

# Comparison of the effect of freezing on the quality of 'nam dokmai' mango fruit

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**Abstract.** This study evaluated effect of freezing methods on freezing rate and physical qualities of mango flesh before and after thawing. The method of freezing included still air freezing (at -20°C), air blast freezing (at -35°C, velocity 3 m/sec) and Air Blast Combined Vacuum Freezing (at -40°C, were configured core temperature 2 level is -5°C and -10°C) until the temperature reaches -20°C. The frozen flesh were thawed and evaluated for drip loss, pH, total soluble solid, colour, texture (firmness and %firmness decrease). The results showed that Air Blast Combined Vacuum Freezing (-5°C) Quality of mango frozen after thawing did not show significant effect on pH and total soluble solid of fresh mango. The frozen mango had highest lightness (L\*) and the total colour differences ( $\Delta E$ ) had lowest and can maintain the maximum. Therefore, it's possible to introduce air blast combined vacuum freezing techniques applied to frozen mango industry as a result of significant increases freezing rate.

## 1. Introduction

Mango (*Mangifera indica* Linn.) is an economic tropical fruit of Thailand. Ripe mango is high nutrient fruit, consisted of vitamin, carotenoids and beta carotene. As referred to year 2016, Both mango fruits and mango products were exported to other countries created value more than 521,472 million baht. Frozen mangos were exported around 2,409 tons which created value 365 million baht [8]. In present, air freight is selected to be the best way of ripe mango exportation because mango was categorized as short shelf life fruit. However, air freight caused higher cost than other shipping. Nowadays, freezing is the most selected process for ripe mango. The freezing is the method of reducing temperature until lower than -18°C which inhibits microorganism growth or deterioration of food. Water activity was reducing by freezing process to restrain the growth of bacteria and reduce enzyme activity. [1]; [2]; [5].

The quality of freezing fruit is depended on many components which are fruit types, variety, maturity stages or shelf life. However, the problem of producing freezing mangos were occurred from high water volume, changing texture, such as soften, changing of color and changing of important nutrient, such as vitamin C, carotenoids and microstructure, were occurred from freezing mango but all changing was high or low depended on the drip loss while freezing. [1]; [4-5]

Karl and Da-Wen (2000) studied about cooling by vacuum chilling which was used with product contained water volume than 90% such as mushroom and lettuce. Vacuum chilling can be used with freezing mango. Another advantage of vacuum chilling is to specify temperature and degree. Moreover, the study of vacuum chilling and mushroom browning by Polyphenol oxidase (PPO) were shown the mushrooms frosted by vacuum chilling were browned lower than other process. The study of Cheng and Lin (2007) showed the liquid state was changed faster when reducing pressure. Therefore, there are possibility to compile with reducing pressure and freezing to keep quality of mango.

In the past, the problems between different freezing was not studied and there was no the study about the using of vacuum system in freezing. Then, Still Air Freezing and Air Blast Freezing, which were most selected in freezing industry and Air Blast Combined Vacuum Freezing were compared for the advantages of freezing industry.

## 2. Materials and Methods

### 2.1 Materials

Mango (cv. Namdokmai) the variety of mango used in this study, No.4 were purchased from Chachoengsao province, Thailand, the fruits were selected for the pH value and total soluble solids were  $4.12 \pm 0.22$  and  $14.78 \pm 0.98^\circ\text{Brix}$ , amount 60 kg.

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## 2.2 Sample preparation

The sample were washed in chlorine solution (concentration 200 ppm) for 2 minutes, air dried and peeled. Only the central segments of the fruit sample were cut into size 2 x 2 x 1.5 cm and soaked in solution (1% ascorbic acid :1% calcium chloride (w/w)) for 10 minutes. Place them apart in a stainless-steel tray.

## 2.3 Freezing experimental

Mango were divided into 4 sections for four freezing methods by Still Air Freezing (at -20°C) was carried out in a still air freezer (SF-PC997, Panasonic Co., Ltd., Japan), Air Blast Freezing (at -35°C velocity 3 m/sec) was performed in an air blast freezer (Compact freeze, PATKOL Co., Ltd., Thailand) and Air Blast Combined Vacuum Freezing (ABCVF) (at -40°C, were configured core temperature 2 level is -5°C and -10°C the system will stop the air blast freezing process and was used a vacuum system to reduce the pressure at 40 Pa until the core temperature of sample reaches -20°C) was executed in a Kryo ·D· Freezer (ITC Co., Ltd. Thailand), Four freezing process were used thermocouples K type, (TRES-8, LogTag Recorder, USA) insert into the core temperature of the sample, Record temperature every 30 seconds since the core temperature of 24°C, the temperature reached to -20°C. The freezing rate of the samples the freezing rate was calculated by modifying the equation: [4]

$$\text{freezing rate (cm/hr.)} = \text{Distance} / \text{Freezing time} \quad (1)$$

Where Distance from the surface to the thermal center of fruits per freezing times of temperature decrease from the initial temperature (24 °C) to -20°C).

### 2.3.1 Thawing processes

The frozen sample were placed on napkin on plastic grate and thawed in control temperature and control relative humidity room (at temperature 25 °C, 50% relative humidity). Were used thermocouples K type insert into the core temperature of the sample until the temperature reaches 0 -4°C and quality was then analysed.

## 2.4 Drip loss

Drip loss of the frozen samples were sampling ten sample drip loss was defined as the percentage and was calculated following equation:

$$\text{Drip loss (\%)} = (W_0 - W_1) \times 100 / W_0 \quad (2)$$

Were  $W_0$  is weight of frozen mango (g) and  $W_1$  is weight of tawed mango (g). Drip loss was expressed as percent (%).

## 2.5 pH and Total Soluble Solid (TSS)

Frozen mango sampled after thawed was blended with a blender (HR2115, Philips Electronics Co., Ltd., Nederland), measurement of pH Volume 10 ml with pH meter (Lab855,SI Analytics, Germany) and total soluble solid was determined by refractometer (HI96800, Hanna, Romania) and repeat three repetitions.

## 2.6 Colour and Colour difference

The colour of the fresh and frozen-thawed sample was measured through a Hunter Lab Colorimeter (ColorFlex EZ, Hunter Associates Laboratory, Inc., UK). In this system,  $L^*$  is presented to lightness (0-100 scale, black to white);  $a^*$  relate to red colour (+) and to green colour (-). and  $b^*$  corresponds to yellow colour (+) and blue colour (-). Compare colour difference ( $\Delta E$ ) of fresh and frozen was calculated following equation

$$\Delta E = [(L_0^* - L_1^*)^2 + (a_0^* - a_1^*)^2 + (b_0^* - b_1^*)^2]^{1/2} \quad (3)$$

Where  $L_0^*$ ,  $a_0^*$  and  $b_0^*$  are the colour of fresh mango sample, and  $L_1^*$ ,  $a_1^*$  and  $b_1^*$  are the colour of frozen-thawed mango sample.

## 2.7 Texture analysis

The texture of the sample both fresh and frozen samples was determined a Texture Analyzer (TA.XT2i Stable Micro Systems, Surrey, UK) with a 100 mm cylinder probe (P/100), using a compression of 50% strain and Pre-test speed : 1.0 mm/s. ; Test speed: 0.2 mm/s; Post-test speed: 10.0 mm/s. The maximum peak force was represented a firmness value in Newton. five pieces of fruit were tested for each treatment. The results are used to calculate the percentage decrease in firmness (% Firmness decrease) by equation: [1]

$$\% \text{ Firmness decrease} = (F_i - F_f) \times 100 / F_i \quad (4)$$

Where  $F_i$  is the firmness of fresh sample, and  $F_f$  is the firmness of frozen-thawed sample.

## 2.8 Statistical analysis

The experiment was completely Randomize Design (CRD), the data were analysed by analysis of variance (ANOVA) according to the Duncan's Multiple Range Test (DMRT) at 95 percentage confidence intervals. Statistical

analysis was presented by SPSS Statistics Software 20.0 for Windows (SPSS, Inc., Chicago, Illinois)

### 3. Results and Discussion

#### 3.1 Effect of freezing time and freezing rate

The freezing times of each freezing methods were present in Table 1. The ABCVF(-5°C) method had the fastest time 30 minutes, freezing rate was 2.00 cm/hr. Each of these freezing methods has a different rate depending on the method of heat transfer, can be divided into freezing rates according to the efficiency of the equipment. The freezing rate it is classified the ABCVF and air blast freezing method was quick-freezing. In addition, found that still air freezing spends more time in the critical zone than other freezing (Fig 1.). The longer it takes for the critical zone, the greater the ice crystals [10]. On the other hand, the ABCVF and air blast freezing methods has the slope of the freezing temperature curve and passes through the critical zone. For this reason, the possibility of accelerating the freezing rate is significant of the vacuum combined air blast freezing.

#### 3.2 Effect of freezing methods on Drip loss of mango.

Effect of difference of freezing method on drip loss of sample after frozen-thaw (Table 4.). It was found that the samples of frozen mangoes with the ABCVF (-5°C) has lowest value was 4.82%. The drip loss increases when the freezing rate decreases [10]. The results are consistent with Table 1. This results in a more complete microstructure of fruit. So, the loss of water after thawing is associated with reduced cell integrity.

**Table 1.** Freezing time and freezing rate of each freezing methods.

Freezing methods	Freezing time (minutes)	Freezing rate (cm/hr)
still air freezing	307.33±0.05 <sup>d</sup>	0.20±0.01 <sup>d</sup>
air blast freezing	33.33±0.03 <sup>b</sup>	1.80±0.09 <sup>b</sup>
ABCVF (-10°C)	36.50±0.01 <sup>c</sup>	1.64±0.03 <sup>c</sup>
ABCVF (-5°C)	30.00±0.02 <sup>a</sup>	2.00±0.03 <sup>a</sup>

Data are recorded as the mean ± standard deviation from 3 replications. And different letter in each column are significantly different (p < 0.05)

#### 3.3 Effect of freezing methods on pH and Total Soluble Solid (TSS) of mango.

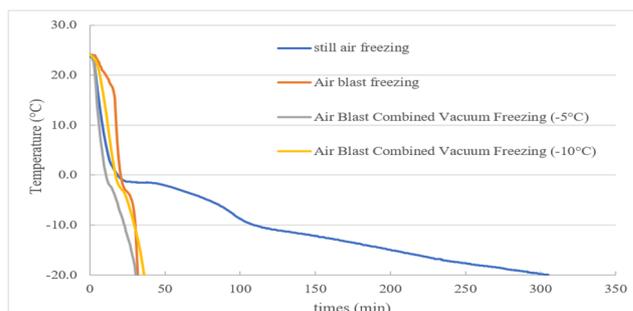
In the Table 2. pH and total soluble solids content of the frozen-thawed samples was indicated air blast

freezing and ABCVF (both -10°C and -5°C) there was no statistically significant difference in fresh mangoes. At the same time, the frozen sample of still air freezing observed increase pH value and decrease total soluble solids content statistical significance when compared to fresh mango. Due to during frozen, the water in the sample formed ice crystal which damaged the cellular. This causes the solids inside the cell to come out of the cell with the fluid lost [1].

**Table 2.** pH and Total Soluble Solid (TSS) content of fresh and frozen-thawed mangoes

sample	pH	TSS
fresh	4.12±0.22 <sup>b</sup>	14.78±0.98 <sup>a</sup>
still air freezing	4.50±0.03 <sup>a</sup>	12.37±0.06 <sup>b</sup>
air blast freezing	4.01±0.01 <sup>b</sup>	13.20±0.10 <sup>b</sup>
ABCVF (-10°C)	3.92±0.01 <sup>b</sup>	14.77±0.06 <sup>a</sup>
ABCVF (-5°C)	3.91±0.01 <sup>b</sup>	14.67±0.15 <sup>a</sup>

Data are recorded as the mean ± standard deviation from 3 replications. And different letter in each column are significantly different (p < 0.05)



**Fig. 1.** Freezing curves obtained from four freezing method of mango.

#### 3.4 Effect of freezing methods on Color and Color difference of mango.

The experiment data on the color parameters (L\*, a\* and b\*) of mango frozen-thawed by four freezing methods, and color difference. In the Table 3 show that the brightness (L\*) of the frozen mangoes ABCVF (-5°C) with the highest brightness. The red colour (a\*) of frozen-thawed mangoes with still air freezing has highest value and more than fresh mango. Arasorn et al., (2558) reported that color changes after freezing and defrosting were the main problem of enzymatic browning reactions. This is an oxidation reaction when cell injury enzyme and oxygen are in contact with monophenols, resulting in browning index in the mango. For this reason, freezing slows the freezing rate, the cells are highly destroyed, resulting in higher reaction rates. When all values were calculated for colour difference (ΔE), it was found that the samples of mangoes,

**Table 3.** Chang of color L\* value, a\* value, b\* value and color difference color of fresh and frozen-thawed mangoes.

sample	L*	a*	b*	ΔE
fresh	64.06±0.16 <sup>a</sup>	14.50±0.05 <sup>b</sup>	61.72±0.17 <sup>a</sup>	-
still air freezing	60.08±0.14 <sup>f</sup>	15.51±0.02 <sup>a</sup>	57.97±0.05 <sup>c</sup>	54.10±0.31 <sup>d</sup>
air blast freezing	60.43±0.07 <sup>d</sup>	10.80±0.02 <sup>f</sup>	57.53±0.11 <sup>c</sup>	45.81±0.16 <sup>e</sup>
ABCVF (-10°C)	61.34±0.12 <sup>c</sup>	12.35±0.09 <sup>c</sup>	61.56±0.55 <sup>a</sup>	30.88±0.26 <sup>b</sup>
ABCVF (-5°C)	62.23±0.10 <sup>b</sup>	11.22±0.06 <sup>d</sup>	60.26±0.11 <sup>b</sup>	24.75±0.20 <sup>a</sup>

frozen-thawed with ABCVF (-5°C) had the difference of mango colour least than compared to other frozen-thawed samples statistically significant. So, ABCVF (-5°C) method is possible can be maintain the quality of frozen mango colour.

### 3.5 Effect of freezing methods on texture of mango.

**Table 4.** Firmness and drip loss or the both fresh and frozen-thawed mangos.

sample	Firmness (N)	Firmness decrease (%)	Drip loss (%)
fresh	8.31±0.83 <sup>a</sup>	-	-
still air freezing	2.62±0.33 <sup>c</sup>	68.22±4.95 <sup>b</sup>	15.99±0.66 <sup>d</sup>
air blast freezing	2.94±0.24 <sup>c</sup>	64.51±2.91 <sup>b</sup>	11.46±0.36 <sup>c</sup>
VCAF(-10°C)	3.67±0.19 <sup>b</sup>	55.38±5.04 <sup>a</sup>	9.53±0.59 <sup>b</sup>
VCAF (-5°C)	3.68±0.16 <sup>b</sup>	55.30±6.47 <sup>a</sup>	4.82±0.11 <sup>a</sup>

Data are recorded as the mean ± standard deviation from five replications for firmness and ten replications for drip loss. And different letter in each column are significantly different (p < 0.05)

The texture change of frozen foods is mainly due to the freezing rate. The experiments showed that the firmness value of fresh was 8.31 N. Frozen samples with ABCVF (-5°C) where have significant of densely more than those at various levels was 3.68 N. (Table 4) The results of the experiment corresponded to the effect of freezing rate as shown in Table 1. In addition, different freezing methods also contributed to the firmness decrease (%) after thawed. It was found that ABCVF (-5°C) still had the lowest percentage reduction, and same trend as the firmness. Furthermore, the less drip loss effected less destroyed cell it possible to maintain many internal structures.

## 4. Conclusion

Among the four freezing methods studied in this research, the ABCVF (-5°C) method was found to be a greatly freezing method, with quality similar to fresh mango, whereas still air freezing method led to deterioration of fruits. The higher freezing rate and lowest drip loss of frozen-thawed mango of ABCVF (-5°C) method likely explained the higher preservation quality in

terms of reduce pH, TSS, color and color different and texture quality. Among these treatment, the high freezing rate in ABCVF (-5°C) method the most effect to good quality during freezing because of the small size of ice crystal and reduced damage to the fruit cellular. However, since father studies the effect of long-term preservation on the quality, microstructure of frozen mango should be studied.

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