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Freezing point depression of different Sucrose solutions and coconut water

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Abstract
The addition of non-volatile substances to a solvent decreases the vapor pressure and added solute particles affects with the formation of pure solvent crystals. Decrease in freezing point directly correlated to the concentration of solutes dissolved in the solvent. This study determines freezing point depression of Sucrose solutions and coconut water with respect the amount of dissolved soluble solids in the solvent. Brix 5^0, 10^0,15^0,20^0 and 25^0 of sucrose solutions were prepared and each sample was allowed to freeze at – 20^0C.The decreasing temperature during freezing was recorded with time. Then it was allowed to melt and change in the temperature (^{0}C) was recorded with time (s). Same procedure was carried out for coconut water. Freezing curve and melting curve were plotted and freezing and melting points of Sucrose solutions were -0.4^{0}C,-1.7^{0}C.-2.2^{0}C,-2.3^{0}C and -3.3^{0}C for brix 5^0, 10^0,15^0,20^0 and 25^0 respectively. Freezing point of coconut water was -2.4^{0}C at brix 3.5.

Keywords: freezing point, freezing point depression, brix^0, freezing curve, melting curve

1. Introduction
Boiling point or freezing point of liquid solution would be affected by the dissolved solids in the liquid phase. A soluble solid in solution has the effect of raising its boiling point and depressing its freezing point. The addition of non-volatile substances to a solvent decreases the vapor pressure and the added solute particles affect the formation of pure solvent crystals. According to many researches the decrease in freezing point directly correlated to the concentration of solutes dissolved in the solvent. This phenomenon is expressed as freezing point depression and it is useful for several applications such as freeze concentration of liquid food and to find the molar mass of an unknown solute in the solution. Freeze concentration is a high quality liquid food concentration method where water is removed by forming ice crystals. This is done by cooling the liquid food below the freezing point of the solution [2, 10, 11].

The freezing point depression is referred as a colligative property and it is proportional to the molar concentration of the solution (m), along with vapor pressure lowering, boiling point elevation, and osmotic pressure. These are physical characteristics of solutions that depend only on the identity of the solvent and the concentration of the solute. The characters are not depending on the solute's identity [3, 4].

Today, there is a growing demand for coconut water in tropical countries as well as European countries as a healthy beverage because of its constituents such as minerals, Vitamin (Vitamin C and Vitamin B complex), low fat, sugar, etc. To mass production of coconut water as a beverage, major problem to come across is handling the volume. The possible solution for this problem is to reduce the volume of the coconut water. Commercially viable method to reduce volume is to remove water to concentrate the coconut water by evaporation, not a better method since application of heat will destroy the natural taste and nutrients of the product. Low temperature operation is mostly feasible operation to prevents microbial activity and at the same time preserving the natural properties of the product. Freeze-concentration can be used as a good alternative method for concentrating coconut water.

This research work carried out to understand how the freezing point lowers with the effect of brix values for different Sucrose solutions and to find the freezing point of coconut water, which is useful information in concentrating coconut water by freeze concentration. Freezing curve and melting curve were plotted against Temperature (^{0}C) vs. Time (s) to determine the freezing point of sugar solutions and coconut water.

2. Materials and Methods
2.1 Sample preparation for freezing point determination
The Sucrose solutions with different brix values were prepared (Brix 5 ^{0}to Brix 25 ^{0}) using purified sugar and distilled water. The concentration of soluble solids in the samples was measured with a Digital pocket Refractometer (ATAGO PAL-1, Japan; 0-53% Brix) at room temperature (29 ^{0}C ± 0.5^{0}C). Samples were kept in the refrigerator at 2 ^{0}C until the start of the trials.

2.2 Analysis of freezing points in different sugar solution using freezing curve and melting curve
About 15 ml of each sample was placed in a plastic tube (10 mm in diameter) which was equipped with a Thermocouple (TECPEL-317 Data logger, Taiwan) ±0. 1 ^{0}C in accuracy was frozen completely at – 20^{0}Cin freezer. The decreasing temperature was recorded with time, and then the frozen tube was placed on the Vortex mixer (VELP-Scientifica, Europe) to melt frozen sample. The sample tube was stirred at 15Hzand the change in the temperature (^{0}C) was recorded with time (s). The procedure was carried out according to the research work of Miyawaki *et al*, 1997 [11].

Same procedure was carried out for coconut water (Brix 3.5) to analyze the freezing point depression.

3. Results and discussion
3.1 Freezing curve

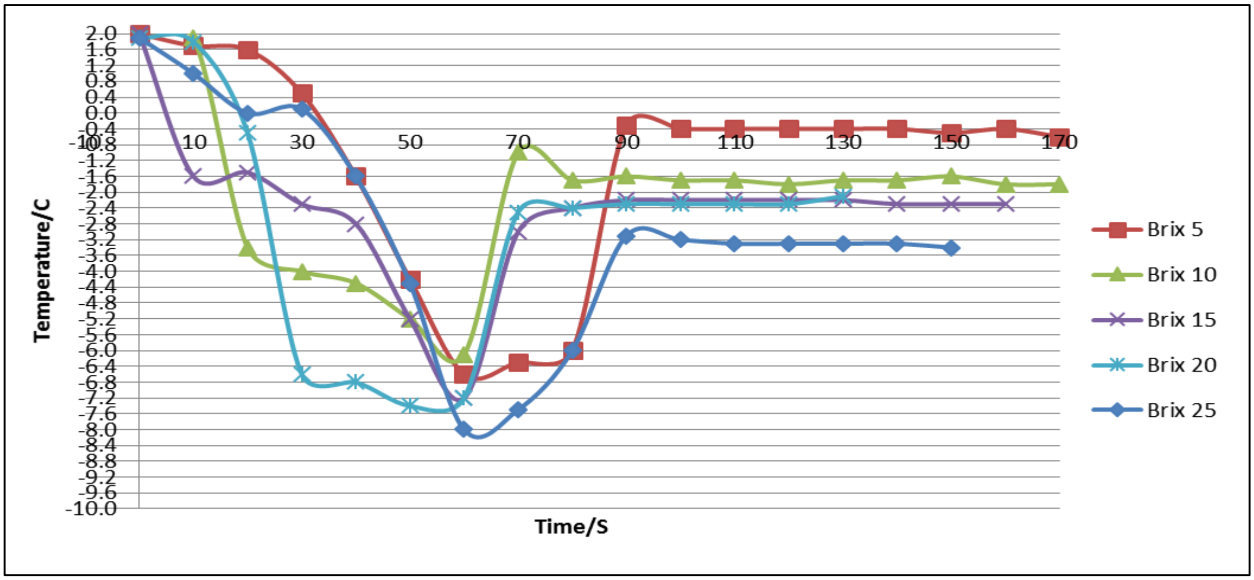

Fig 1: Freezing curve for different Sucrose solutions

According to the recorded results decreasing temperature (^{0}C) was plotted against Time (s). Fig. 1 illustrates the freezing curves of different Sucrose solutions and the freezing point depression clearly visible. With increase of brix value (Total soluble solids) of the solution, freezing point depression is increased and the freezing point was decreased. The lowest point of the curve shows the super cooling peak point in freezing process. Fig. 2 (Schematic diagram of freezing curve) clearly describes the obtained results.

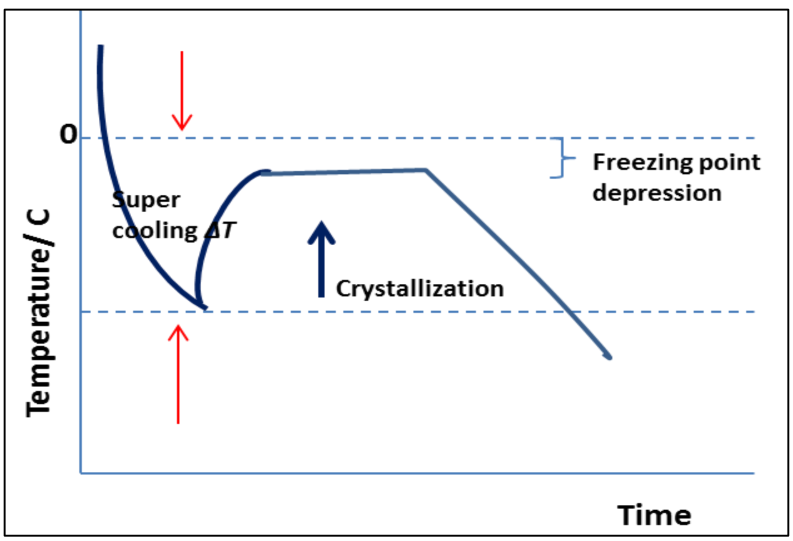

Fig 2: Schematic diagram of freezing curve

According to Auleda the lowest temperature of the freezing curve illustrates the initial process of ice crystal development, it is called nucleation. It is monitored by increasing temperature due to latent heat of the phase change, and that process called crystallization. The maximum temperature reached at that point relates to the freezing point (T_{fp}) of the sample [2]. According to the freezing curve freezing points of different brix solutions were obtained.

Table 1: Freezing point of different sucrose solutions

Brix value	Freezing point/ ^{0}C
5^0	-0.4
10^0	-1.7
15^0	-2.2
20^0	-2.3
25^0	-3.3

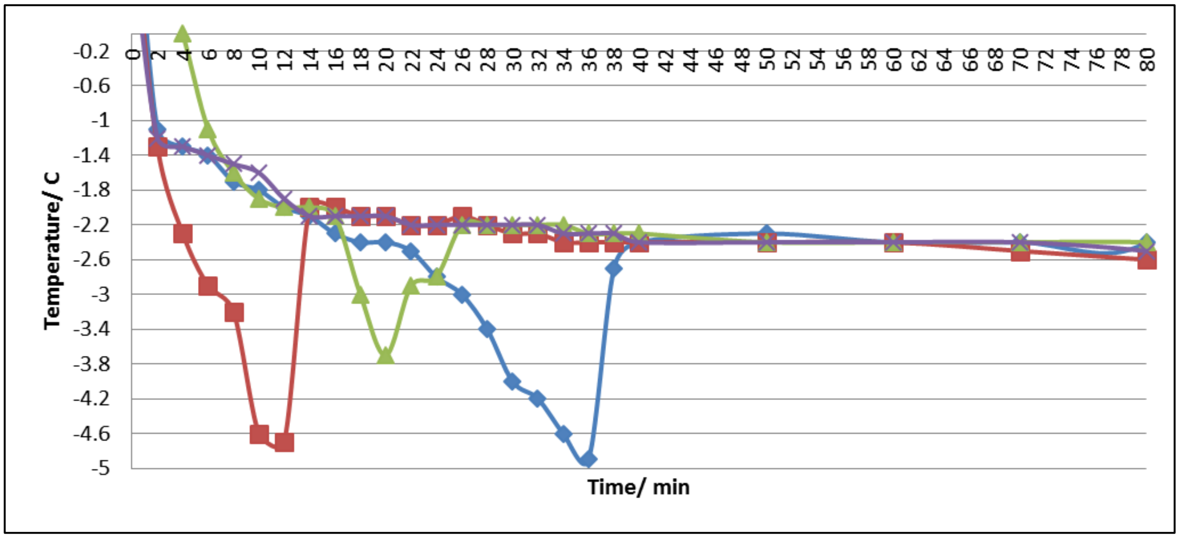

Fig 3: Freezing curve for coconut water

According to Fig.3 freezing point of coconut water (Brix 3.5) was -2.4 ^{0}C. This value differs with dissolve solutes and growth stage of coconut nut. Here matured coconut water was used for the experiment.

3.2 Melting curve

The frozen sample was melted by continuous stirring using Vortex mixer and the increasing temperature (^{0}C) was plotted against with Time (s).

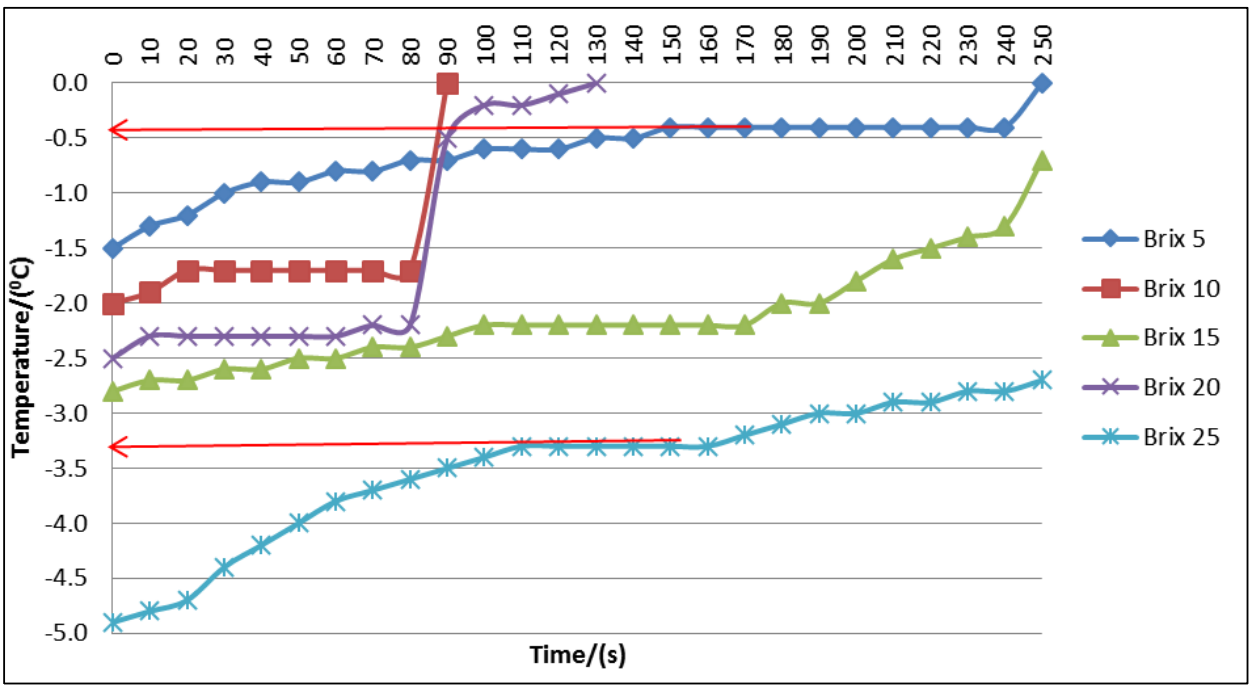

Fig 4: Melting curve for different sucrose solutions

According to the melting curve (Fig. 4) melting points of different brix solutions were obtained.

Table 2: Melting point of different sucrose solutions

Brix value	Melting point/^{0}C
5^{0}	-0.4
10^{0}	-1.7
15^{0}	-2.2
20^{0}	-2.3
25^{0}	-3.3

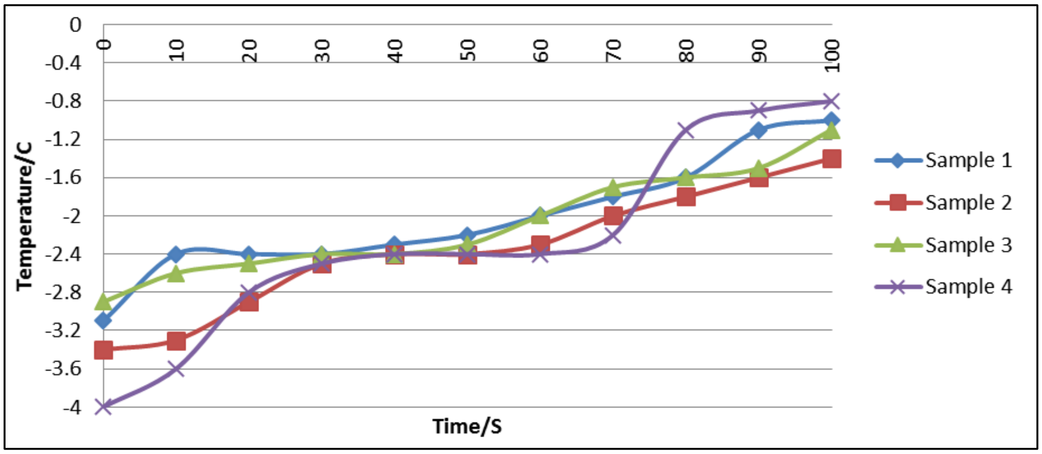

Fig 5: Melting curve for Coconut water

Melting point for coconut water (Brix 3.5) was -2.4 which obtained from plotted melting curve.

By comparing freezing curve and melting curve freezing point and melting point of solutions obtained the same value. Obtained freezing point can be used to find freezing point depression of solutions.

$\Delta T_{f=} \Delta T_{f(Pure\ solvent)} - \Delta T_{f(solution)}$

Brix 5; $\Delta T_{f=} 0 - (-0.4) = 0.4$

Brix 10; $\Delta T_{f=} 0 - (-1.7) = 1.7$

Brix 15; $\Delta T_{f=} 0 - (-2.2) = 2.2$

Brix 20; $\Delta T_{f=} 0 - (-2.3) = 2.3$

Brix 25; $\Delta T_{f=} 0 - (-3.3) = 3.3$

According to Atkins (2006) the justification for the freezing point depression is solvent molecules separate from the liquid and connects with the solid; they leave behind a slighter volume of liquid that the solute particles can settle. That causing reduced the entropy of the solute particles. This estimation terminates to hold when the concentration turn into large solute-solute contacts. Therefore the freezing point depression depends on certain properties of the solute except its concentration [1].

4. Conclusions

Freezing point of a solution varies with dissolved non - volatile compounds in the solvent. With brix value freezing point decrease gradually and the decreasing freezing point refers as freezing point depression. Freezing points of Brix 5, 10,15,20,25 sucrose solutions were -0.4, -1.7, -2.2, and 2.3 and -3.3^{0}C respectively and melting points were similar as the freezing point of the solution. Also freezing point for coconut water was -2.5^{0}C at brix 3.5^0

5. Acknowledgement

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