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## Influence of alternating magnetic field strength on Frozen-Thawed Quality of Jackfruit Bulb

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Jackfruit contained a rich source of nutritional and phytochemical components. Jackfruit bulb was highly preferred by its edible portion. However jackfruitbulb had high perishability due to cut-damaged surface, exposed tissues and availability of cell nutrients to pathogens. One of the most common efficient way to preserve this fruit for extended shelf life was freezing. The crystalization was extremely important to textural and physicochemical characteristics of frozen-thawed product. This research evaluated the influence of alternating magnetic field during freezing jackfruit bulb. The bulbs were frozen at  $-20\pm 2^{\circ}\text{C}$  for 15 min with the alternating magnetic field strength ranging from 0 to 4 mT at frequency 30 Hz. The frozen samples were stored at  $-25\pm 2^{\circ}\text{C}$  for 6 months before thawing to determine drip loss, water holding capacity, toughness. Results showed that magnetic field strength efficiently improved water holding capacity (63.62% to 93.05%) of treated samples. The alternating magnetic field strength slightly decreased toughness (2.05 N to 8.30 N) and drip loss (0.6% to 6.45%) of frozen-thawed jackfruit bulb. Generally, toughness and drip loss of frozen-thawed samples accelerated during preservation while water holding capacity decreased. Alternating magnetic field could be considered as an efficient approach to create a synergistic cryoprotection effect by forming fine ice crystal.

**Keywords:** Alternating magnetic field, drip loss, ice crystal, jackfruit bulb, toughness, water holding capacity

### INTRODUCTION

Freezing was one of the most popular techniques successfully applied for food processing and preservation. It converted mobile water into ice, reduced water activity, retarded the microbial proliferation, limited enzymatic and chemical reactions, slowed down degradation rate inside foodstuffs (Piyush et al. 2017). The major drawbacks of frozen product was physical and chemical modifications such as drip loss and loose textural properties due to the mechanical stress as well as damage of membranes and cell walls during thawing (Otero et al. 2000; Pham, 2008; Sirijariyawat and Charoenrein, 2012; Rinaldi et al. 2015; Charoenrein and Owcharoen, 2016; Rodriguez et al. 2017). Among three main steps of the freezing process, the crystalization was

extremely important in determining the quality of the frozen product (Kiani and Sun, 2011). Ice crystal dimension was a critical factor decided to textural and physicochemical characteristics of frozen product (Petzold and Aguilera, 2009). Fine ice crystal was highly preferred to make a pleasant feeling and to avoid detrimental effect of textural destruction during thawing. High cooling rate would obtain fine ice crystal. Alternating magnetic field could resolve this matter. Water subjected to alternating magnetic field had a larger degree of supercooling compared to the untreated sample (Semikhina and Kiselev, 1998). When magnetic field was applied, moment of the electron spin was aligned in one direction. The thermal vibration caused by electron spin was strengthened and increased. The temperature was dropped quickly

to an extent at which freezing was generally initiated. This induced the molecules rearranged according to the hydrogen bond, and rapid freezing could be obtained (Woo and Mujumdar, 2010; Otero et al. 2016). Tertiary structures of proteins could be effectively protected against oxidation owing to the boundary water layer. Under magnetic field fluctuation, the magnetic flux modified and an electromagnetic induction took place. This provided free electrons inside the sample, supporting the interaction with water molecules to generate hydroxyl-radicals attacking the cell membranes of microorganism. Application of alternating magnetic field in range of 50 Hz to 5 MHz while freezing would retard the nucleation of ice crystals, while super-cooling could be obtained without the nucleation of ice crystals down to -10 °C (Otero et al. 2016; Purnell et al. 2017; Rodriguez et al. 2017).

Jackfruit contained a great amount of carbohydrates, minerals, dietary fibres, vitamins, and phytonutrients contributing to physiological benefits such as anticancer, antihypertensive, antiulcer, and antiaging properties (Rahman et al. 1999; Jagtap et al. 2010; Baliga et al. 2011). It's beneficial to control high blood pressure, heart diseases, strokes, bone loss, muscle and nerve function, homocysteine levels in the blood (Swami et al. 2012). Its edible fleshy bulb occupied around 35 % of the whole fruit. It's prone to flavor loss, tissue softening, cut-surface browning and postharvest decay owing to the highly perishable nature (Saxena et al. 2009). Freezing could preserve jackfruit bulb for long stability. However drip loss and loose texture firmness were major disadvantages of frozen-thawed product. In order to improve quality of frozen-thawed jackfruit bulb, objective of our study investigated the effect of alternating magnetic field strength during freezing jackfruit bulb.

## MATERIALS AND METHODS

### Material

Jackfruits were harvested in local gardens at maturity (70% fully ripen) to ensure rigid textural properties during processing and freezing. Seeds were removed from bulbs. Experimental equipments included CAS freezer, centrifugator, texture analyzer, infrared moisture analyzer, digital weight balance.

### Researching method

Magnetic field freezing experiments were conducted in a commercial CAS freezer consisting

of consisted of one cooling unit, two fans, one control panel, and one freezing cabinet. The jackfruit bulbs were frozen at  $-20\pm 2^{\circ}\text{C}$  for 15 min with the alternating magnetic field strength ranging from 0 to 4 mT. The frozen samples were stored at  $-25\pm 2^{\circ}\text{C}$  for 6 months before thawing to determine drip loss, water holding capacity, toughness.

### Physicochemical evaluation

The frozen jackfruit bulbs were thawed at  $4^{\circ}\text{C}$  for 24 hours. Drip loss (%) was expressed as the percent of mass loss of jackfruit bulbs before and after the storage period. Water holding capacity (%) was estimated by using centrifugator to remove mobile water from the samples. Toughness (N) was evaluated by a Warner-Bratzler test to measure the force necessary to shear the sample.

### Statistical analysis

The experiments were run in triplicate with different groups of samples. The data were presented as mean  $\pm$  standard deviation. Statistical analysis was performed by the Statgraphics Centurion version XVI.

## RESULTS AND DISCUSSION

The alternating magnetic field strength had significant influence on drip loss (%), water holding capacity (%) and toughness (N) of frozen-thawed jackfruit bulb. Magnetic field strength decreased drip loss percentage. Generally, drip loss increased by storage duration (table 1). Purnell et al. (2017) showed drip loss values for apple and potato which ranged from 9.4% to 10.5% and from 10.0% to 13.7% under alternating magnetic field. Magnetic field strength efficiently improved water holding capacity of treated samples. It's obviously noticed that water holding capacity decreased by storage duration (table 2). The alternating magnetic field strength slightly decreased toughness (N) of frozen-thawed jackfruit bulb meanwhile toughness of frozen-thawed samples accelerated during preservation (table 3). The decrease in toughness could be attributed to the effect of freezing while acceleration in toughness was due to the effect of storage (Sirijariyawat et al. 2012). It might be attributed to the nature of the cell structure of jackfruit bulbs consisting of semi-rigid, polyhedral cells with cellulosic cell walls bound by a pectinaceous middle lamella (Otero et al. 2000).

**Table 1: Drip loss (%) of frozen-thawed jackfruit bulbs by alternating magnetic field strength (mT)**

Storage (months)	Magnetic field strength (mT)				
	0	1	2	3	4
1	4.19±0.03 <sup>a</sup>	2.32±0.01 <sup>b</sup>	1.46±0.00 <sup>bc</sup>	0.73±0.03 <sup>c</sup>	0.60±0.03 <sup>c</sup>
2	4.72±0.02 <sup>a</sup>	2.56±0.00 <sup>b</sup>	1.69±0.03 <sup>bc</sup>	0.87±0.01 <sup>c</sup>	0.79±0.00 <sup>c</sup>
3	5.13±0.00 <sup>a</sup>	2.89±0.02 <sup>b</sup>	1.85±0.01 <sup>bc</sup>	0.95±0.00 <sup>c</sup>	0.94±0.01 <sup>c</sup>
4	5.68±0.01 <sup>a</sup>	2.97±0.03 <sup>b</sup>	1.99±0.02 <sup>bc</sup>	1.08±0.00 <sup>c</sup>	1.03±0.02 <sup>c</sup>
5	6.02±0.03 <sup>a</sup>	3.11±0.01 <sup>b</sup>	2.23±0.00 <sup>bc</sup>	1.23±0.02 <sup>c</sup>	1.17±0.00 <sup>c</sup>
6	6.45±0.02 <sup>a</sup>	3.26±0.00 <sup>b</sup>	2.41±0.01 <sup>bc</sup>	1.34±0.03 <sup>c</sup>	1.26±0.01 <sup>c</sup>

Note: the values were expressed as the mean of twenty two samples; the same characters (denoted above), the difference between them was not significant ( $\alpha = 5\%$ ).

**Table 2: Water holding capacity (%) of frozen-thawed jackfruit bulbs by alternating magnetic field strength (mT)**

Storage (months)	Magnetic field strength (mT)				
	0	1	2	3	4
1	66.43±0.12 <sup>c</sup>	78.06±0.07 <sup>b</sup>	87.69±0.11 <sup>ab</sup>	92.37±0.08 <sup>a</sup>	93.05±0.13 <sup>a</sup>
2	65.71±0.07 <sup>c</sup>	77.62±0.05 <sup>b</sup>	87.12±0.14 <sup>ab</sup>	91.85±0.11 <sup>a</sup>	92.64±0.17 <sup>a</sup>
3	65.02±0.15 <sup>c</sup>	77.05±0.11 <sup>b</sup>	86.54±0.09 <sup>ab</sup>	91.24±0.18 <sup>a</sup>	92.11±0.12 <sup>a</sup>
4	64.53±0.11 <sup>c</sup>	76.49±0.08 <sup>b</sup>	86.05±0.16 <sup>ab</sup>	90.92±0.12 <sup>a</sup>	91.33±0.09 <sup>a</sup>
5	64.09±0.06 <sup>c</sup>	75.91±0.14 <sup>b</sup>	85.47±0.12 <sup>ab</sup>	90.31±0.07 <sup>a</sup>	90.57±0.16 <sup>a</sup>
6	63.62±0.14 <sup>c</sup>	75.23±0.19 <sup>b</sup>	85.02±0.08 <sup>ab</sup>	89.95±0.22 <sup>a</sup>	90.04±0.08 <sup>a</sup>

Note: the values were expressed as the mean of twenty two samples; the same characters (denoted above), the difference between them was not significant ( $\alpha = 5\%$ ).

**Table 3: Toughness (N) of frozen-thawed jackfruit bulbs by alternating magnetic field strength (mT)**

Storage (months)	Magnetic field strength (mT)				
	0	1	2	3	4
1	3.61±0.04 <sup>a</sup>	3.15±0.03 <sup>ab</sup>	2.81±0.00 <sup>b</sup>	2.32±0.03 <sup>bc</sup>	2.05±0.04 <sup>c</sup>
2	4.37±0.01 <sup>a</sup>	4.01±0.02 <sup>ab</sup>	3.45±0.03 <sup>b</sup>	2.98±0.00 <sup>bc</sup>	2.31±0.02 <sup>c</sup>
3	5.02±0.03 <sup>a</sup>	4.63±0.04 <sup>ab</sup>	4.01±0.02 <sup>b</sup>	3.57±0.01 <sup>bc</sup>	3.02±0.03 <sup>c</sup>
4	5.94±0.06 <sup>a</sup>	5.11±0.01 <sup>ab</sup>	4.66±0.04 <sup>b</sup>	4.01±0.03 <sup>bc</sup>	3.63±0.01 <sup>c</sup>
5	6.75±0.02 <sup>a</sup>	6.04±0.03 <sup>ab</sup>	5.53±0.01 <sup>b</sup>	4.92±0.02 <sup>bc</sup>	4.10±0.00 <sup>c</sup>
6	8.30±0.01 <sup>a</sup>	7.55±0.02 <sup>ab</sup>	6.47±0.00 <sup>b</sup>	5.84±0.01 <sup>bc</sup>	5.09±0.03 <sup>c</sup>

Note: the values were expressed as the mean of twenty two samples; the same characters (denoted above), the difference between them was not significant ( $\alpha = 5\%$ ).

Yamamoto et al. (2005) confirmed that the electric magnetic field freezing at 30 Hz was appropriate to preserve chicken breasts for six months. Pang and Bo (2008) concluded that magnetic field significantly decreased the surface tension force and the viscosity. The refractive index, dielectric constant and electric conductivity of water were accelerated upon magnetization (Hosoda et al. 2004). It could be due to the greater population of charged particles presented in it. In another report, Toledo et al. (2008) realized an increase in the surface tension and viscosity of water under magnetic field. Zhou et al. (2012) noticed the accumulation in the degree of

supercooling with the increase in magnetic field strength. Wang et al. (2013) reported that magnetic field weakened the hydrogen bonds and consequently decreased the average hydrogen bonding number between the water molecules. It implied that the dimension of water cluster would be smaller. James et al. (2015) successfully applied alternating magnetic field in freezing of garlic bulbs using CAS technology. Choi et al. (2015) demonstrated that beef sample frozen by magnetic field had fine ice crystals and their rate of size accumulation in preservation was lower than those of air blast frozen sample. The drip loss and protein denaturation of sample frozen by magnetic field were significantly lower than

than those of the air blast frozen sample during preservation. Aldoradin-Puza et al. (2019) examined the impact of freezing with alternating magnetic field on drip loss of mango. They found that drip loss was about 2.45% to 4.15% in the frozen-thawed mango. Yinying et al. (2019) investigated the impact of alternating magnetic field with high uniformity and multi-directions at 4 mT and 50 Hz on the frozen-thawed avocado puree. They concluded that the temperature zone for maximum ice crystal formation was reduced. Junyan et al. (2020) verified the effects of different magnetic fields on the freezing parameters of cherry. They concluded that magnetic field significantly reduced drip loss. The average ice crystal area was reduced 78% by alternating magnetic field. The optimum alternating magnetic field intensity was noticed at 1.26 mT.

### CONCLUSION

There were 3 steps of the freezing process including the pre-cooling, phase transition and tempering. Alternating magnetic field created an oscillating electric field efficiently interacting with water crystallisation, disrupting hydrogen bonds, accelerating supercooling rate to form fine ice crystals. Jackfruit bulb was a rich source of nutritional and phytochemical components like carbohydrates, proteins, vitamins, minerals, phenolics.

### CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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### AUTHOR CONTRIBUTIONS

Nguyen Phuoc Minh arranged the experiments and also wrote the manuscript.

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