase in absorbance could be explained by nonenzymatic browning reactions such as the assumption that high temperature accelerated the carotenoid isomerization, which led to the loss of yellowness (Chen et al 1995).

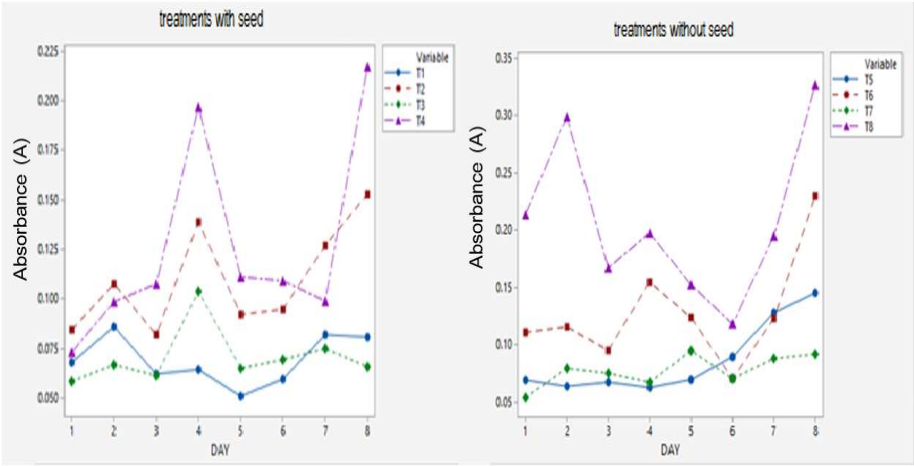

Figure 6. Absorbance (A) of different treatments at different storage periods (T1-with seed, vacuum and chilled, T2-with seed, vacuum and ambient, T3- with seed, without vacuum and chilled, T4- with seed, without vacuum and ambient, T5-without seed, vacuum and chilled, T6-without seed, vacuum and ambient, T7- without seed, vacuum and chilled, T8- without seed, without vacuum and ambient)

Table 10. Analysis of variance for absorbance parameter of fresh-cut jackfruit

Main Effects	Storage Period (Day)							
	1	2	3	4	5	6	7	8
A: preparation	0.96	0.60	0.72	0.01	1.46	0.05	1.62	0.85
B:packaging method	0.16	0.43	0.93	13.33*	0.75	0.52	0.00	0.10
C:storage condition	2.65	2.17	8.75*	96.13***	10.10*	6.92	2.54	12.95*
Interaction								
A x B	0.42	1.19	0.26	0.06	0.04	0.00	0.32	0.0
A x C	2.62	1.61	0.49	0.43	0.30	0.73	0.14	0.56
B x C	0.66	0.94	2.08	2.06	0.02	3.24	0.72	2.32

*,**,***Significant to P≤0.05, 0.01 and 0.001, respectively.

Biochemical reactions such as respiration speed up at higher temperatures. The increase in absorbance could be explained by nonenzymatic browning reactions such as the assumption that high temperature accelerated the carotenoid isomerization, which led to the loss of yellowness (Chen et al 1995). Another factor is the favorable environment for increase in microbial quality that causes the degradation of the tissues those results to browning.

Firmness

Results show that as time of storage increases, fruit pulp becomes softer thus readings in all the treatments decrease by approximately ≤0.77 (Table 11). During fruit ripening, cell wall polysaccharides are extensively modified by a variety of ripening-related enzymes secreted from the symplast into the cell wall space. This process continues even after cutting open the fruit pulp. The changes affect the structure and strength of the wall, and ultimately bring about fruit softening (Brummell 2006). It was observed that packaging method and storage condition significantly affect the firmness of the pulps with storage (Table 12). As cited by Bruwell (2006), firmness is determined largely by the physical anatomy of the tissue, particularly cell size, shape and packing, cell wall thickness and strength, and the extent of cell-to-cell adhesion, together with turgor status.

Table 11. Penetrometer (kg/cm^2) reading of each treatment during the 8-day storage period

Treatments	D0	D1	D2	D3	D4	D5	D6	D7	D8	Mean
1	1.29	1.25	1.06	0.97	1.04	1..27	0.99	1.21	1.24	1.11
2	1.29	1.24	0.87	0.75	0.72	0.86	0.67	0.89	1.06	0.88
3	1.29	1.11	1.06	0.99	0.82	1.08	1.22	1.22	1.18	1.09
4	1.29	1.03	1.12	0.74	0.8	0.812	0.68	0.61	0.57	0.79
5	1.29	1.24	1.09	0.92	1.17	1.16	0.9	1.04	1.62	1.14
6	1.29	1.14	1.95	0.97	0.76	1.03	0.74	0.83	0.88	1.04
7	1.29	1.08	0.95	1.01	1.32	0.75	1.18	1.07	1.04	1.05
8	1.29	1.1	0.64	0.71	0.67	0.55	0.54	0.6	0.52	0.67

Table 12. Analysis of variance for firmness parameter (kg/cm^2) of fresh-cut jackfruit

Main Effects	Storage Period (Day)							
	1	2	3	4	5	6	7	8
A: preparation	0.31	0.31	0.13	0.42	0.96	0.05	0.21	0.00
B:packaging method	16.41*	1.64	0.13	0.01	4.29	0.12	0.30	11.16*
C:storage condition	1.78	0.13	9.93*	22.95**	4.64	80.57***	47.04**	21.13*
Interaction								
A x B	1.22	3.30	0.13	0.06	1.44	0.03	0.01	0.12
A x C	0.01	0.26	0.64	6.07	0.28	0.02	0.47	0.31
B x C	0.15	0.60	2.77	0.01	0.02	14.33*	5.49	0.22

,**,***Significant to P≤0.05, 0.01 and 0.001, respectively.

It was observed that treatments stored at ambient temperature have very significant decrease in the firmness of the pulp (Figure 7). While treatments stored at chilled condition and with intact pulps showed minimal changes in their firmness. For treatments stored at chilled condition, the firmness of the pulp was mostly retained or only changed slightly. This implies that the optimum condition for the storage of fresh-cut is in chilled conditions. Processes of plant senescence increase as the tissue of the harvested plant undergoes degradative changes in membranes, cell walls, subcellular organelles, proteins and texture. Wounding (fresh-cut processing) activates not only 1-aminocyclopropane-1-carboxylate (ACC) synthase but also ethylene production (Yu & Yang 1980). For best quality retention of fresh-cut fruits, the preferred storage temperature is not higher than 5°C, which is considered a chilling temperature for chilling sensitive tropical fruits (Dea et al 2010).

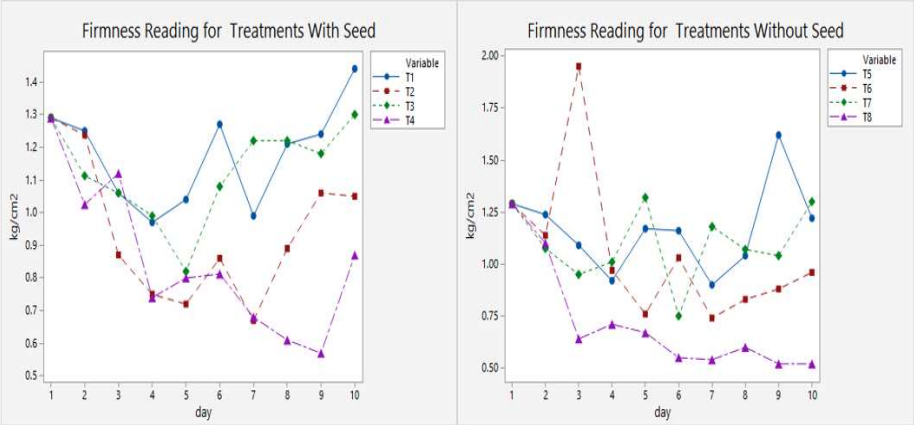

Figure 7. Firmness (Kg/cm^2)of different treatments at different storage periods (T1-with seed, vacuum and chilled, T2-with seed, vacuum and ambient, T3- with seed, without vacuum and chilled, T4- with seed, without vacuum and ambient, T5-without seed, vacuum and chilled, T6-without seed, vacuum and ambient, T7- without seed, without vacuum and chilled, T8- without seed,without vacuum and ambient)

CONCLUSIONS

Deseeded products have faster deterioration compared to seed-intact treatments. Treatments stored in chilling (4-6°C) condition exhibited lesser variation in TA, TSS, pH, browning and firmness during the storage period compared to those stored at ambient temperature. Chilled treatments packed in vacuum have slower deterioration compared to treatments which are conventionally packed.

IMPLICATION

The study shows that for fresh cut jackfruit processing, it is essential to use intact-seeds pulp, vacuum packing and keeping in a low temperature storage to lengthen the shelf life of the product.

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