PAPER 2:
PHYSICO-CHEMICAL 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 is noted to play a significant role in the physico-chemical properties of the food product. This study was conducted to evaluate the effects of deseeding, storage condition, and packaging method on the physico-chemical properties of fresh-cut jackfruit during the 8-day storage period. A 2x2x2 factorial experiment was used in the study making a total of 8 treatments. All of the treatments were subjected to physico-chemical 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 are deseeded have shown significant decrease in the physico-chemical attributes of the product which is an indicator for product quality. Deseeded products have much faster deterioration compared to treatments with seeds. Treatments stored in chilling (4-6°C) condition exhibited lesser variation in TSS, pH, browning and firmness during the storage period compared to those stored at ambient temperature. Packaging method protects the product from contamination of the product but it does not solely dictates the pH and TA reading during storage. Treatments packed in vacuum have slower deterioration compared to treatments which are conventionally packed.

Keywords: fresh-cut, jackfruit, physico-chemical, low-temperature, vacuum packed

INTRODUCTION

Jackfruit is a huge fruit, which is becoming more popular in the market due to its unique flavor and the health benefits offered to the consumers. One way of producing this fruit into a high value product is through minimal processing which can also reduce its weight.

Fresh-cut products are highly perishable due to the disruption of tissue and cell integrity, with a concomitant increase in the enzymatic, respiratory and microbiological activity, which reduce 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. Also, higher respiration rates can result in more rapid loss of acids, sugars and other components that determine flavor quality and nutritive value.

In general, fresh-cut fruit should be rinsed just after cutting with cold (0 to 1°C, 32 to 34 °F) chlorinated water at pH 7.0. 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-cutting washing or dipping may have negative consequences regarding 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 increases 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 the wounding response.

Strict temperature control is required to minimize the increased respiration rates of fresh-cut 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 fresh-cut 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 physico-chemical properties of minimally processed jackfruit.

METHODOLOGY

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.

Preparation and Processing of Fresh-Cut Jackfruit

The jackfruits were washed with soap and water, scrubbed until visually clean from adhering organic matter such as leaves, soil, and stems. The whole fruit was sanitized with chlorine solution of 100 ppm concentration equivalent to 0.01% solution and was sliced longitudinally for ease of handling. The pith was removed and fruit pulps were segregated from the seed and other jackfruit by-products. The jackfruit pulps were trimmed and only those that are undamaged were used. Food grade sodium hypochlorite (NaOCl) solutions with concentrations of 0.04374% w/v, calcium chloride (CaCl2) solutions (w/v) at 0.74% and ascorbic acid solutions (w/v) at 0.65% (Patindol, 2016) were prepared. The product was soaked to pretreatment solutions (NaOCl, CaCl2, ascorbic acid) for 2 minutes. The product was put into sanitized hanging baskets to remove excess water.

After draining off the liquid, treatments were packed in respective containers. For vacuum packaging, polyethylene bags with 0.003 mm 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 the refrigerator (crisper) (4-6°C), and the remaining treatments (2, 4, 6, and 8) were stored at ambient temperature (30 °C) (Table 1). The process flow of fresh-cut jackfruit production is shown in Figure 1 and 2.

Experimental Design

A 2x2x2 factorial design was employed to compare the different responses of physico-chemical 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

TREATMENTS	JACKFRUIT PULP PREPARATION	PACKAGING METHOD	STORAGE CONDITION
T1		Vacuum	Chilled
T2	With seed		Ambient
T3		Without vacuum	Chilled
T4			Ambient
T5		Vacuum	Chilled
T6	Without seed		Ambient
T7		Without vacuum	Chilled
T8			Ambient

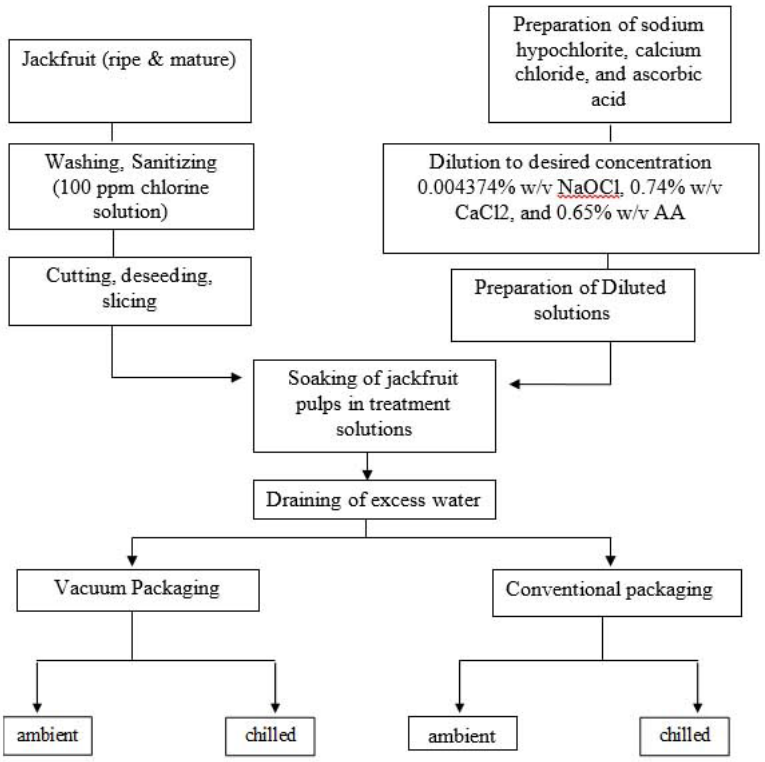

Figure 1. Process flow for fresh-cut jackfruit preparation

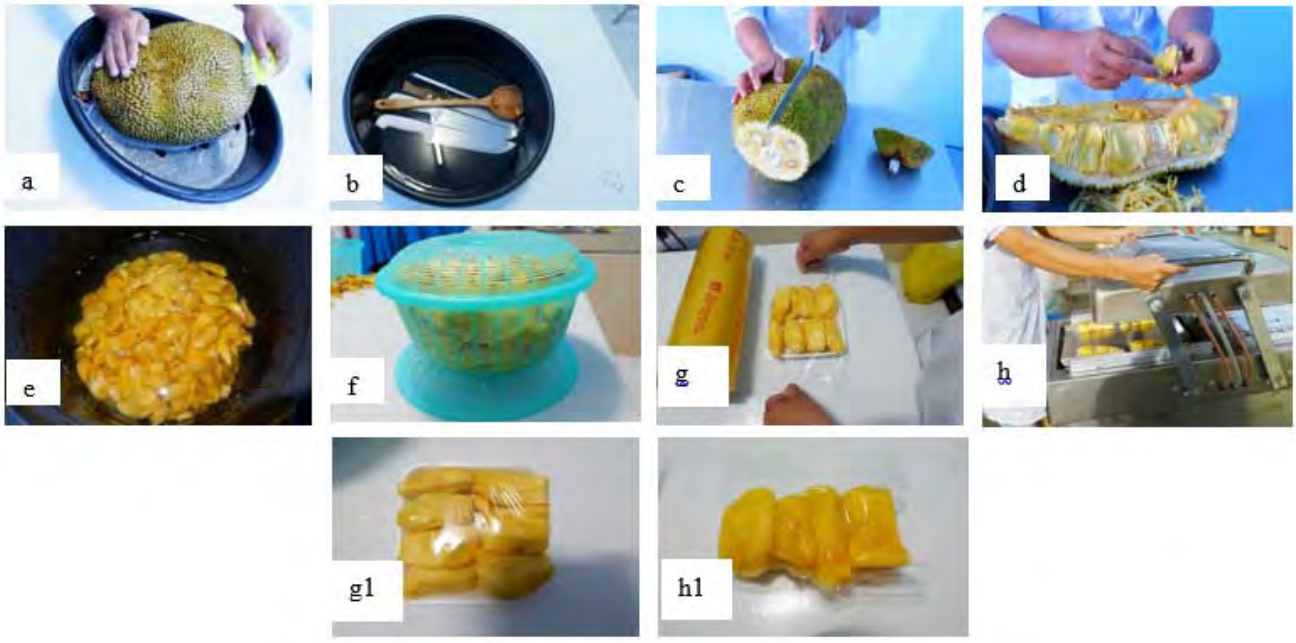

Figure 2. Preparation of fresh-cut jackfruit. (a) cleaning and sanitizing of whole fruit, (b) sanitizing of utensils for cutting and dipping, (c) opening of fruit, (d) depulping/deseeding, (e) pretreatment soaking, (f) draining of pretreatment solution, (g) (1 conventional packaging) (2 vacuum packaging), (g1 & h2) product

Physicochemical Analysis

Evaluation of all physico-chemical properties of fresh-cut jackfruit was done on the first until the eighth 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. Then the percent of dry substance from the reading was obtained as the correction factor. After calibrating, a drop of pure juice from squeezing the sample was placed on the prism.

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 25 ml distilled water in a volumetric 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 following formula:

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

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=(weight of sample (g))/(vol.aliquot) x 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 five gram pureed sample. Reading was done in three replications.

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 50 ml of 2% (v/v) acetic acid solution for 2 hrs. Subsequently, the sample was placed in the plastic centrifuge tubes (50 ml capacity) then centrifuged at 3,000 ppm for 1 hr. The supernatant was obtained and the absorbance was read at 420 nm with UV-Vis double beam spectrophotometer (Genesys™ 10S, USA). Two percent acetic acid was used as a blank. Three readings was done and the results was 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 values were reported in kg/cm^2 force.

The sample was put in levelled 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. 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 physico-chemical properties of fresh-cut 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. It was observed that there is no significant difference ($p \leq 0.05$) on the TSS readings between treatments during

0 and 1 day, but apparent changes occurred during day 2 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

Main Effects	STORAGE PERIOD (DAY)							
	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

NS: not significant. *,**,*** Significant to P≤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). Suslow and Cantwell (2013) mentioned higher respiration rates indicate a more active metabolism and usually a faster deterioration rate in fruit tissues. Also higher respiration rates can result in more rapid loss of acids, sugars and other components that determine flavor quality and nutritive value.

Another observation noted was treatments with intact fruit pulps stored at chilled condition also exhibit increase in their TSS at the early stage of storage. The chilling condition helps decrease the rate of respiration thus allowing senescence to take place slowly and makes the fruit pulp sweeter (Figure 3).

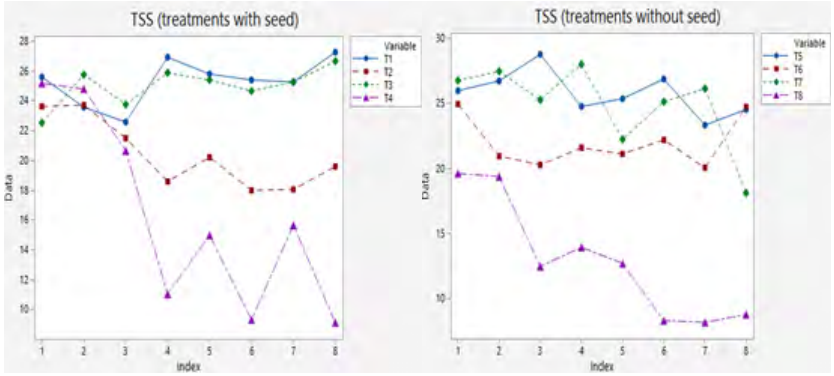

Figure 3. TSS of different treatments at different storage period *T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient

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 TSS (24.6, 24.32, 25.03 and 24.23) during the storage period compared to those stored at ambient temperature (20.26, 16.64, 21.66, and 13.61). Again, 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 (Figure 3). It was further observed that treatments which have intact fruit pulps (with seed) have slight decrease in TSS during the 3-day storage of period (±1.84) compared to treatments which are deseeded that shows abrupt decrease in TSS (±4.35). 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. Fresh-cut 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. 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 4, 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) have maintained its vacuum throughout the storage period.

Figure 4. Vacuum packed fresh-cut jackfruit at (left) chilled and (right) room temperature storage (3 days)

A significant increase in TA was observed in all treatments as storage time increases. It was observed that treatments stored at ambient temperature establish 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 increases by ≤0.007888 (Figure 5). Table 3 shows the ANOVA of TA during the 8-day storage. It was observed that storage condition as well as packaging method greatly affects the TA of the product. And the interaction of factors: packaging method and storage temperature is highly significant starting day 3.

It was further observed that TA of treatments stored at room temperature rapidly increased compared to refrigerated samples which show decrease in TA during early days of storage and increased during late days of storage (Figure 5). 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. Treatments stored at chilled condition, established a slow

change in TA compared to treatments stored in ambient condition during the storage period. As mentioned by Cantwell & 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.

Table 3 and Figure 5 show that rapid increase in TA was observed in treatments which were deseeded and stored at ambient temperature. This implies that fresh-cut jackfruit's TA quality can be retained or variation from the produce can be minimized when the pulps' tissue is not ruptured due to deseeding and when it is stored at chilling conditions.

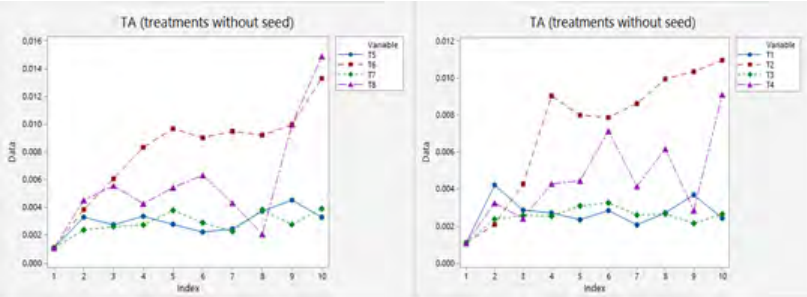

Figure 5. TA of different treatments for 8-day storage period (T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient).

Table 3. Analysis of variance of TA of fresh-cut jackfruit stored for 8 days

Main Effects	STORAGE PERIOD (DAY)							
	1	2	3	4	5	6	7	8
A:preparationns	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 Bns	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

NS: not significant. *,**,*** Significant to P≤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 decreases at different treatment by ≤1.4. The decrease in pH corresponds to the increase in TA during the storage period (Figure 6) but they are not directly correlated.

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.

Figure 6 shows that treatments stored at ambient condition have 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 will exhibit increase in fermentation because environment for microbial activity is very favorable for microbial growth. Period of handling of the pulps may also contribute to microbial contamination thus deseeded samples (T1-T4) exhibit lower pH reading compared to sample with intact pulps (T5-T8) during the last day of storage period.
Table 4 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 7. It was observed that treatments which are deseeded have more significant decrease in pH compared to intact fruit pulps. 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, 2002).

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 physico-chemical properties of the fruit as well the method of how it's handled.

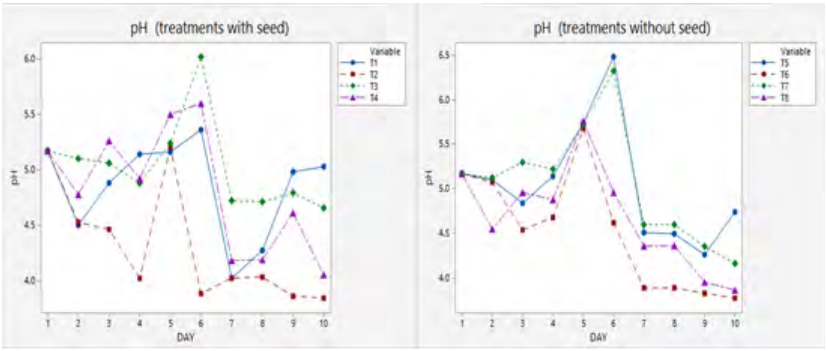

Figure 6. pH of different treatments for 8-day storage period (T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient)

Table 4. Analysis of variance of pH of fresh-cut jackfruit stored for 8 days

Main Effects	STORAGE PERIOD (DAY)							
	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

NS: not significant. *,**,***Significant to P≤0.05, 0.01 and 0.001, respectively.

Color Evaluation

The analysis of variance of the color parameters (Tables 5 & 6) shows how the interaction

of the three factors was significant for lightness (Hunter L* value), and 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 5. 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**

NS: not significant. *,**,*** Significant to P≤0.05, 0.01 and 0.001, respectively.

Table 6. 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**

NS: not significant. *,**,*** Significant to P≤0.05, 0.01 and 0.001, respectively.

Figure 7 shows the Hunter *b. Positive *b indicates yellowness of the product. It can be observed that treatments stored in ambient conditions (T2, T4, T6 & T8) have observable lower b* than those stored at chilled conditions (T1, T3, T5 & T7). 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).

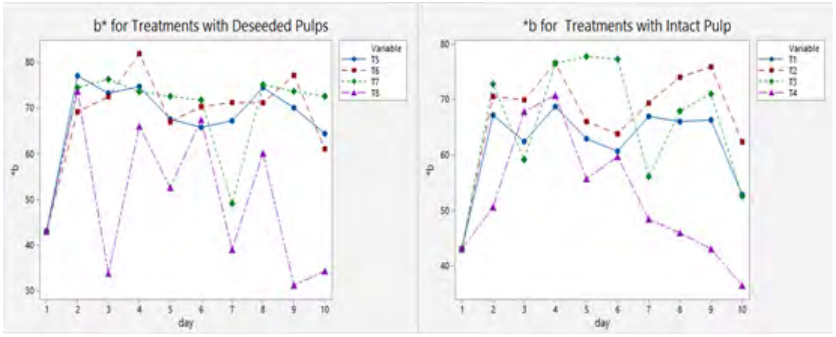

Figure 7. Hunter b*of different treatments at different storage period *T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient

Degree of Browning

Accumulation of the formation of 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 8, deseeded pulp has a very significant 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. Treatments stored at room temperature have higher degree of browning compared to those chilled (Figure 8 & Table 7).

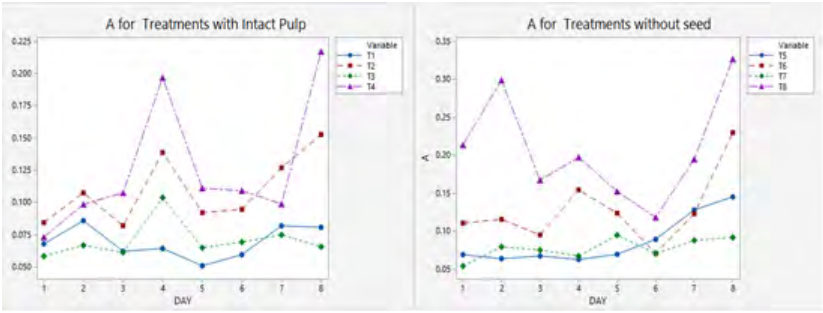

Figure 8. Absorbance of different treatments at different storage period *T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient

Table 7. 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

NS: not significant. *,**,***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

Firmness of the fruit pulp was measured using a fruit penetrometer (GY-3 fruit sclerometer). As expected, as time of storage increases, fruit pulp becomes softer thus readings in all the treatments decrease by approximately ≤0.77. 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 8). 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 8. Analysis of variance for firmness parameter (kg/cm²) 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

NS: not significant. *,**,*** 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 9). 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 were 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 tissue is harvested from the plant and involves degradative changes in membranes, cell walls, subcellular organelles, proteins and texture. Wounding (fresh-cut processing) activates not only ACC synthase and ethylene production (Yu & Yang, 1980). For best quality retention of fresh-cut fruits, the preferred storage temperature is not higher than 5oC, which is considered a chilling temperature for chilling sensitive tropical fruits (Dea et al., 2010).

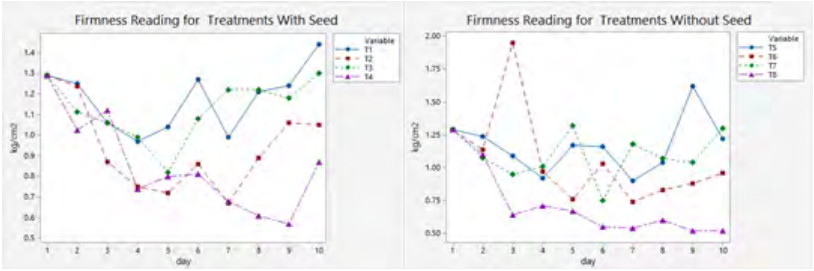

Figure 9. Firmness of different treatments at different storage period (T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient)

CONCLUSIONS

Processing method plays a significant role in the physico-chemical property of the product. Jackfruit pulps which are deseeded have shown significant decrease in the physico-chemical attributes of the product which is an indicator for product quality. Deseeded products have much faster deterioration compared to intact treatments.

Treatments stored in chilling (4-6°C) condition exhibited lesser variation in TSS (24.6, 24.32, 25.03 and 24.23) during the storage period compared to those stored at ambient temperature (20.26, 16.64, 21.66, and 13.61).The chilling condition helps decrease the rate of respiration thus allowing senescence to take place slowly and makes the fruit pulp sweeter. Treatments stored in chilled condition also have minimal change in pH (±0.59), TSS (±1.84), browning (±0.28) and firmness (±0.025) compared to treatments stored in ambient conditions (±0.855), (±4.35), (±0.2214) and (±0.44) respectively. Low temperature storage minimizes 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.

Packaging method protects the product from contamination of the product but it does not solely dictates the pH and TA reading during storage. Treatments packed in vacuum have slower deterioration compared to treatments which are packed with cling wrap. Limitation of oxygen as well as protecting the product from contaminants helps reduce the physico-chemical changes in the product.

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