Determination of the Effect of Freezing Methods on the Quality of Frozen Tomato Pieces

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ABSTRACT

Background: Due to their highly perishable nature, vegetables possess a higher chance of deterioration and damage after harvesting. Freezing is a potential preservation technique used to reduce the deterioration and increase the shelf life of vegetables by preventing the wastage of substantial quantities of tomatoes in Sri Lanka.

Methods: In this research calcium chloride (2.4% w/w) pretreated *Thilina* and RIDA F1 tomato variety pieces were analyzed drip loss, pH, color, hardness, cutting shearing strength, ascorbic acid content and sensory parameters under air blast freezing (-30°C, 3 ms^{-1} air velocity) and conventional freezing (-18°C) conditions.

Result: The L* values of colour, pH and ascorbic acid content were shown significant differences ($p<0.05$) but a*, b* values, driploss%, cutting and shearing strength didn't show any significant differences ($p<0.05$) during different freezing conditions. The magnitude of color change (ΔE) is higher ($p<0.05$) in conventional freezing treatment than in air-blast freezing. The preference among the panelists is significantly ($p<0.05$) higher for blast frozen tomato samples than conventional frozen samples concerning color, odor, texture and overall quality parameters. According to the statistical analysis, air blast freezing preserve better physiochemical and sensory parameters of *Thilina* and RIDA F1 tomato varieties.

Key words: Air blast freezing, Conventional freezing, Frozen tomatoes, Quality tomato.

INTRODUCTION

The frozen food market is one of the largest and most dynamic sector in the food industry. Compared to other preservation techniques freezing process is one of the most convenient and easiest food preservation method. Freezing can arrest some qualities of freshness from losing during handling and distribution (Sweeney *et al*., 1962; Burr *et al*., 1966). Thus the main objective of the freezing of vegetables is maintaining that fresh quality (Deitrich *et al*., 1977).

Tomato is the second most cultivated crop in Sri Lanka and the average annual yield (t/ha) was recorded as 15.17 in 2017. In the year 2017, 63 tons of tomatoes were exported simultaneously 7 tones were imported (Anonymous, 2018). Low or prevention of transportation damage causes big demand among the growers and sellers (Weligama *et al*., 2017). Even though they are high-demand vegetables in Sri Lanka but they have higher postharvest losses. A survey said that 54% of cumulative (measured at the wholesale market) postharvest losses happen for tomatoes in Sri Lanka (Kitinoja *et al*., 2015). Considering the Sri Lankan scenario, the Ministry of Internal Trade and Cooperatives has estimated in 2012, over 30% of the harvest of vegetables and fruits get wasted in Dambulla Economic Centre. In 2016 on 2nd December an article by Waruni Karunaratne to Sunday Leader mentioned that Rs.15 lakhs worth of vegetable stock had been thrown away to Habarana forest from Dambulla Economic Centre in the recent past (Weerasinghe and Priyadharsan, 2017).

Tomato can quickly deteriorate by microorganisms due to high water content. Therefore it is important to prolong the shelf life of such vegetables. High-temperature treatment of these vegetables can cause flavor, aroma, texture and nutritional losses compared to low-temperature preservation (Obenland *et al*., 2012). Blast freezing is the most suitable method to result in better quality and safe vegetables. At the same time, the extracellular crystals cause progressive separation of cells due to their large size. But in rapid freezing, it is vice versa (Canet *et al*., 2005).

The frozen food industry needs facilities for transporting, storage and marketing the products from the processing plant which can cause a large amount of capital investment. In rural or semi-rural areas in developing countries, the freezing of food products was not that much applicable. With the economic developments, the societal needs move towards high quality with freeze preservation. Consumption of high-valued commodities is dependent on the wealth of a country

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which determines the demand for frozen foods. Lack of time spent on the preparation of food due to more women entering the workforce has increased the consumption of ready-to-eat food products. Approximately 10% of the total cost of production is spent on the freezing process and storage conditions (Persson and Lohndal, 1993).

In this research, specific chemical, physical and sensory parameters of tomatoes after blast freezing and conventional freezing will be analyzed. Through the findings, the possibility of introducing frozen tomatoes to the Sri Lankan market can be evaluated.

MATERIALS AND METHODS

The research was conducted from December 2020 to July 2021 at the Faculty of Agriculture, University of Peradeniya, Sri Lanka and the Food Research Unit, Department of Agriculture, Gannoruwa, Peradeniya, Sri Lanka.

Materials

Uniform fresh tomatoes (*Solanum lycopersicum*)-Thilina (local variety) were purchased directly from a local market in Gannoruwa, Sri Lanka. Uniform fresh tomatoes (*Solanum lycopersicum*)-RIDA F1 (imported variety) were got from HORDI, Gannoruwa, Sri Lanka.

Sample preparation

The samples were washed in chlorine water for 2 minutes, dried and manually cut with stainless steel knife into specific shapes. Tomatoes were cut into pieces (1/3 of whole fruit).

Calcium chloride pretreatment

Freshly cut tomato pieces were immersed into 2.4%, calcium chloride solution for 3.5 minutes and then drained into sieves for 1 minute (Zhou, 2016) at ambient temperature (28°C).

Packaging

After calcium chloride pretreatment, the remaining surface water on the pretreated vegetable samples was removed by muslin cloth. After that tomato pieces were packaged into labeled polypropylene packaging material and well-sealed by the sealer (300 FE, SEPACK, Sevana, India).

Freezing

Conventional freezing at -18°C was carried out in a conventional freezer (RS55K5010S9/TL, SAMSUNG, Digital Inverter Technology Co., Ltd.) and air blast freezing at -30°C (velocity 3 m/sec) was performed in an air blast freezer (Bitzer 75 hP, BITZER Co., Ltd., Thailand). During both the freezing processes K type thermocouples (RS-232 Test Link, TECPEL) were used. Blast feezing treated (BFT) and conventional freezing treated (CFT) samples were separately analyzed.

Thawing process

The frozen sample packages were placed into a water bath and thawed in control temperature and control relative humidity room (at temperature 25°C, 50% relative humidity).

Analysis

Drip loss

Analytical balance (AS 310.R2, RADWAG) was used to measure drip loss of the tomatoes according to the following formula (Phothiset and Charoenrein, 2014).

$$\text{Drip loss\%} = \frac{\text{Weight before thawing-Weight after thawing}}{\text{Weight before thawing}} \times 100$$

pH

The pH of tomatoes was measured by a digital pH meter (EUTECH PC 450, Thermo scientific pH meter) at 25°C according to AOAC, 981.12 methods.

Color

The surface color of the tomato was measured by colorimeter (CS-10, CHN Spec). Color difference (ΔE) was also calculated using the following formula:

$$\Delta E = \sqrt{[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]}$$

Where,

$\Delta L = L-L_o$, $\Delta a = a-a_o$, $\Delta b = b-b_o$, L_o, a_o, b_o and L, a, b are the color values of fresh and frozen vegetables respectively (Rajkumar *et al*., 2017).

Hardness and cutting and shearing strength

Hardness and cutting and shearing strength of tomato pieces (N) were measured by texture analyzer (SHIMADZU compact tabletop testing machine EZTest, EZ-X Series) for analysis. The determination was done using a single-point aluminum probe; the test speed was 1 m/s.

Ascorbic acid content

Standardization of dye

Standard ascorbic acid solution 5 ml and phosphoric acid 5 ml were taken. A micropipette was filled with dye. The dye solution was titrated until getting the endpoint to a pink color which should persist for 15 sec. Dye factor was determined as mg of ascorbic acid per ml of the dye using the following formula:

$$\text{Dye factor} = \frac{0.5}{\text{Titre}}$$

Titration

Two grams filtrate of tomato extract made up to 20 ml with 3% of phosphoric acid. Pipette out five milliliters of this mixture solution and titrated against the standard dye solution (Ranganna, 1977).

Sensory analysis

Frozen-thawed (into distilled water for 2 hours at room temperature 28°C). Thilina tomato samples were served to 30 panelists for sensory evaluation using a five-point hedonic scale. The sensory analysis was conducted at the sensory lab, Department of Food Science and Technology, “Faculty of Agriculture, University of Peradeniya.

RESULTS AND DISCUSSION

Evaluation of the acceptability and compare the freezing treatments

According to the statistical analysis preference for the blast and conventional freezing, a method was significantly ($p<0.05$) different for color. But, concerning odor, texture and overall acceptability both freezing methods didn't show significant ($p<0.05$) differences. Preference for blast freezing was significantly ($p<0.05$) higher than the conventional freezing concerning color, texture and overall acceptability (Fig 1). Survey results say that the most attractive attribute of tomatoes towards purchase is the color, especially the red color is preferred (Oltman *et al*., 2014). Sensory analysis for color, BFT tomatoes have a higher magnitude of preferences.

Chemical analysis of frozen tomato pieces

Color

For *Thilina* variety, both freezing conditions showed significant ($p<0.05$) differences in L* value. But for a* and b* values both freezing conditions didn't show any significant ($p<0.05$) differences. So the changes in the color of *thilina* tomatoes were the same for both freezing conditions in a* and b* values except L* values. For RIDA F1 variety, there were not any significant ($p<0.05$) differences in L*, a* and b* values during both blast and conventional freezing treatments. Despite the fact that there were some differences in measurements (Fig 2 and 3), there were no statistically significant variations in color pigment oxidation.

When considering the ΔE values (Table 1) of tomatoes, the median of the BFT tomato samples showed lesser ΔE values than CFT in both *thilina* and RIDA F1 varieties. The magnitude of color change was higher ($p<0.05$) in conventional freezing treatment. So, the color pigments of tomatoes are well preserved in blast freezing than in conventional freezing.

The main color pigment present in tomatoes is lycopene (Kong *et al*., 2010). Approximately 4 to 6% of lycopene gets degraded during initial freeze-thaw and 30 to 40% loss of lycopene occurs at -20°C, after one year storage periods in watermelons (Fish and Davis, 2003). Heat treatments, exposure to oxygen and light destroy lycopene (Cole and Kapur, 1957) but in low freezing conditions, the destruction is very low (Sherkat and Luh, 1976). Increasing optimum

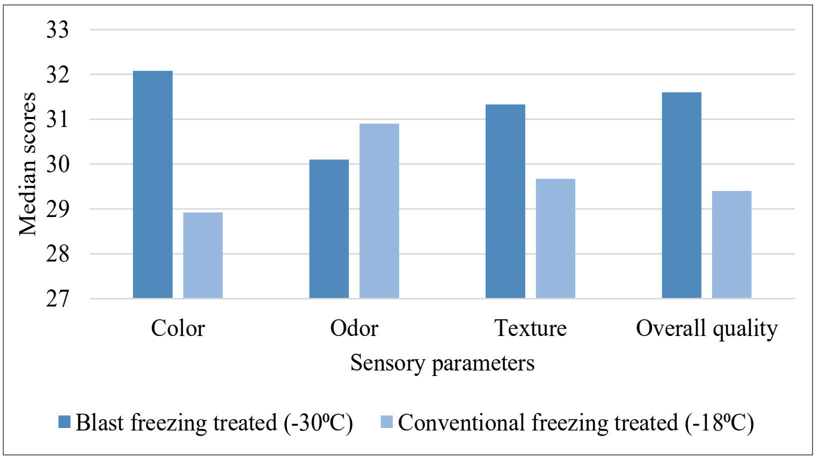

Fig 1: Median scores of consumer preference for blast and conventional frozen thilina variety tomato dices.

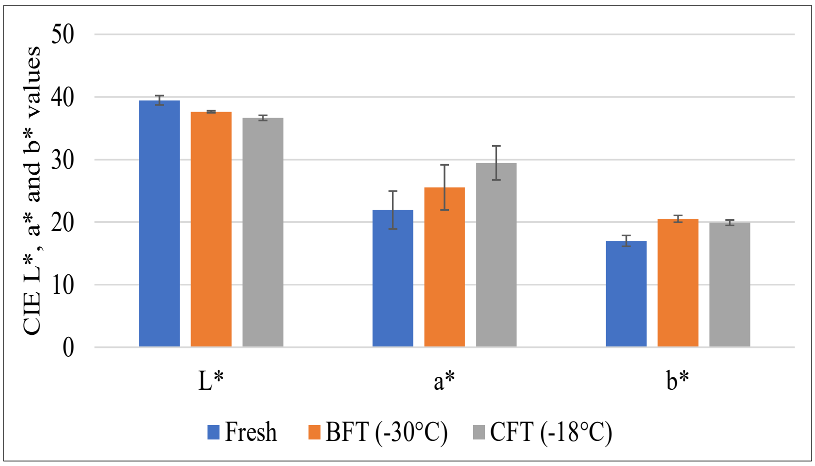

Fig 2: Change of L*, a* and b* values of Thilina variety tomato pieces during different freezing conditions.

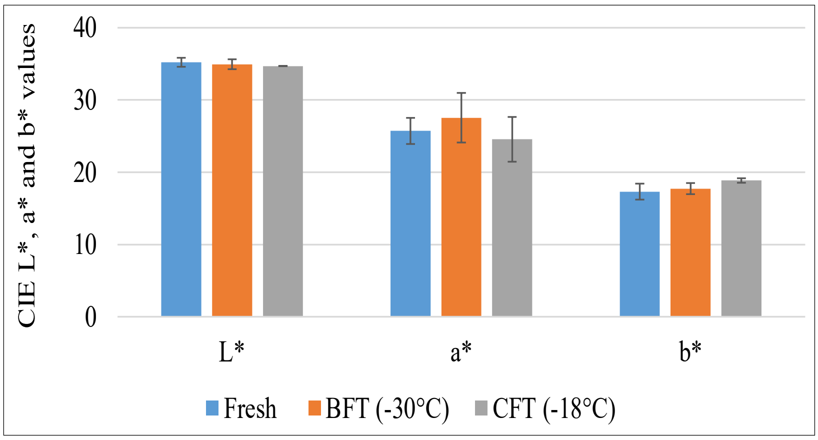

Fig 3: Change of L*, a* and b* values of RIDA F1 tomato pieces during different freezing conditions.

Table 1: Color variables of the blast and conventional freezing treated tomato pieces.

Parameters	Mean±SD					
	Thilina variety			RIDA F1 variety		
	Fresh	BFT (-30°C)	CFT (-18°C)	Fresh	BFT (-30°C)	CFT (-18°C)
L*	39.46±0.76	37.63±0.15[a]	36.64±0.41[a]	35.20±0.94	34.92±0.69	34.68±0.02
a*	21.94±3.03	25.55±3.62	29.44±2.72[a]	25.71±1.80	27.53±3.42	24.56±3.10
b*	17.01±0.86	20.51±0.55	19.92±0.43[a]	17.30±1.10	17.73±0.76	18.86±0.31
ΔE		6.03±1.37	8.58±2.53		1.81±0.49	2.86±1.85

[a]Mean±SD values are significantly different (p<0.05) with fresh samples.

temperature increases the rate of reactions. Therefore, -18°C/higher temperature than blast freezing may increase the reaction rate of oxidation/degradation.

pH

Blast freezing (-30°C) tomatoes and conventional freezing (-18°C) tomatoes showed significant (p<0.05) differences in pH chemical parameters in both tomato varieties. That means, both frozen treatments didn't show fresh quality in pH parameters. When comparing the mean values of pH (Table 2), BFT samples showed a lesser deviation with fresh pH values than CFT samples.

The pH values were reduced in both freezing conditions than the fresh samples. The increasing freeze concentration of solutes and precipitation (Ca and Mg phosphates) result in an initial pH drop in foods (Powrie, 1984).

Drip loss%

A higher amount of water (93-96%) in the intracellular space gets frozen during freezing and after thawing, water and juices are leached out through the damaged cell membranes. The drip ratio (mL/g vegetable) was increased mostly in the method of windless freezing followed by air-blast freezing and liquid nitrogen freezing (Sawada and Fukuda, 2018). By forming small size ice crystals, cell membrane disruption is less in blast/quick freezing. Therefore the cell membrane acts as a barrier to loss of cell sap resulting in lesser drip loss after thawing.

In this research, when mean±SD (Table 3) of drip loss% are compared, BFT samples in both varieties showed lesser values of drip loss % than CFT samples. But the statistical analysis was shown that the mean drip loss% values are equal in both freezing conditions for the two tomato varieties.

Table 2: pH of blast and conventional freezing treated tomato pieces.

Tomato variety	Mean±SD		
	Fresh	BFT (-30°C)	CFT (-18°C)
Thilina	4.15±0.02	4.09±0.01[a]	4.02±0.01[a]
RIDA F1	4.18±0.01	4.03±0.05[a]	4.07±0.01[a]

[a]Means±SD values are significantly different (p<0.05) with fresh samples.

Table 3: Drip loss% of blast and conventional freezing treated tomato pieces.

Tomato variety	Mean (%) ±SD	
	BFT (-30°C)	CFT (-18°C)
Thilina	5.98±0.38	7.40±0.64
RIDA F1	6.87±0.31	8.31±0.35

Table 4: Ascorbic acid content of the blast and conventional freezing treated tomato pieces.

Tomato variety	Mean (mg/100 g) ±SD		
	Fresh	BFT (-30°C)	CFT (-18°C)
Thilina	848.5±105.0	792.9±22.0	793.0±20.6
RIDA F1	47.3±1.9	44.7±1.0	42.9±1.9[a]

[a]Means±SD values are significantly (p<0.05) different with fresh samples.

Table 5: Hardness and cutting and shearing strength of blast and conventional freezing treated tomato pieces.

Parameter	Mean±SD					
	Thilina variety			RIDA F1 variety		
	Fresh	BFT (-30°C)	CFT (-18°C)	Fresh	BFT (-30°C)	CFT (-18°C)
Hardness (N)	27.07±3.45	25.76±7.47	21.76±3.67	23.54±7.65	25.86±10.70	25.04±10.15
Cutting and Shearing strength (J)	0.178±0.009	0.217±0.081	0.186±0.029	0.119±0.006	0.183±0.057	0.159±0.025

Ascorbic acid content

The stability of nutrients, especially vitamins in fruits and vegetables are better preserved at low temperatures than other storage methods. A higher level of vitamin C loss may occur during pre-freezing conditions (Fennema, 1988); (Lisiewska and Kmiecik, 2000). According to the statistical analysis results (Table 4), for *Thilina* variety, both the freezing conditions didn't show any significant ($p<0.05$) differences in vitamin contents of fresh tomato. But in RIDA F1 variety CFT samples have shown significant ($p<0.05$) differences with fresh tomato vitamin contents. When considering the means values, the CFT samples were shown less ascorbic acid content values than BFT samples. Water losses also can change the ascorbic acid content of frozen fruits and vegetables (Bonat Celli *et al*., 2016). So the higher drip loss during the conventional freezing may cause an ascorbic acid loss in conventional frozen samples than blast frozen samples.

It is a known fact that the ascorbic acid content is used as an indicator for other chemical reactions of processed vegetables. Therefore it can be concluded that chemical reactions/ degradation/ oxidation can be lowered during blast freezing techniques for tomatoes. Oxygen is the most destructive ingredient for vitamin C degradation of foods (Padayatty *et al*., 2003). Oxygen content in the packaging material may cause vitamin loss in frozen tomatoes.

Hardness and cutting and shearing strength

BFT and CFT samples didn't show any significant ($p<0.05$) differences in hardness and cutting and shearing strength physical parameters among both varieties (Table 5).

Even though the statistical analysis didn't show any significant differences for freezing conditions, when considering the mean values of texture, there is the same pattern of increasing values during blast freezing. Due to the same calcification pretreatment for both blast and conventional frozen samples they have shown an increase in hardness and cutting and shearing strength than the fresh samples. Another result says that when the density increase, food expansion causes tensile stresses (Pham *et al*., 2005). It may be the reason for the higher texture values of frozen tomatoes than fresh tomatoes. In the blast frozen (-30°C) tomatoes higher firmness than conventional frozen (-18°C) tomatoes were observed.

CONCLUSION

In comparison to conventional freezing (-18°C), blast freezing (-30°C) preserves ($p<0.05$) chemical parameters (pH, ascorbic acid content) and physical parameters (color, length, hardness and cutting and shearing strength) of tomatoes. Small size of ice crystal formation and fast freezing rate results in preserving the freshness of tomatoes-*Thilina* and RIDA F1 variety. Sensory analysis showed higher consumer preference ($p<0.05$) in terms of color, odor, texture and overall acceptability for blast frozen samples which indicates that the blast frozen samples will be of higher market demand. According to the vegetables and their varietal characteristics certain chemical and physical parameters change for freezing conditions.

RECOMMENDATION

- Need to analyze the physiochemical parameters of frozen vegetables at air-tight packaging conditions.
- The thawing time with microbiological properties should be analyzed to ensure the quality and safety of frozen vegetables.

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