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Effects of Freezing Time on Degradation of Durian (*Durio Zibethinus* Murr.) Fruit's Attributes During the Frozen Storage

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Effects of Freezing Time on Degradation of Durian (*Durio Zibethinus* Murr.) Fruit's Attributes During the Frozen Storage

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Running head: Fresh durian freezing preservation

Abstract. Freeze-process has been applied in preserving many fresh horticultural commodities addressed to the medium-distancing distribution. In this study, effect of freezing process and storage time on durian's attributes degradation was observed. A hundred durian fruits were treated with two-level combinations of the freezing process which freezing at the core's temperature -15^{o}C for 10 minutes (treatment A) and 20 minutes (B) subsequently followed by the frozen-storage for -10 ^{o}C for 0, 10, 20, and 30 days. At different interval time, the frozen samples were thawed at 4^{o}C for 24-hours. Then, physical, chemical, and sensory parameters were periodically assessed. The result showed that treatment B provided a significantly better output than treatment A, proved through a lower weight loss, brighter and lighter yellow on pulp, softer pulp, lower value of moisture content on the pulp, and a remained stable of succinate acid's profile. Furthermore, based on the preference evaluation test, the fruits were accepted by respondents.

Keywords: Freezing, Core Temperature, Medium Distribution, Fruit’s Attributes, Customer’s Preference

INTRODUCTION

Durian (*Durio zibethinus* Murray) is one of the tropical horticultural commodities gaining great attention worldwide. This fruit is categorized as the super-premium class due to its yellowish of the pulp color, its sweetness of the taste, and its unique ripening flavor (Ketsa *et al.* 2020; Somsri & Vichitrananda 2007). Thailand, Malaysia and Indonesia have been recognized as the global producers supplying those fruits throughout the world (Subhadrabhandu & Ketsa 2001; Wilaipon 2011). Due to the global costumer’s expansion, the most promising markets consisted a new segmented costumers demanding several local cultivars of durian with their own unique characteristics relating with their performances has been properly increasing (Leontowicz et al. 2008)

Those cultivars have a wide range of different indications on performing their optimal maturity based on physiological alterations (Ketsa et al. 2020; Thongkum et al. 2018; Tifani et al. 2018). Changing husk into yellowish green, appearing a specific durian-flavor at abscission layer, softening the spines as well as rising the fruit’s stalk elasticity have distinctly indicated for demonstrating the initial maturity gradually leveling-up during the postharvest period (Ketsa and Daengkanit 1998; Pascua and Cantila 1992; Tongdee et al. 1990; Wattanawichean et al. 2002). As one of the climacteric tropical fruit, durian’s maturity has a limited shelf of life. Therefore, freezing storage as one of the physical fruit preservations has inspired in creating a wide range of opportunities in extending the fruit supply chains, particularly in supporting the export-import trade distribution (Arancibia-Avila et al. 2008; Yahia 2011).

Applying freeze-process as the tool for handling fruit preservation has contributed many beneficial effects. Some previous studies have confirmed reducing water activity relating to hampering microbial growth and also decaying the initial fruit’s decay due to slowing-down of several enzymatic reactions having a critical role in maximizing the shelf of life of several frozen foods (Alhamdan et al. 2018; Sanz et al. 1999; Ratti 2001; Sun and Li 2003). A rapid incline of the rate of frost formation has been occurred in the initial period due to higher relative humidity. This phenomenon has accumulated the frost formation on the surface caused by air circulating blockage, which is truly destructive to the stability of air-flow rate cascading on the surface of the frozen material (Ameen et al. 1993; Fisk et al. 1985; O'Neal et al. 1989). Consequently, the partial moisture pressure has drastically dropped, then it has created much more work-loads related to the fan operation affecting the terminating freezing operation (Amer and Wang 2017; Padki et al. 1989; Yan et al. 2005). To normalize the situation, then a regular defrosting process has been selected as a way out for reducing the pressure gap. Therefore, no more an excessive rate of condensate formed in-lining with an improvement of freezing capacity scheduled in a range of measured time allocation (Dong et al. 2011; Jhee et al. 2002; Kim and Lee 2011).

Once releasing a frozen commodity from the refrigeration system, a type of thawing process has held on an essential key for readjusting the fruit's physiological development. Introduction of thawing process through moisture supply near its freezing point has maintained the integrity of the fruit's structure (Assgehegn et al. 2019; Martinez-Navarrete et al. 2019; Novak and Jakubczyk 2020). Therefore fruit's discoloration and its versatile texture have been less impacted (Khalloufi and Ratti 2003; Krzykowski et al. 2018; Silva-Espinoza et al. 2019) and more acceptable by consumer's perception (Tagubasse et al. 2016; Zhang et al. 2007; Zhang et al. 2004). Whereas inducing hot moisture's supply as a prime-medium has gained more positive effect in maximizing the specific flavor produced by the aromatic's enzyme contained in many particular fruits, such as strawberry (Modise 2008), mango (Chassagne-Berces et al. 2010), peach (Chassagne-Berces et al. 2009), and dates (Alhamdan et al. 2018). Previous studies focusing on exposure of the frozen environmental storage addressed to the whole durian as one of the prospective tropical horticultural commodities are relatively rare to be published.

The objective of the research was to determine effects of freeze-process and frozen storage period on physics-chemical's fruit attributes and also sensory preferences during the storage. The research could be implemented on estimation of self-life and far away distribution as well. Therefore, these data would be crucial as a scientific evidence for expanding market access of local durians coming from Indonesia.

MATERIALS AND METHODS

Time, Site Locations and Durian Fruits

This research was conducted at the Applied Research Institute of Agricultural Quarantine (ARIAQ), Bekasi Regency, from January – December 2020. One hundred local durian fruits were utilized in this study. The local cultivar namely "Langgang Kamang" was traditionally cultivated in a local orchard “R.E Durian Farm” located at Selareh Aia urban-village, Palembayan sub-district, Agam Regency, West Sumatera Province 26164, Indonesia, with a global-map coordinate at -0.1209792,100.1085487. The durian fruits used in this research had a ranging-level of physiological maturity ranging from 85-90% under the regular cultivation sessions and territorial circumstances, in late August 2020. Twelve hours were required to distribute those fruits through a land expedition using a vehicle equipped with the air ventilator, for defending the temperature from 25-28 ^{o}C to the final destination-workshop of the Applied Research Institute of Agricultural Quarantine-Bekasi Regency, West Java Province.

Freeze-Process and Its Freezing Storage

Initially, it was selected 10 whole fruits as the control for further assaying of their physics-chemical and organoleptic properties. In other side, three fruits of 90 whole ones were chosen out for monitoring temperature-process through inserting thermometer loggers (K Type SD Card PH99, China), in between 20-25 cm of depth, reaching into the pulp. Together with the three selected fruits for observing the pulp’s temperature locating 40 cm from the blowing cold-air source, then the whole fruits were inserted into a reefer consignment (Daikin LXE-10E, Japan) for chilling at 4^{o}C for 24 hours.

The next process was freezing process for achieving the targeted temperature at -15^{o}C. A series of regular observations was taken out to monitor the relationship between the reached temperature observed on thermometer-probes and the certain time-process during this step. When the defrost-cycle was naturally occurred, indicated by noisy and abnormal-engine sounds, then it required several periods to normalize this cycle through an approach of the off-cycle defrost method as previously studied (Amer and Wang, 2017; Amer and Wang 2021; Zheng et al. 2020). Soon after the process was normalized, marked by regular and normal-engine sounds, then further observations were resumed up to the targeted temperature finally achieved. After that, calculation of time- process was commenced, subsequently for 10 minutes (as treatment A) and 20 minutes (as treatment B).

When the entire freezing process was accomplished, then the freeze-storage temperature was adjusted into -10ºC for 30 days. In each of the 10 day-interval of storage time, a series of physics-chemical and sensory examinations were conducted to both, 15 pieces of fruits treated with the A-level and the same quantity of other fruits treated with the B-one, previously transferred into a fruit showcase (LG-800, South Korea) at 4ºC for the thawing process, in a day before.

Weight Loss

This parameter was periodically calculated based on a method described by Nunez and Emond (2007).

Moisture Content

This analytical procedure and its calculation were formulated based on AOAC (2000).

Color

Color attributes measured on the pulp's surface were determined by using a colorimeter (Konica Minolta CR 13, Japan). There are three observed parameters, such as: L (lightness), a (+a = red; -a = green), and b (+b = yellow; -b= blue) (Voon et al. 2006) read on the screen. Chroma value and hue angle have subsequently been calculated as follows:

$$\text{chroma} = (a^2 + b^2)^{(0.5)}$$

$$\text{hue}^o = \tan^{-1}\left(\frac{b}{a}\right)$$

Total Soluble Solids

The content of total soluble solids was periodically measured using a pocket refractometer (Atago Co, Japan) based on a method developed by Booncherm and Siriphanich (1991). This observation was carried out on the flesh of the durian fruit by squeezing the flesh until the fruit liquid came out, then three were observed on the prism of a hand-refractometer. Observations were made at each interval of the storage period.

Determining of Fruit Firmness

A whole fruit was peeled. Then, the fleshes of fruit were released from the peel to be moved in a plastic plate. At least, five fruit's ones were assayed by using a fruit hardness tester (Cat No. 9300, Tokyo-Japan) based on a method developed by Prasetia et al. (2018).

Succinate Acid

Analysis of succinate acid was taken out in the testing laboratory of Saraswanti Indo Genetech, Bogor, West Java Province, Indonesia using a method proposed by Tagubasse et al. (2016).

Organoleptic Test

The 21 trained panelists were involved in evaluating the pulp‘s color, fruit's aroma, taste, and texture. Panelists trained as organoleptic examiners aged between 20-45 years with organoleptic analyst profession consisted of 10 men and 11 women. Samples of durian fruit were presented as many 2 pieces of durian's fleshes carried out in an organoleptic test laboratory with a controlled temperature of around 22-24^{o}C. The hedonic scale consists of 5-points (5: like very much; 4: like; 3: moderate acceptance; 2: dislike; 1: dislike very much). There were the two- types of samples, in between 10 minutes in a break by adding the mineral water to neutralize from the previous senses, served to the panelists in the four different periods.

Statistical Analysis

The experimental design used in this study was the factorial completely randomized design with the three replications in each of observations. The profiles of temperature –time relationships were processed by using Microsoft Excel 2010. While the periodic-values gained from the durian samples observations were statistically differentiated through ANOVA followed by Duncan Multiple Range Test (DMRT) for determining the further significant results using SPSS 20.0 and were expressed as mean ± S.E.

RESULTS

Relationship between the Time Process and the Core Freezing Temperature

A definite period was required for this process of declining temperature inside the durian fruit core until the targeted freezing temperature was achieved. A complete temperature oscillation during the treatment was described in Figure 1. Initially, the trend was sharply declining. Then, it sharply decreased due to the defrosting cycle of time. Once the circulation of the cooled fresh air was retreated into a normal freezing indicated a steady pattern of lowering of three temperature-probes, until the final temperature, as described in Figure 1.

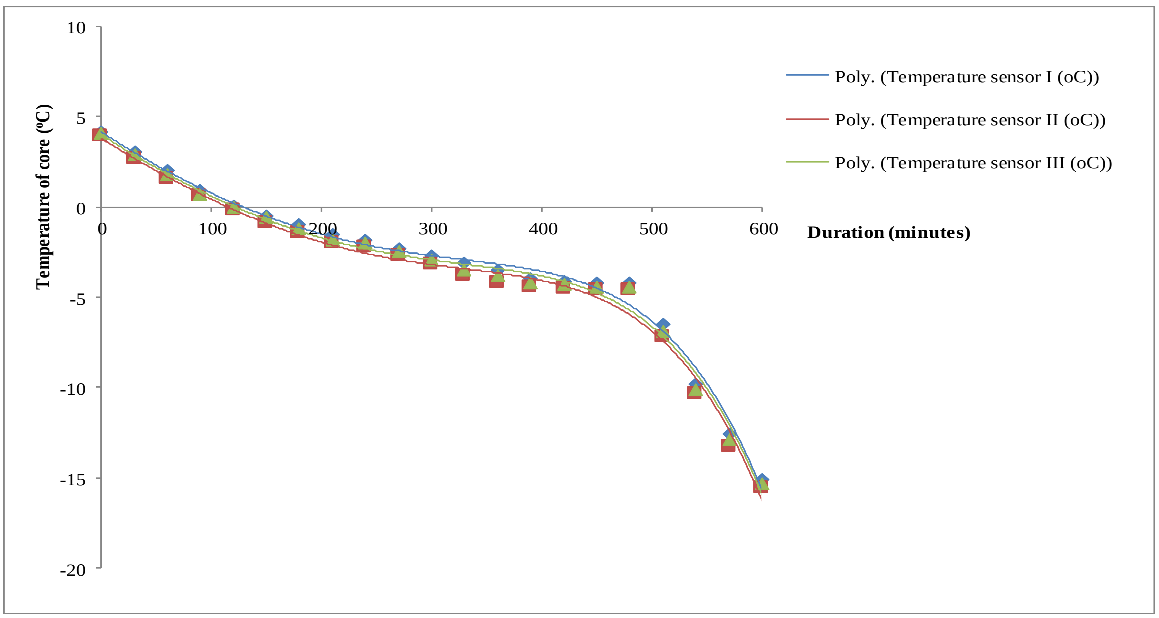


Figure 1. Core's profiling temperature from the pre-cooling process, at 4ºC, to the targeted freezing point, at -15ºC.

The entire temperature-loggers briefly showed a series of data having a close relationship with each other. In between the data obtained from this experiment, it is distinct that the temperature sensor I have the best correlation (R^2-value = 0,991) than another (Table 1)**.** In the following step of freezing storage, nearby achieving the two-targeted freezing temperatures, the three temperature-probes were in a consistent performance matching with the previous one (Figure 2). Up to the sixth day of storage, a sharp decline in the temperature margins monitored on the three temperature sensors indicating a massive effort in reaching out to the targeted one (Table

2). Soon after, the targeted temperature has almost reached out briefly described by the value shown by the entire final temperature profile in a steady pattern, supported by the standard errors less than 10% consistently observed until the end of storage.

Table 1. Summary of the proposed models describing the relations between the measured core's temperature (y) and the required time (x) on achieving the targeted freeze point, at -15°C.

Number of probes	Polynomial equation	Correlation (R^2-values)
I	$y = -8\ 10^{-13}\ x^5 + 5\ 10^{-10}\ x^4 – 10^{-7}\ x^3 + 7\ 10^{-5}\ x^2 – 0.04\ x + 4.18$	0.991
II	$y = -6\ 10^{-13}\ x^5 + 3\ 10^{-10}\ x^4 +10^{-8}\ x^3 + 4\ 10^{-5}\ x^2 – 0.04\ x + 3,81$	0.989
III	$y = -7\ 10^{-13}\ x^5 + 4\ 10^{-10}\ x^4 -7\ 10^{-8}\ x^3 + 6\ 10^{-5}\ x^2 - 0.04\ x + 4,03$	0,99

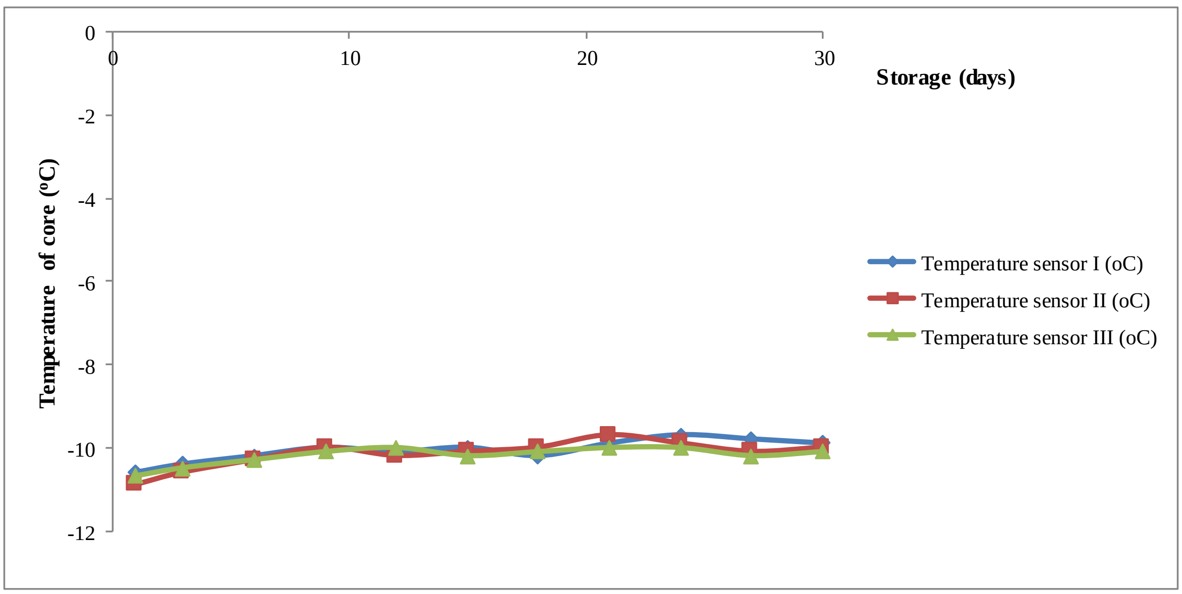


Figure 2. Profile of the core-temperature periodically observed during the freezing storage.

Table 2. The absolute margins between the recorded temperature (T_r), and the targeted one (T) at -10°C, and the average margin temperature equipped with the standard errors (SE) observed during the freezing storage period.

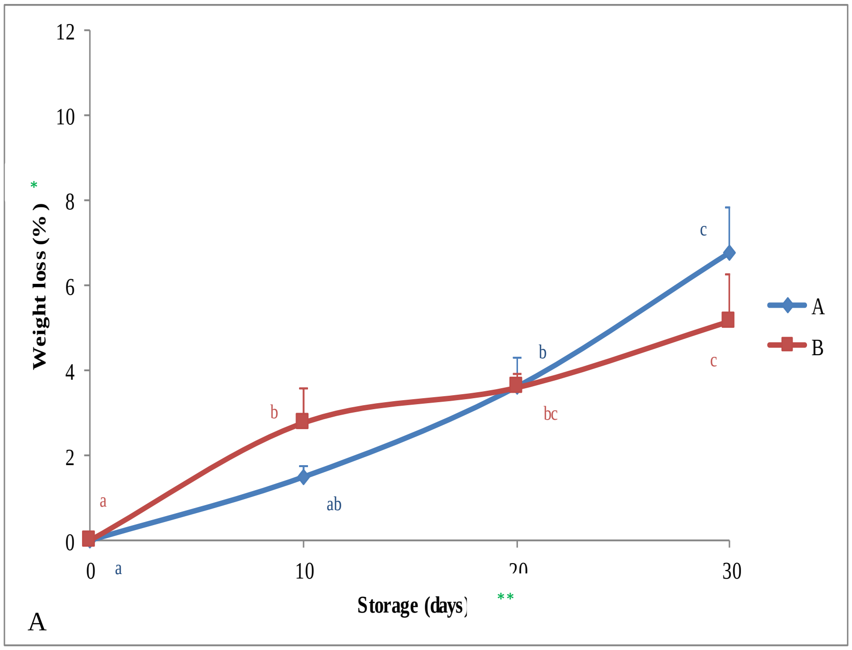
Storage (days)	$\lvert T_r - T \rvert_{I}$	$\lvert T_r - T \rvert_{II}$	$\lvert T_r - T \rvert_{III}$	$\Delta \lvert T_r - T \rvert_{avg} \pm SE$
0	0.6	0.9	0.7	0.73 ± 0.023
3	0.4	0.6	0.5	0.50 ± 0.010
6	0.2	0.3	0.3	0.27 ± 0.003
9	0	0	0.1	0.03 ± 0.003
12	0.1	0.2	0	0.10 ± 0.010
15	0	0.1	0.2	0.10 ± 0.010
18	0.2	0	0.1	0.10 ± 0.010
21	0.1	0.3	0	0.13 ± 0.023
24	0.3	0.1	0	0.13 ± 0.023
27	0.2	0.1	0.2	0.17 ± 0.003
30	0.1	0	0.1	0.07 ± 0.003

Impact of Freezing Storage on the Physical Characteristics of Durian's Pulp

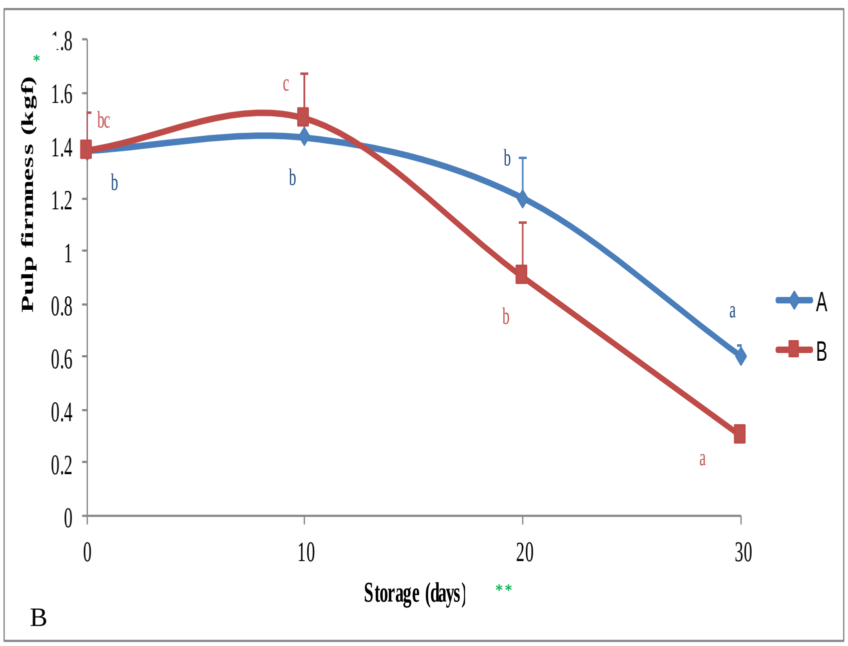
Physical characteristics such as: weight losses, flesh firmness, and pulp color were affected by freeze-process and time as well-implemented. Effect of freezing on those characteristics by the time-observation was demonstrated in Figure 3. A-G. In overall, the B-level of treatment moderately impacted on controlling the inclination of weight losses until the end of storage period (Figure 3.A).

A vice versa than the previous finding, the firmness profile of those fruits treated by the both levels of treatments was steadily the same until the two-thirds period of freeze-storage. The lowest values of flesh firmness observed at the end of storage were distinctly shown by the pulp becomes softer and watery (Figure 3.B).

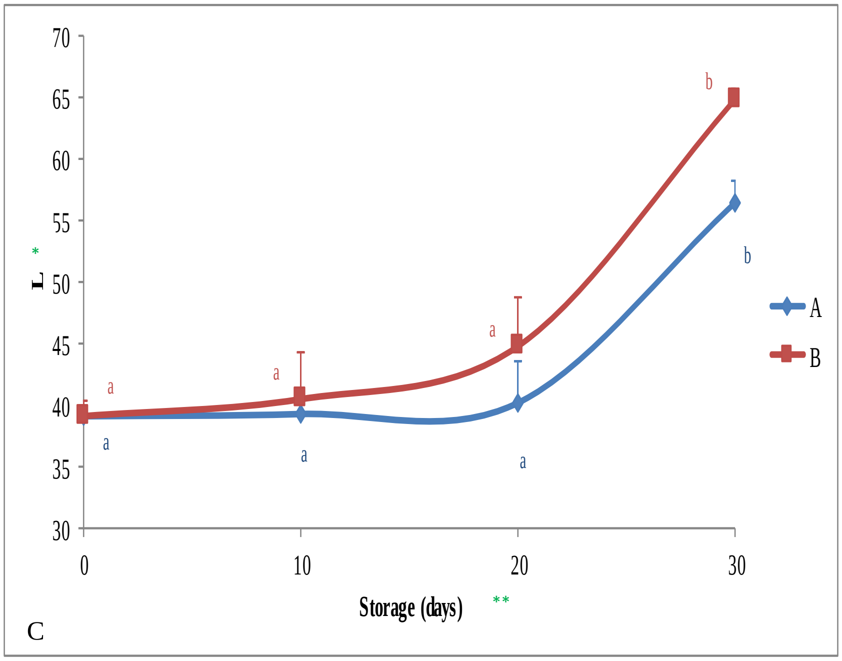
On the other hand, color characteristics have regularly formed preferences, observed on fruits treated with the B-level. Except a- values were mostly lowered as well, raisings of lightness, b and chrome-values, and also hue angle have consistently taken on at each of the scheduled timelines. It means that fruits treated at B-level are distinctly more precise and consistent performances (Figure 3. C-G) compared to the fruits treated at A-one. Moreover, entire trends of color's parameters have revealed that the color characteristics were still acceptable, even though fruit's treated with the A-level showed more fluctuated performance.

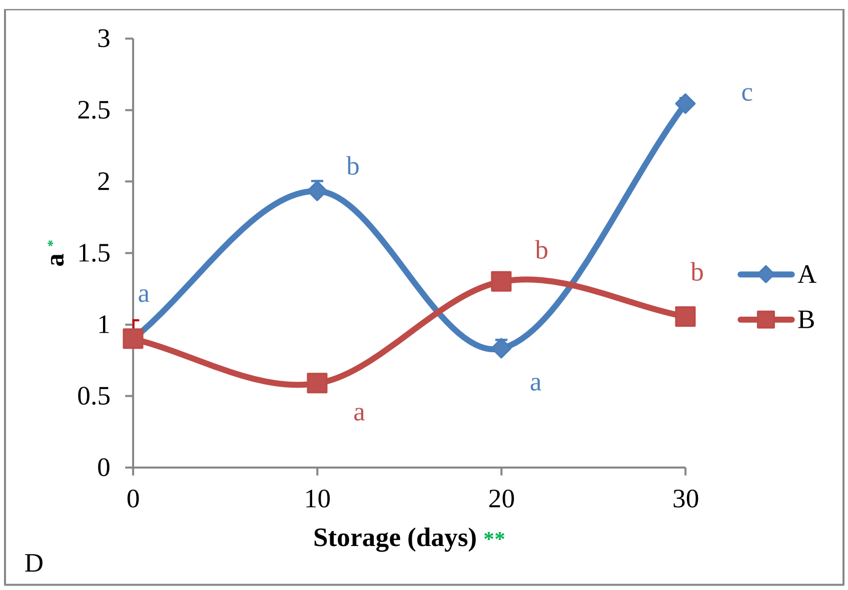


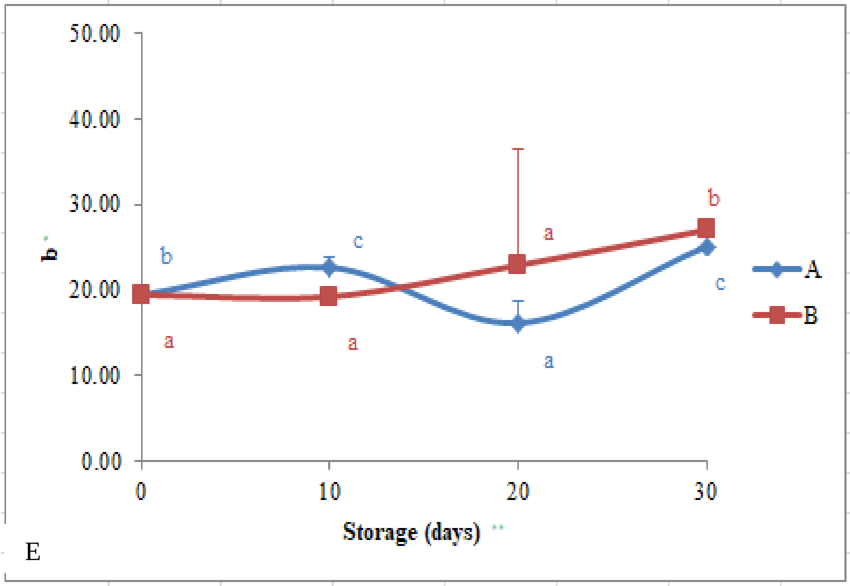
12
10
8
6
4
2
0
0
10
20
30
Weight loss (%)
Storage (days)
A
B
c
b
b
c
bc
ab
a
a
A

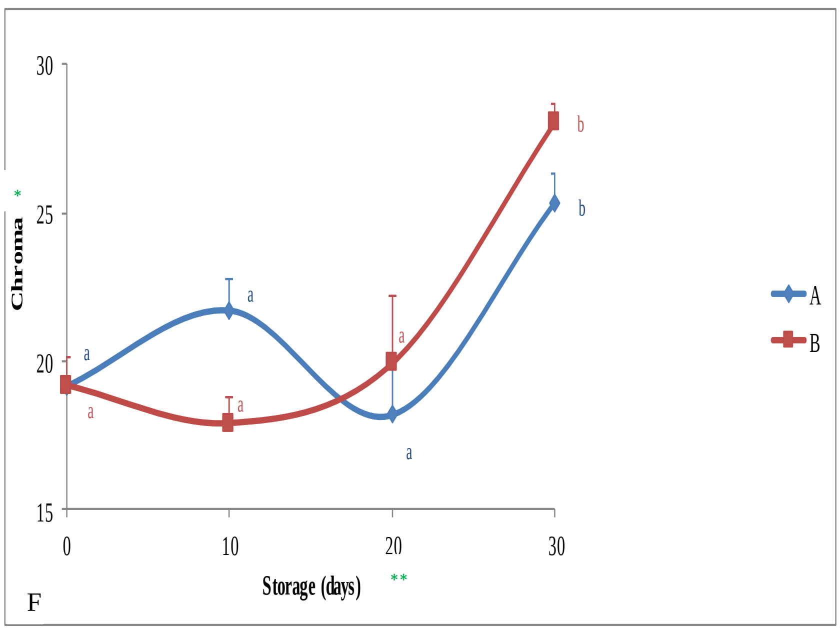


1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
Pulp firmness (kgf)
Storage (days)
A
B
bc
c
b
b
b
b
a
a
B


70
65
60
55
50
45
40
35
30
L*
0
10
20
30
Storage (days) **
A
B
a
a
a
b
a
a
a
b
C


3
2.5
2
1.5
1
0.5
0
a*
0
10
20
30
Storage (days) **
A
B
a
b
a
c
a
b
b
D


50.00
40.00
30.00
20.00
10.00
0.00
b*
0
10
20
30
Storage (days)
A
B
a
b
c
E


30
25
20
15
Chroma
0
10
20
30
Storage (days)
A
B
a
b
F

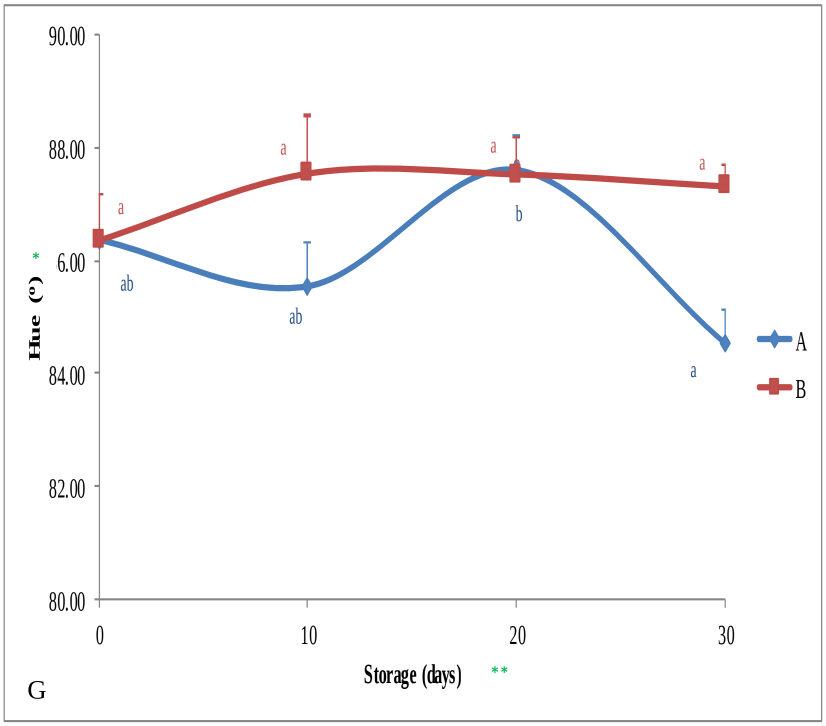
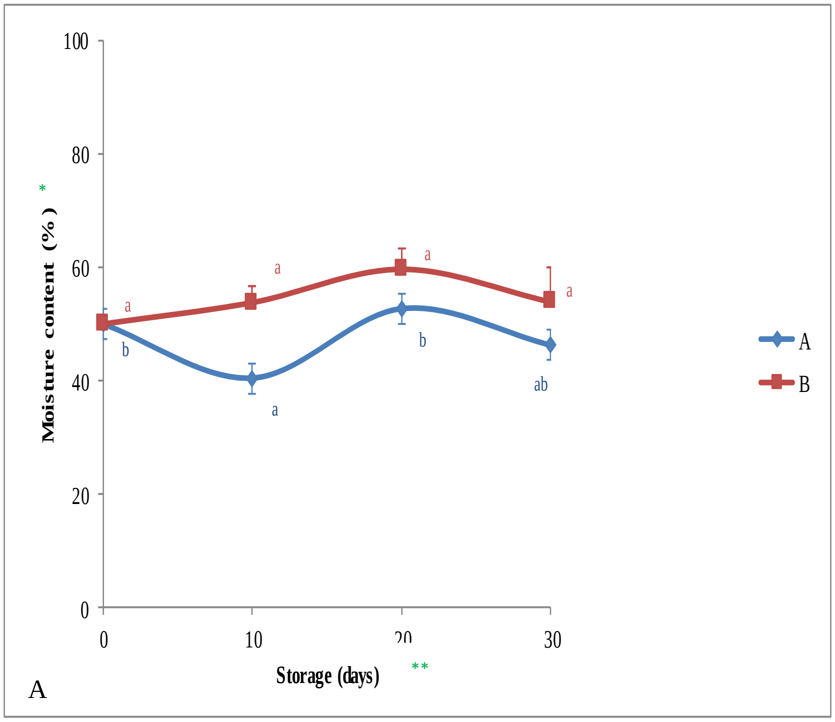


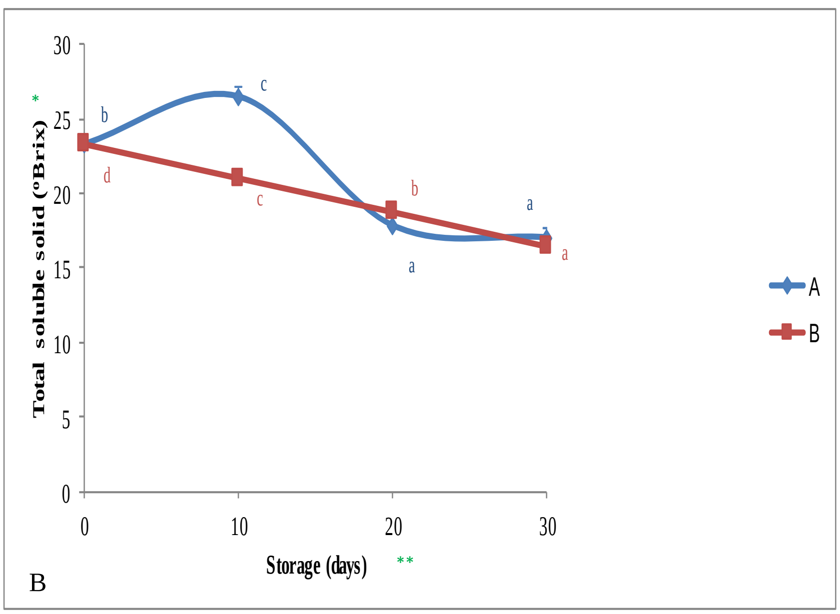
Figure 3. Changing in weights losses (A), fruit firmness (B), and color characteristics (C-G) observed on whole durians var. Langgang Kamang in different level of treatment. * Results expressed as means ± SE; ** Each of different lowercase letters indicating significant-results in between time storage- observations ($p < 0.05$) based on DMRT.

Influence of Freezing Storage on Chemical Properties of Durian Fruits

Chemical properties such as: moisture content, total of dissolved solids and succinate acid level were altered during freezing storage. Those alterations based on time-interval of storage were completely performed in Figure 4. A-C. A less-fluctuating patterns of material humidity was fairly observed (Figure 4. A) on the fruits treated by the B-level. However, no significant differences were found on the material humidity between those two groups of the treated fruits.

A differ from the previous, trends of total soluble solids and organic acid were finally fallen down. The correlation between the linier declining of total dissolved solid and the hyperbolic trend of succinate acid found on fruits treated by the B-level were remain unclear. However, the fruit flavoring compound as well maintained this result was important in maintaining fruit flavoring agent traced by consumers, rather than the more oscillated result gained from the fruits treated with the A-level (Figure 4. B-C). This finding also confirmed why the peak maturity was not homogenously achieved yet at the end of storage-time.





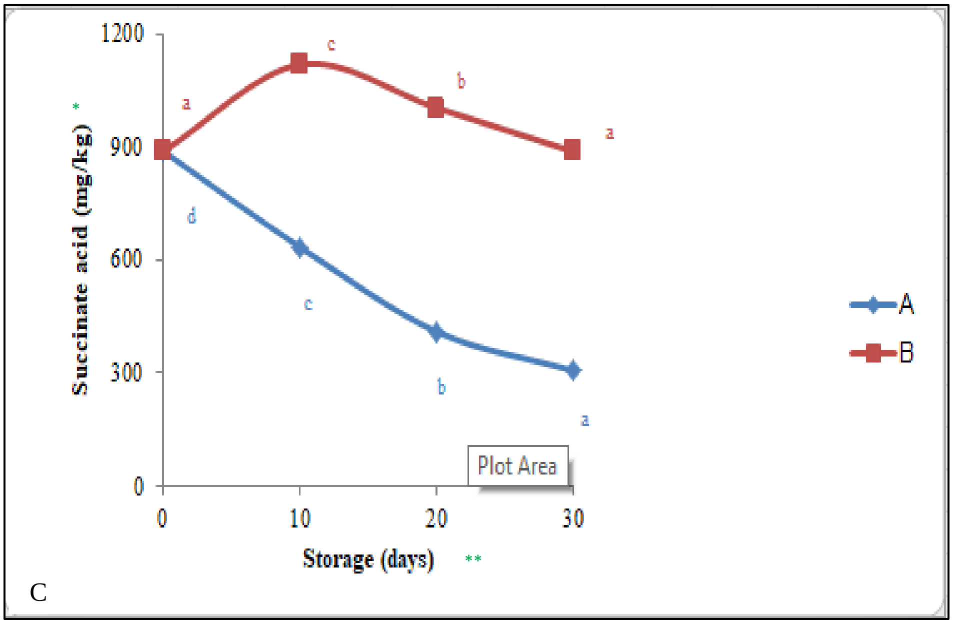
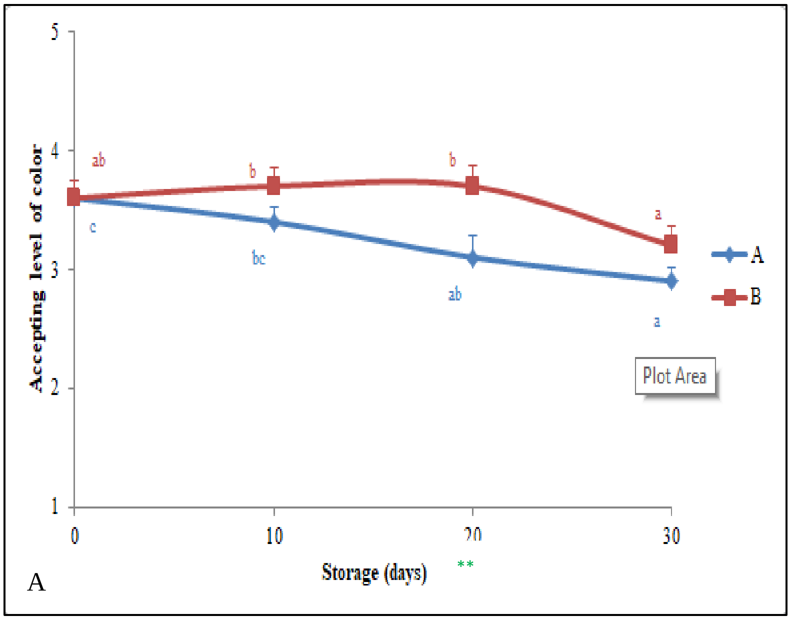


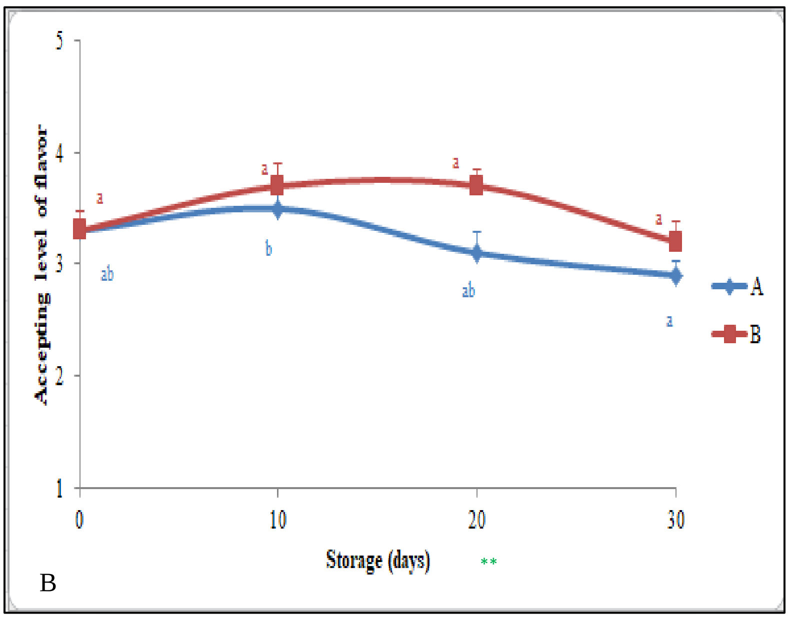
Figure 4. Altering in moisture content (A), total dissolved solid (B), and succinate acid (C) monitored on the whole treated durians in disparate level of treatment. *Results expressed as means ± SE; **Each of different lowercase letters indicating significant-results in between time storage- observations ($p < 0.05$) based on DMRT.

Preference Test to Freeze Durian Fruit

No rejection was given by all panelists toward five parameters (color, flavor, taste, and texture) of freeze flesh durian treated by treatment A and B. However, the highest score was reached by fruit treated with B. A complete preference score based on time storage was shown in Figure 5. A-D. There is an obvious fact faced on the tested fruits, ideally not in the peak ripeness. Therefore, the highest scores did not achieve until the end of storage time.

Predominantly, higher scores obtained in fruits treated with the B-level from panelists were affected by their perceptions on accepting physical appearances of the fruits. The brightness of color, the sweetness of pulp, and the dominant fragrance of ripening fruits are the three-main indicator in making many more differences of respondent marks.


5
4
3
2
1
Accepting level of color
ab
b
b
a
c
bc
ab
a
A
B
Plot Area
0
10
20
30
Storage (days)
**
A


5
4
3
2
1
Accepting level of flavor
a
a
a
a
ab
b
ab
a
A
B
0
10
20
30
Storage (days)
**
B

*

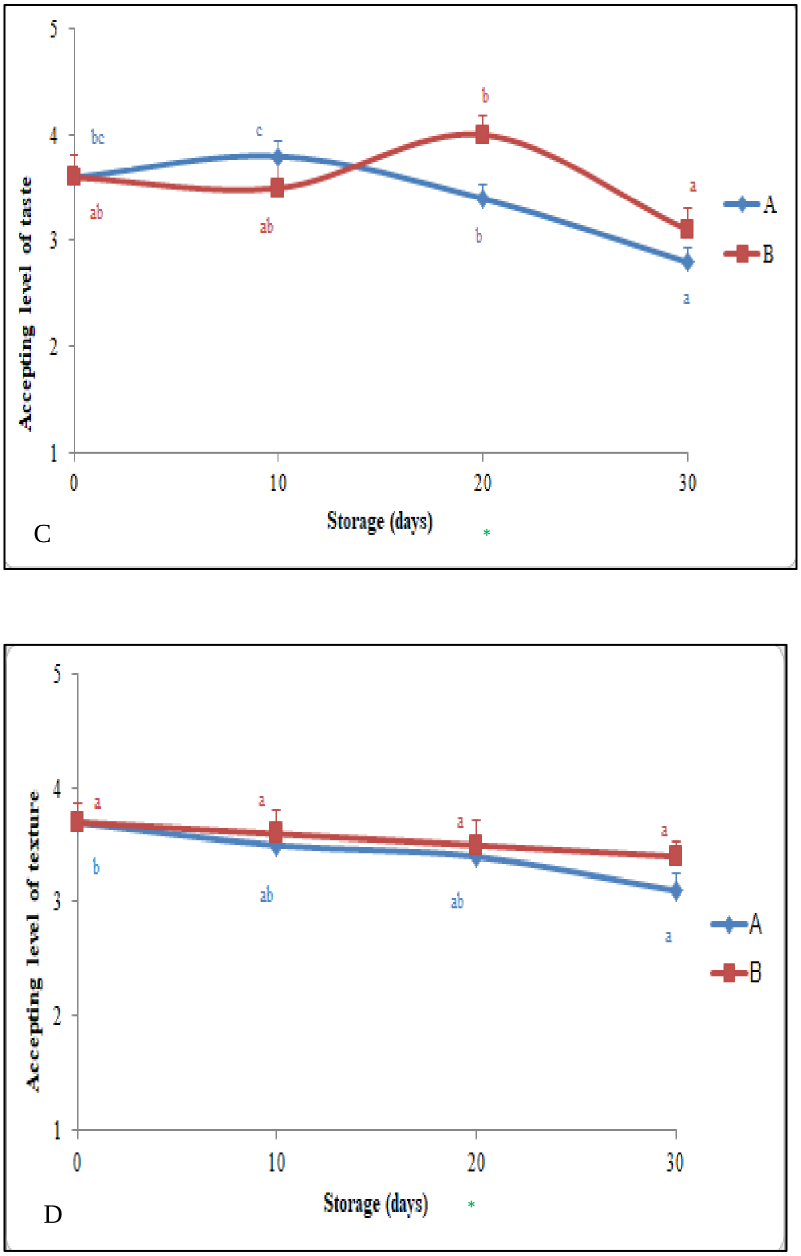


Figure 5. Respondents preferences to color (A), flavor (B), taste (C), and texture (D) of fruits treated with the two-level of treatment. * Results expressed as means ± SE. ** Each of different lowercase letters indicating significant-results in between time storage- observations ($p < 0.05$) based on DMRT.

DISCUSSION

As one of the physical preservation tools, dry-freezing systems have several unique characterizations on preserving horticultural commodities. Most of those systems have adequate capacities for covering a wide range of capabilities in suppressing many advance-reactions of biochemistry, maintaining the essential nutrition, and also preventing the latent threat of microorganism's contamination, properly suitable applied for extending the shelf of life (Ciurzynska et al. 2014; Franceschinis et al. 2014; Harguindeguy and Fissore 2019; Santos and Silva 2008). Specifically, the heat transfer rate needs to be designed appropriately, particularly on minimizing the excessive heat blockage. As one of the most common technical procedures, the defrosting process has regularly been actuated for removal of this uncontrolled heat through compensating an extra accessible-ambient makeup in replacing the saturated air gradually to renormalize the operating temperature as the crucial feedback for the freezing process (Dong et al. 2011; Hossain 1995; Kim and Lee 2011; Salvadori et al. 1997).

Once upon a time, the final temperature was finally achieved with a minimum fluctuation, indicating the targeted scheme has been under control, as observed in our study. Consequently, the work-performance in between a series of specific thermo-sensors has indicated the homogenously distributed heat-transfer values occurred on the entire freezing process (Resende 2001). This result shown on Table 2 is also positively related to the previous one mentioning a sharp decline of the heat transfer reaching almost zero-value has steadily correlated with the homogeneity of the final temperature finally reached out (Resende et al. 2002).

On the other hand, observing fruit's quality performances based on the time-series evaluation has affected the selected thawing process. As previously mentioned, the cold-thawing has positively affected inclining moisture content gradually, more brightening the pulp, and decreasing the weight loss (Arancibia-Avila et al. 2008; Ikram et al. 2009; Tagubase et al. 2016). Our study has also confirmed with the previous studies mentioning softening of the pulp's texture, declining of total suspended solids, and stabilizing of organic flavor have been strongly related to high intensity of the low-temperature preservation (Burdon et al. 2017; Gwanpua et al. 2018; Ishiwu et al. 2014; Yang et al. 2013; Zhao et al. 2015). Our result also confirmed it was difficult, ideally for returning to the normal maturity process. This finding was closely associated with the abnormality of ethylene production drastically caused by a sharp decline of three enzymes activities, namely: ACS (1-aminocyclopropane-1-carboxylate synthase), ACO (1-aminocycloprapane oxidase), and ACC (1-aminocyclopropane-1-carboxylate) (Lara and Vendrell 2003), particularly carried on a range of extreme temperatures, including freeze environment (Maninang *et al.* 2011; Sirijariyawat *et al*. 2012).

Our study have also showed that a strong indication of delaying post-maturity due to the freezing storage as obviously seen in a consistent pattern based on several previous studies (Burdon et al. 2015; Burdon et al. 2016; Manning et al. 2016). Therefore, those products have become less sensitive to several enzymatic activities when they have been warmed (Chassagne-Berces et al. 2010) and therefore the dissolved solid's profile has gradually declined due to an inclining of respiration rate observed on the late maturity (Harman, 1987). In addition, a complex structure of durian together with post-freezing temperature alteration, has been suspected as the main factor in effecting the downtrends in dissolved solids (Alhamdan et al. 2016; Lara and Vendrell 2003). As regarded to be in a crucial role, thawing process has mostly affected in minimalizing the loss of antioxidants as well as organic compound (Dantes et al. 2014). Our result confirmed the two hyperbolic trends of succinic acid and moisture content, particularly observed on the fruits treated with B, were intimately related to the blocked enzymatic reaction as well as the fully inhibited ripe process (Maninang et al. 2010; Moya-Leon et al. 2006; Rizzolo et al. 2005). It is a strong indication in evaluating the fruits as no perfectly ripe ones concerning some particular treatments for achieving the targeted criteria.

Furthermore, sensory characteristics marked a specific preference have been a particular interest, mostly in differentiating the customers. To address this case, mostly Asian people have preferably marked the fully ripened ones. (Nanthachai et al. 1994; Maninang et al. 2010). While others have more concerned with a more juicy and less sweet taste. The odors of sulfur and esters containing substances subjectively traced, aligning to the full-ripe fruits indication, were regulated by a thermodynamic equilibrium (Defilippi et al. 2005), ideally hard to be achieved for this study. Whereas the flat-pattern of texture gained in this research, was strongly correlated to stability of flesh water holding capacity mainly important on determining food sensory preferences (Sriyook et al. 1994; Tagubasse et al. 2016).

CONCLUSION

The freezing process applied on the whole durian fruit (-15ºC for 20 minutes at the core chased by -10ºC for 30 days) was exhibited the best impact in conserving the stability of physics-chemical properties. The result gained from the organoleptic test was proved the overall fruit's attributes still acceptable by the panelists. Therefore, this freeze-scheme could be implemented as the prospective model, particularly for freezing preservation. Fruit's deteriorating could be overcome by an advance time of treatment (30 days) without any significant decrease on the fruit's quality. However, further research is still required to verify this recent inventory.

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