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FULL PAPER

Cryogenic freezing preserves the quality of whole durian fruit for the export market

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Abstract

Durian (*Durio zibethinus* cv. Musang King; D197) is a popular durian cultivar due to its thick flesh and strong sweet taste. The high market demand and shortage of out-of-season supply contribute to the increase in durian price. Other than that, durian has a short storage life, and to prolong the storage life of Malaysian durian, freezing treatment has been applied. This study was conducted to evaluate the effect of freezing methods on the physical and sensory qualities of the whole durian. The freezing method included conventional (at -18°C) and cryogenic freezing (-110°C). The frozen durian was thawed and evaluated after 12-hours, 24-hours, and 36-hours for external and internal quality, dehiscence incidence, and physicochemical parameters (pulp colour, soluble solids content, total titratable acidity, and percentage of moisture) during 36-hours storage. The results showed that conventional freezing at -18°C adversely affected the quality of durian. The fruits were severely dehiscent due to the slow freezing rate. Later, the freezing injury became obvious when exposed to ambient temperature. In comparison, during cryogenic freezing durian fruit froze rapidly without any dehiscence. The freezing methods used in this study did not affect the physicochemical parameters of durian pulp during 36-hours storage. Cryogenic freezing is noted to be a promising method for preserving the quality of durian fruit, thus extending the storage life for market expansion.

1. Introduction

Durian (*Durio zibethinus*), often known as the "King of Tropical Fruits," is the most important tropical fruit crop in Southeast Asia. Durian D197, known as "Musang King" or "Mao Shan Wang" is the most popular variety, with many loyal fans in China. This variety is reported to be in high demand despite its high price, which can reach up to USD 120/kg (Plantations International, 2018). The Musang King is known for its greenish-brown skin with broad thorns and a star shape at the end. The arils are thick with small and flat seeds. The pungent aroma and taste of durian make this clone more popular among durian fans in China than other clones from Thailand. Malaysian durian is different from Thai durian because it is harvested when the mature-drop is at 100% maturity and full ripe stage where the taste and quality profile is optimal (FreshPlaza, 2019).

The value of Malaysia's total durian exports increased by 172% between 2002 and 2019 (International Trade Centre, 2020). In 2011, after gaining access to the durian fruit and paste market in China, exports increased 151% from USD 8.8 Million (2011) to USD 22.2 Million (2019). Production and export of durian fruit in 2018 also increased compared to 2017 (DOSM, 2018). The subsistence rate (SSL) for the Malaysian durian industry is 104.8%, indicating that the durian supply is sufficient to meet local needs and has excellent potential for the export market. Malaysia's durian export destinations are mostly Asian markets and some non-Asian markets (Australia, United Kingdom, and Canada) (Suhana *et al*., 2018). In 2017, China and Hong Kong accounted for 48% of the export market share, followed by Singapore 46%. In 2019, durian imports increased by 48%, surpassing cherries and becoming the "king of imported fruits" (FreshPlaza, 2020). Even during the Covid-19 pandemic this year, the import volume still maintains a high growth.

Being a seasonal fruit, durian is prone to encounter an oversupply problem at some point when suppliers

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simultaneously deliver produce into the market, leading to a lower selling price compared to its production cost (Udomsri, 2011). Since harvesting is conducted at the fully ripe stage, the shelf life of Musang King durian is only three days at an ambient of 30°C and seven days at 10°C which has hampered its exporting potential. Longer shelf life is needed for Musang King durian to be marketed globally and shipped by sea, which generally takes longer but is cheaper than air transport. In order to address this issue, it is necessary to develop technologies that can preserve and prolong this fruit's shelf life.

Freezing is one of the best techniques to maintain the quality of fruits for a prolonged period and make them available throughout the year. Through freezing, durian oversupply during the primary season can be controlled, and the fruits can be marketed off-season. It is generally understood that storage at cold temperatures reduces microorganisms' growth, maintains quality, and extends the shelf life of various food products, including fruits (Heldman, 2006; Fellows, 2009). Rapid freezing using liquid nitrogen provides better quality and improves the internal micro-structure of blueberries (Allan-Wojtas *et al*., 1998). In terms of food safety, frozen fruit is safer because the reduced water activity can inhibit microorganisms' growth during freezer storage (De Ancos *et al*., 2012).

Cryogenic freezing is an alternative method for freezing food using mediums such as nitrogen or carbon dioxide. Liquid nitrogen, at a temperature of -196°C, is a cryogenic liquid that can cause rapid freezing in living tissues. Pressurized liquid nitrogen is sprayed onto the product at high velocity to freeze it immediately. This method removes heat quickly by permeating beyond the product's thermal resistance and producing ice around it which locks in natural flavours, nutrients, and moisture (Linde, 2020). Cryogenic freezing prevents water loss up to ten times more efficient compared to conventional methods of freezing.

This study was conducted to develop a freezing method suitable for whole durian fruit and compare the freezing methods, liquid nitrogen cryogenic and conventional, on the quality and appearance of durian fruits (Musang King) harvested at the full maturity stage. Parameters evaluated were visual appearance, pulp colour, soluble solids content (SSC), total titratable acidity (TTA), and moisture percentage. These parameters were measured three times during 36-hours storage.

2. Materials and methods

2.1 Sample preparation of durian

Durian fruits (*Durio zibethinus*) cv. 'Musang King' used in this study was obtained from a farm in Johor, Malaysia. Naturally ripened durian fruit that had dropped in the morning was collected and transported to a packing house. Injured fruits were sorted out and only good quality fruits were selected for freezing treatments. After the freezing process was completed, all fruits were packed in a corrugated fibreboard (CFB) box and stored in the freezer (-18°C) for 36 hrs.

2.2 Freezing methods

Two different freezing methods were used, namely cryogenic freezing using liquid nitrogen and conventional slow freezing using a walk-in freezer.

2.2.1 Liquid Nitrogen Cryogenic Freezing (LNCF) method

A cryogenic freezer using liquid nitrogen (Cryo Cabinet, Air Liquide, Paris, France) was utilized to freeze the fresh durian at -110°C. The fresh durians were placed inside the cryogenic chamber and after the temperature reached -110°C, which took about 10 mins, they were held for 60 mins. The temperature of the fruit's core and the surrounding air inside the freezer chamber were measured every 30 secs using type K thermocouples.

2.2.2 Conventional slow freezing method

A walk-in freezer (size 8.4 m^2) was used for the conventional freezing of fresh fruits. The fruits were kept in boxes (4 fruits per box). The fruit's core temperature and the temperature inside the freezer were measured every 30 mins using temperature loggers. The freezers' temperature ranged from -17 to -20°C with an average temperature of -18°C.

2.3 Thawing processes

The frozen fruits were removed from the freezers and thawed at room temperature for 3 hrs.

2.4 Visual appearance, pulp colour, soluble solids content, total titratable acidity, and moisture percentage.

On each evaluation day, individual fruit's visual appearance was subjectively rated for a percentage of browning (red lesions) inside the core near the stem end, dehiscence or cracking incidence, and overall appearance and acceptability rating. The durian pulp's surface colour was measured by using a reflectance colourimeter (Minolta Chroma Meter, Model CR200, Osaka, Japan). The soluble solids content (SSC) was determined using a digital refractometer (ATAGO RX-5000, ATAGO, Japan). The total titratable acidity was determined with an automatic titrator (model 888 Titrando; Metrohm, Switzerland). For total titratable acidity (TTA), 5 mL of

juice diluted with 50 mL of water was titrated with 0.1 M NaOH to pH 8.1 and reported as a percentage of malic acid.

2.5 Statistical analysis

The experimental setup was a completely randomized design and performed for each variable. For this purpose, a one-way ANOVA test was used to evaluate the treatments' effects on each measurement day. The Duncan Multiple Range Test was used for means difference testing. A 95% confidence interval was used for all calculations ($p \leq 0.05$). SAS statistical software version 9.4 was used to perform statistical analyses.

3. Results and discussion

The cryogenic freezing technique developed for frozen durian involved freshly dropped fruits and several steps of sanitation treatment. The durian fruits were subjected to cryogenic freezing (-80°C to - 110°C) for at least one hour to ensure the freezing process penetrated the core of the durian fruit (Figure 1).

Figure 1. Liquid Nitrogen Cryogenic Freezing (LNCF) method

3.1 Browning (red lesions) area, dehiscence incidence, and overall acceptability

Freezing injury occurs when there is a reduction of the ambient temperature below that of the tissue's freezing point. The symptoms include water-soaked areas in the tissue, collapse, and even disruption of the epidermis, limp, and flaccid tissues. Secondary symptoms include discolouration (browning) and decay (Brecht *et al*., 2008). As described above, we observed freezing injury symptoms as discolouration (red lesions) along the suture (core) at the centre of the fruit (Figure 2). This red lesion symptom has also been observed when the fresh durian was stored at a low temperature beyond the optimum cold storage temperature of 7°C as stated in a report by Razali (2020).

During 24-hours storage at -18°C, conventional frozen fruits developed red lesions area at the core near the stem end (Table 1). After 36-hours of storage and transfer to ambient temperature, the incidence of red lesions increased. No red lesions were observed in cryogenically frozen fruit even after 36-hours of storage and thawing at ambient temperature. The lack of observable red lesions in cryogenically frozen fruit could be due to a decrease in the injurious effects of crystallization and recrystallization on the microstructure of fruit tissues during such a quick-freezing method. The rate of freezing influences the size of the ice crystals that are formed (Sun and Li, 2003). During fast freezing, smaller ice crystals are formed causing less damage to cell membranes. Damage to the cell membrane is usually connected to enzyme activity that contributes to tissue discolouration. Alhamdan (2018) reported a significant role of the freezing rate in maintaining frozen fruits' enzyme activity.

Figure 2. Red lesions located internally near the stem end of the durian fruit

Table 1. Effect of different freezing methods on browning (red lesions) area, dehiscence incidence, and overall acceptability rating (score 1-5) for mature-drop frozen durian during the 36-hours storage.

Characteristics	Hour	Cryogenic Freezing	Conventional Freezing
Browning/red lesions	0	-	-
	12	-	-
	24	-	+
	36	-	++
Dehiscence incidence	0	-	-
	12	-	+
	24	-	++
	36	-	+++
Overall acceptability ratings	0	5	5
	12	5	4.1
	24	5	3.3
	36	5	2.4

-: no trace, +: slightly affected, ++: moderately affected, +++: badly affected

Husk dehiscence is a primary problem limiting the storage life of durian (Khurnpoon *et al.*, 2008). Table 1 shows that some conventional frozen durians began to dehisce after 12-hours of storage. Half of the conventional frozen durian samples dehisced after 24-hours, and after 36-hours all conventional frozen samples had dehisced. Throughout the 36-hours of storage, none

of the cryogenically frozen samples developed cracking. This data shows that cryogenic freezing is a more suitable freezing method that maintains durian quality. Liquid nitrogen is a cryogenic fluid that can cause rapid freezing on contact with living tissue. When pressurised liquid nitrogen is sprayed onto the product at high velocity it freezes immediately and limits water loss. According to Sriyook (1994), water loss is one of the main factors that cause the durian fruit to dehisce. Water loss causes the husk to shrink causing the carpels to separate from each other along the suture in the middle of each locule. Many studies have confirmed the close relationship between quick freezing and high-quality frozen products resulting in increased shelf life and preservation of initial quality (Sanz *et al.*, 1999; Zhang *et al.*, 2004; Alhamdan *et al.*, 2018).

After 36-hours of storage, cryogenically frozen durian scored excellent for overall acceptability compared to conventional frozen durian, which scored poor (Figure 3). The fruit that underwent conventional freezing was rated as poor due to red lesion development and a high rate of cracking. These results show that the cryogenic freezing method is preferable compared to the conventional freezing method since the durian fruits maintained an acceptable appearance and quality.

Figure 3. The appearance of durian after cryogenic and conventional freezing during 36-hours storage at -18°C.

3.2 Pulp colour, soluble solids content, total titratable acidity and moisture percentage.

The durian from both freezing methods maintained its quality with only slight variations in pulp colour and chemical results (Table 2). The golden-yellow colour of 'Musang King' durian was retained throughout the storage period, the L value, chroma, and hue° were 78.51, 58.26, and 89.21° respectively.

There was no significant difference ($p<0.05$) between the two freezing methods for soluble solids content, total titratable acidity, and moisture percentage. The SSC (40.88%), TTA (0.13%), and moisture loss (81.25%) remained unchanged during storage. Therefore, the freezing method does not affect the chemical parameters of frozen durian.

4. Conclusion

In this study, the freezing method greatly influenced the quality of the durian fruits. Cryogenic freezing prevented durian fruit from dehiscing compared to conventional freezing. This method potentially locks in natural flavours, nutrients, and moisture, providing excellent quality which cannot be achieved with conventional freezers. Additionally, frozen durian should be treated as a frozen product and kept at -18°C during transport and on the retail shelves. If the cold chain is been interrupted, the quality of frozen durian will deteriorate and will not be safe to be eaten.

Conflict of Interest

The authors declare no conflict of interest.

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References

Alhamdan, A., Hassan, B., Alkahtani, H., Abdelkarim, D. and Younis, M. (2018). Cryogenic freezing of

Table 2. Mean values of pulp colour, total soluble solids, total titratable acidity, and moisture loss of frozen durian.

	L*	C*	h°	Total soluble solids (%)	Total titratable acidity (%)	Moisture percentage (%)
Mean	78.51±1.49	58.26±3.69	89.21±1.55	40.88±2.67	0.13±0.03	81.25±1.33
No. of samples	24	24	24	24	24	24

fresh date fruits for quality preservation during frozen storage. *Journal of the Saudi Society of Agricultural Sciences*, 17(1), 9–16. https://doi: 10.1016/j.jssas.2015.12.001

Allan-Wojtas, P., Stark, R., Goff, H.D. and Carbyn, S. (1998). The Effect of Freezing Method and Frozen Storage Conditions on the Microstructure of Wild Blueberries as Observed by Cold-Stage Scanning Electron Microscopy. *Scanning*, 21(5), 334–347. https://doi.org/10.1002/sca.4950210507

Brecht, J.K., Ritenour, M.A., Haard, N.F. and Chism, G.W. (2008). Postharvest physiology of edible plant tissues. In Damodaran, S., Parkin, K.L. and Fennema, O.R. (Eds.) Fennema's Food Chemistry 4th ed., p. 975-1049, Boca Raton, Florida, USA: CRC Press.

De Ancos, B., Sanchez-Moreno, C., Pascual-Teresa, S. and Cano, M.P. (2012). Freezing preservation of fruits. In Sinha, N., Sidhu, J.S., Barta, J., Wu, J.S.B. and Cano, M.P. (Eds.), Handbook of Fruits and Fruit Processing. 2nd ed., p. 103-119. Oxford, United Kingdom: John Wiley and Sons.

DOSM. (2018). The value of Malaysia's durian exports increased significantly. Retrieved on November 1, 2020 from Department of Statistic Malaysia (DOSM) Website: https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=164&bul_id=OTM1TDMzS1IvYm5mU1JiU1Fwekt3UT09&menu_id=Z0VTZGU1UHBUT1VJMFlpaXRRR0xpdz09].

Fellows, P.J. (2009). Food Processing Technology: Principles and Practice, Elsevier, The Netherlands. In Handbook of Fruits and Fruit Processing. 2nd ed., p. 103-119. Oxford, United Kingdom: John Wiley and Sons. https://doi.org/10.1533/9781845696344

FreshPlaza. (2019). Malaysian durian reaches important turning point in export to Chinese market. Retrieved on November 17, 2020 from FreshPlaza Website: https://www.freshplaza.com/article/9103546/malaysian-durian-reach-important-turning-point-in-export-to-chinese-market/

FreshPlaza. (2020). Large volumes of Malaysian top durian variety expected to enter China. Retrieved on November 17, 2020 from FreshPlaza Website: https://www.freshplaza.com/article/9244104/large-volumes-of-malaysian-top-durian-variety-expected-to-enter-china/

Heldman, D.R. (2006). Food freezing. In Handbook of Food Engineering, p. 439–482. USA: CRC Press. https://doi.org/10.1201/9781420014372-10

International Trade Centre. (2020). Trade statistics for international business development. Retrieved on November 17, 2020 from International Trade Centre Website: https://www.trademap.org/Index.aspx?AspxAutoDetectCookieSupport=1

Khurnpoon, L., Siriphanich, J. and Labavitch, J.M. (2008). Cell wall metabolism during durian fruit dehiscence. *Postharvest Biology and Technology*, 48 (3), 391–401. https://doi.org/10.1016/j.postharvbio.2007.08.012

Linde. (2020). Cryogenic impingement: Boosting freezing efficiency. Retrieved on November 17, 2020 from Linde Website: https://www.linde-gas.com/en/whats-happening/cryogenic-impingement/index.html

Razali, N.A., Rosly, N.K., Hamzah, F.A., Abdullah, S.A. and Wan Husin, W.M.R.I. (2020). Optimum storage temperature of mature drop durian (*Durio zibethinus* cv. Musang King). *International Journal of Agriculture, Forestry and Plantation*, 10, 267-273.

Plantations International. (2018). Durian Global Market Report. Retrieved on October 17, 2020 from Plantation International Website: http://ptdurian.com/pdf/DurianGlobalMarketReport.pdf

Sanz, P.D., De Elvira, C., Martino, M., Zaritzky, N., Otero, L. and Carrasco, J.A. (1999). Freezing rate simulation as an aid to reducing crystallization damage in foods. *Meat Science*, 52(3), 275–278. https://doi.org/10.1016/S0309-1740(99)00002-9

Sriyook, S., Siriatiwat, S. and Siriphanich, J. (1994). Durian fruit dehiscence - Water status and ethylene. *HortScience*, 29(10), 1195–1198. https://doi.org/10.21273/HORTSCI.29.10.1195

Suhana, S., Chubashini, S., Jannatul Ain, J., Nur Fathiah, A. and Razali, M. (2018). Durian as New Source of Malaysia's Agricultural Wealth. Retrieved on October 17, 2020 from FFTC Agricultural Policy Platform (FFTC-AP), 2018 Website: https://ap.fftc.org.tw/article/1321

Sun, D. and Li, B. (2003). Microstructural change of potato tissues frozen by ultrasound-assisted immersion freezing. *Journal of Food Engineering*, 57(4), 337–345. https://doi.org/10.1016/S0260-8774(02)00354-0

Udomsri, N. (2011). The design of a forecasting support models on demand of durian for domestic and export markets by time series and artificial neural networks (ANNs). Bangkok: King Mongkut's University of Technology North Bangkok. PhD Dissertation.

Zhang, M., Duan, Z., Zhang, J. and Peng, J. (2004). Effects of freezing conditions on quality of areca fruits. *Journal of Food Engineering,* 61(3), 393–397. https://doi.org/10.1016/S0260-8774(03)00146-8

