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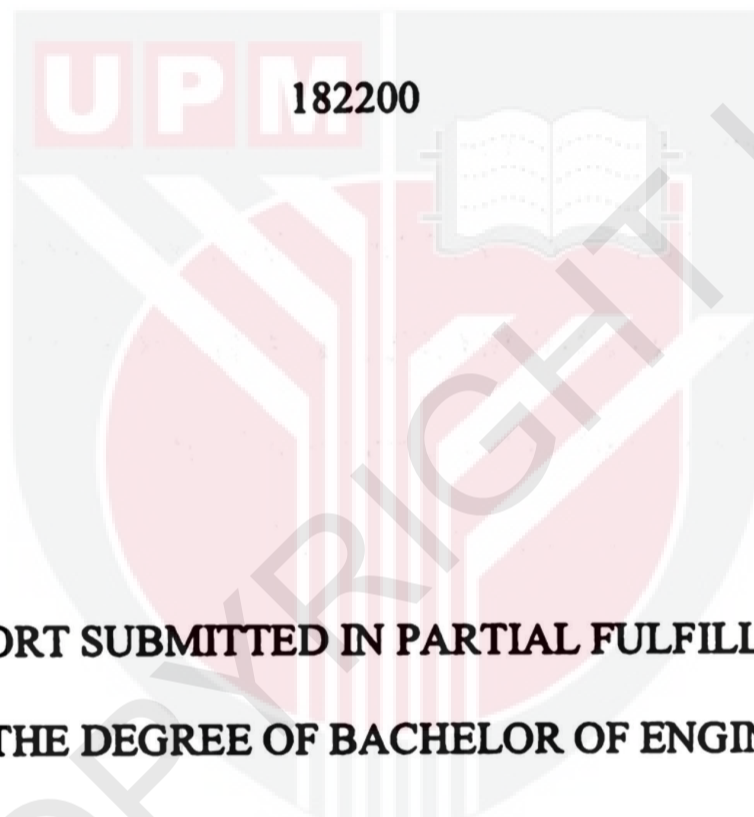
***EFFECT OF HIGH PRESSURE PASTEURIZATION OF ICE CREAM MIX
ON THE QUALITY OF ICE CREAM***

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**EFFECTS OF HIGH PRESSURE PASTEURIZATION OF ICE CREAM MIX ON THE
QUALITY OF ICE CREAM**

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**A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE
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ABSTRACT

The application of high pressure processing of foods has attracted considerable researches and commercial interest in recent years. Processing of food with high pressure rather than by traditional heating technologies offers unique advantages to consumers and food industry. Its main benefit is that high pressure processing inactivates undesirable microorganisms and enzymes activity without causing significant changes to the sensory and nutritional properties of food. Effects of high pressure pasteurization (HPP) treatment to replace conventional pasteurization on ice cream were studied. Ice cream mixtures were pasteurized using both methods and the ice cream produced were analysed on the density, melting rate, firmness and overrun. The viscosity of the ice cream mixture before freezing process was obtained earlier. Results showed that high pressure pasteurization of ice cream mix led to its higher viscosity of 0.483Pa.s when compared to the one pasteurized conventionally with viscosity of 0.211Pa.s. The viscosity of ice cream mix also increased with increasing pressure and treatment time and with increasing fat and sucrose content of the mix. Network of fragments is believed to be responsible for the increased viscosity and reduced melting. Conventional pasteurization of ice cream mix produced ice cream which had higher overrun, higher firmness and faster melting rate. It shows that ice cream with conventional pasteurization have melting rate of 0.817 g/min which is much faster compared to ice cream with high pressure pasteurization with 0.312g/min. While for analysis on firmness, high firmness was recorded for ice cream sample that undergo conventional pasteurization where 29.3N force needed for the probe used to penetrate the ice cream. Same goes with overrun analysis where ice cream mix undergone conventional pasteurization has high

overrun of 50% compared to ice cream mix that undergone high pressure pasteurization treatment which have 25% overrun. While, high density was recorded for ice cream with high pressure treatment with value of 0.900g.mL. These results were largely influenced by the fat destabilization and protein presence in the ice cream mix.



ABSTRAK

Penggunaan high pressure processing ke atas makanan telah menarik banyak kajian dan nilai komersial kian tahun. Pemprosesan makanan menggunakan high pressure daripada menggunakan tradisional teknologi pemanasan menawarkan keunikan kelebihan kepada pengguna dan juga industri makanan. Kebaikan utama high pressure processing ialah menyahaktifkan mikroorganisma dan aktiviti enzim tanpa berlaku perubahan tertentu kepada deria dan nutrisi terkandung dalam makanan. Kesan daripada high pressure pasteurization untuk menggantikan kaedah conventional pasteurization ke atas ais krim seterusnya dipelajari. Campuran ais krim dipasteurisasi menggunakan dua proses tersebut dan ais krim yang dihasilkan di analisis ke atas kadar pencairan, kekerasan, ketumpatan dan juga jumlah overrun. Kelikatan ais krim terhadap campuran ais krim sebelum proses pembekuan didapati lebih awal. Keputusan menunjukkan bahawa untuk analisis ke atas kelikatan, hasil menunjukkan ais krim menggunakan kaedah high pressure pasteurization treatment lebih likat dengan bacaan 0.483Pa.s berbanding ais krim menggunakan kaedah conventional pasteurization dengan bacaan 0.211Pa.s. Kelikatan daripada campuran ais krim untuk kaedah high pressure treatment meningkat dengan meningkatnya tekanan udara dan masa penggunaan dan juga meningkatnya lemak dan juga kandungan sukrosa dalam campuran. Rangkaian fragment dipercayai bertanggungjawab ke atas meningkatnya kelikatan dan juga pengurangan kadar pencairan. Kaedah conventional pasteurization untuk campuran ais krim didapati mempunyai bacaan overrun yang lebih tinggi, kekerasan yang lebih tinggi dan kadar pencairan yang lebih cepat. Keputusan menunjukkan conventional pasteurization mempunyai kadar pencairan sebanyak 0.817g/min iaitu lebih laju daripada kaedah menggunakan teknik high pressure pasteurization iaitu sebanyak 0.312g/min.

Sementara analisis untuk kekerasan pula, kekerasan yang tinggi direkodkan untuk ais krim yang menggunakan kaedah conventional pasteurization iaitu sebanyak 29.3N tekanan digunakan untuk probe menekan masuk ke atas ais krim.. Sama juga dengan analisis untuk overrun di mana campuran ais krim melalui conventional pasteurization mempunyai overrun yang lebih tinggi sebanyak 50% berbanding ais krim yang melalui high pressure pasteurization treatment iaitu sebanyak 25% overrun. Sementara itu, ketinggian ketumpatan direkodkan untuk ais krim yang melalui high pressure pasteurization treatment dengan nilai 0.9000g.mL. Hasil kajian ni sebahagian besarnya dikaitkan dengan ketidakstabilan lemak yang terkandung dalam campuran ais krim.

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CHAPTER 1

INTRODUCTION

In this chapter, an overview of the project conducted which consist of the background, problem statement and objectives was described.

1.1 Background of ice cream

Ice cream known widely as frozen products is one of the delicious that being very popular for a long time in the food industry. Ice cream can be eaten in many ways, some can be eaten as snack and some can be eaten as desserts. Ice cream is high in nutrition and also high in calorific value about 180cal/100gm. Ice cream are made from dairy products such as full cream milk and combination ingredients sugar, water, stabilizer, creamer, flavouring, whey powder and water. The composition range of the ice cream mix ingredients is usually about 10 to 16% of milk fat, 12 to 14% of sucrose, stabilizer-emulsifier blend to 0.5% and lastly about 36 to 45% of total solids. It is found that the emulsion stability, the improved overrun, viscosity increased and free binding water is enhance by the hydrocolloids substances (Goff H. D., 1997). Ice cream is a luxury treat and perceived as a pleasure because ice cream is common and it is loved dessert around the world. Besides the pleasure of eating ice cream, ice cream itself is a complex product and requires creamy and

smooth products throughout the shelf life. However, the processing parameter and recipe is not only the importance for the quality of the product but also during storage and transportation of the ice cream from the factory via the shop and then to the consumer despite a high risk of applying heat-shock with concomitant quality loss exists (Hanne K., 2011).

Consumer nowadays demands on healthy clean-label and nutritious food. Food products have being put additional demands on milk protein to deliver its functional properties such as emulsification, viscosity building, gelation and foaming. Trend of the improvement of textural properties of food products is continuously increasing, which has long focussed on the creation of low fat products. The innovation towards low calorie and low salt products is now become more recent trends in the food industry besides the great demand for high-protein products. To meet the nutritional demands without compromising flavour, stability and texture of the products, all of these trends create increasing challenges in the food industry. Through some research, polysaccharide based stabilizers is used as a convenient solution for texture improvement especially, so it become under increasing pressure, due to consumer demands for additive free, and clean label food products (Huppertz et al., 2011).

Facts showed that consumer nowadays demands on nutritious clean-label products, protein functionality become very important in food industry in achieving its goals. There are many processing technologies of food being produced, such as ultrasound and pulsed electric fields and treatment with high pressure processing (HPP). In the industry of producing ice cream, pasteurization technique were commonly been used. Some particularly promising results in this respect have been reported for HPP for structuring proteins in ice cream application. HPP normally involved in both batchwise and semi continuous treatment. HPP can be conducted in pressure ranging

from 100 to 600 MPa which is equal to 1000 to 6000 bar. The HPP conducted by placed the samples in a cylindrical vessel which is subsequently closed and pressure is built up commonly by using water. The pressure also can be built up by another fluid as a pressure transmitting medium. When the desired pressure is reached, sample is maintained for certain time with maintained pressure, after which pressure is released. In the industry that uses high pressure processing, normally vessels with volumes of several hundred litres are available (Huppertz et al., 2011).

Recently, food industry is moving towards new innovation and product development. The things that could not be done before now can be done through new processing methods. High Pressure Processing (HPP) is one of the most successful developments that can be made in the food industry. High Pressure Processing known as a cold pasteurization technique consists of subjecting food, water resistant packaging and previously sealed in flexible, bring it to a high level of hydrostatic pressure. The pressure transmitted commonly transmitted by water up to 600MPa / 87 000 psi for few seconds to a few minutes. Interestingly, the effect as subjecting the food is said to be the same effect to an ocean depth of 60Km deep, if an ocean this deep existed.

The first high pressure processing products were built on the 1990's although the non-thermal pasteurization effect of high pressure on foods has been introduced since 19th century. High pressure processing then has been increasingly implemented in many types of food industries worldwide since 2000. High pressure processing is an environmentally friendly process that helps in maintaining the fresh food characteristics like flavour and nutrients and also believe can prolong the shelf life of the food. Moreover, high pressure processing can be good alternatives to chemical treatment and traditional thermal.

1.2 Problem statements

Consumer increasingly demand convenience foods of the highest quality in terms of natural flavour and taste, and which are free from additives and preservatives. This demand has triggered the need for the development of a non-thermal approaches to food processing, of which high pressure technology has proven to be very valuable.

In the food industry, there are many high pressure processing of food had being implemented such as dairy industry and industry in making cheese. It was rarely to find the use of the high pressure processing on the ice cream industry. The main reasons for this case are because the cost equipment for a high pressure processing is high and need 24 hours full time support team for the maintenance.

Study on the usage of high pressure processing in food industry is increasing nowadays. However, the study on the high pressure processing on the ice cream is very limited due to the complexity of the ice cream. Therefore, the study on the effect of high pressure pasteurization of ice cream mix on the quality of the ice cream is to be done.

1.3 Objectives

The main objective of this study is to determine the effects of high pressure pasteurization of ice cream mixture on the quality of ice cream. . Effects of high pressure pasteurization (HPP) treatment to replace conventional pasteurization on ice cream were studied. The specific objectives were:

- i. To determine the effects of high pressure pasteurization of ice cream mixture on viscosity and compare with the one pasteurized conventionally

- ii. To determine the effects of high pressure pasteurization of ice cream mixture on the overrun, melting rate, firmness and density of the ice cream produced.

In conclusion, chapter 1 generally discusses the effects of high pasteurization of ice cream mixture on the quality of ice cream, problem statements and objectives of the project conducted. It is important to highlight on the problem statements in order to achieve the objectives of the project.



CHAPTER 2

LITERATURE REVIEW

This section literature review based on journals and other resources related to ice cream in all view from composition until final products.

2.1 Ice cream properties

Ice cream known as the complexity system of foam, containing a gas which is air dispersed as small cells in a partially frozen continuous phase. In continuous phase, fat is dispersed in the emulsion known as inner phase. This is where the stabilizers and milk solids are in colloidal solution and sugar and salts will form a true solution. The main ingredient in ice cream mix is first prepared which contains fat, sweeteners, stabilizer, milk solids non-fat (MSNF) and emulsifier. Typically, the initial process of the mix involves formulation, homogenization and pasteurization. The process continues with aging for at least four hours at 4°C or lower. During this process, sufficient crystallization of the fat being induced and the emulsion droplet surface is restructuring during freezing to facilitate sufficient partial coalescence of fat droplets. Then, the aged mix is simultaneously frozen and aerated. Continuous scraped-surface ice cream freezer is typically used (Huppertz et al., 2011).

2.2 High Pressure Processing

High pressure processing (HPP) is a non-thermal technique using pressure rather than heat to induce a pasteurization effect. HPP inactivates the vegetative spoilage microorganisms and harmful pathogens. HPP apply pressure about 400-600MPa at refrigeration or mild process temperature about less than 45°C. Both process liquids and solid foods could be process during this condition with a high content of moisture. Pressure treatment does not break covalent bonds and has a lower effect on food chemistry although it is legal to microorganisms. HPP also provides a means to preserve food quality while avoid the need for chemical preservatives and excessive thermal treatments. High pressure processing (HPP) also known as high hydrostatic pressure processing (HPP) or ultra-high pressure processing (UHP).

High pressure processing (HPP) is a cold pasteurization technique where the products already sealed in its final package with specific sizes are introduced into a vessel and subjected to a high level of isostatic pressure transmitted by water. Usually the pressure used in food industry are between 300 MPa to 600 MPa equal to 43 500psi to 87 000 psi. Figure 2.1 shows the range of high pressure processing.

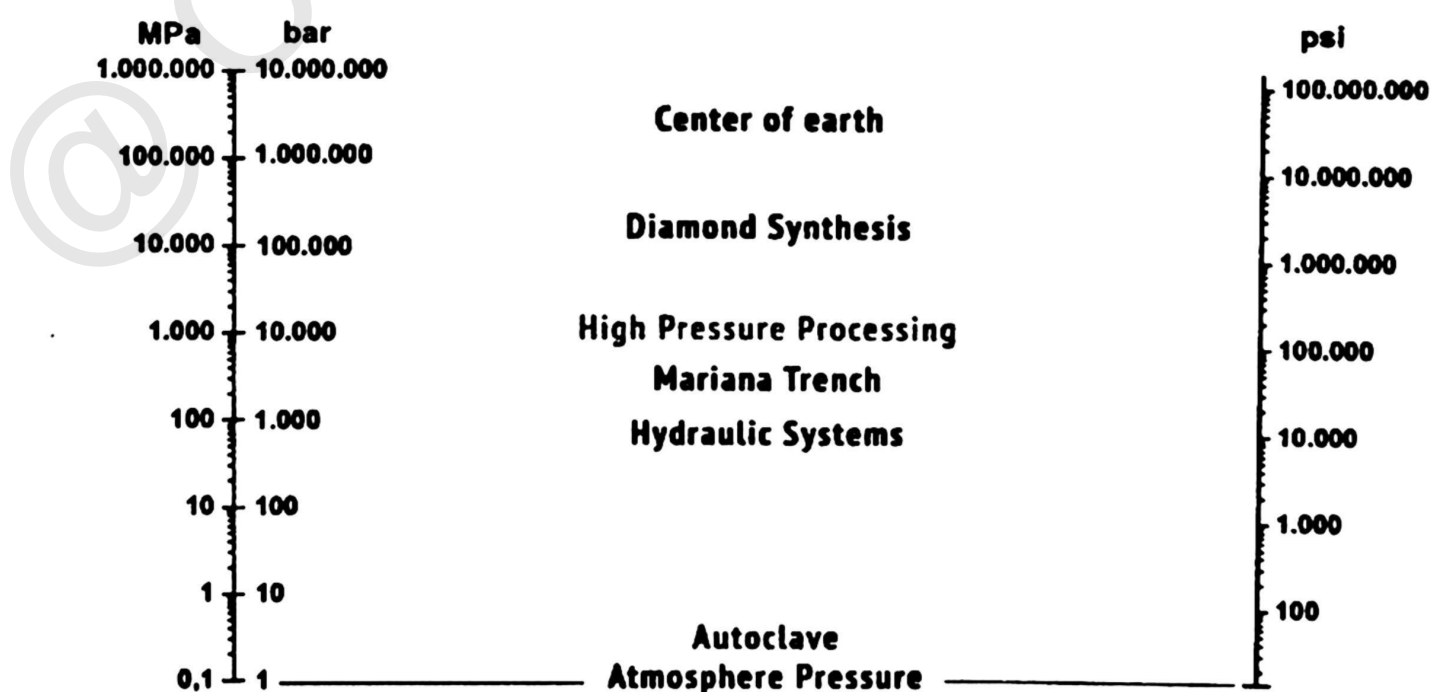


Figure 2. 1: Range of high pressure processing

The vegetative flora such as bacteria, virus, yeasts, moulds and parasites that present in food will be inactivate at pressure above 400 MPa / 58 000 psi at cold temperature between 4°C to 10°C or at ambient temperature. This condition guaranteeing food safety and importantly will extend the products shelf life. High Pressure Processing retain the nutritional properties of food, because there is no heat treatment and thus maintains its original freshness throughout the shelf life.

2.2.1 Advantages of applying HPP (Penchalaraju,2013)

To meet the demands of the 21st century consumer such as convenience foods, higher sensorial and nutritional quality, additive free/natural and functional products, food companies need to innovate by using the latest non-thermal technologies, and High Pressure Processing is the most relevant one. There are many advantages by applying high pressure processing technology (HPP). For a greater food quality, characteristics of the fresh product are retained, sensorial and nutritional properties remain almost intact. HPP also provides food safety and better exportation by destroying the pathogens like Listeria, Salmonella, Vibrio and Norovirus. Next, HPP also extends the product shelf life. HPP process is environmentally friendly process. It only needs water which is recycled water and electricity. Besides, HPP is a new innovation food propositions and have the competitive advantages. Products that cannot be thermally treated can now be high pressure processed. Lastly, HPP provides clean label foods. It is natural and additive free. It avoids or reduces the need for food preservations. Thermal methods, traditionally used in the food industry for food preservation, carry disadvantages like vitamin destruction or flavour changes that can be avoided with HPP.

2.2.2 High pressure processing (HPP) principles

The demand on the commercial high pressure processing of foods is increasing. It provides an opportunity to preserve foods. HPP become process of choice for application where heat pasteurization will affect the product quality. Le Chatelier's principle states that any phenomenon such as change in molecular configuration, phase transition and chemical reaction will lead to decrease in volume is influence by pressure. So, food that undergone HPP process will not return to its actual size and shape because of pressure differences between compressibility of water and air, unless the food is fully elastic.

Late 1800s, the principles of microbial inactivation of High Pressure processing have already known. However, it began largely to been used in last 20 years, when recently innovations allowed construction of high pressure vessels with sufficient durability can withstand thousands cycles without damage, at a prices (Hite, 1899).

The main basic component of a High Pressure Processing are a pressure transmitting vessels, a material handling pressurizing system and supporting unit like cooling and heating elements components as show in figure 2.2 (Heremans, 2003). Water are the most common transmitting fluids in HPP. There are also others transmitting fluid such as silicone oil, food grade glycol-water, ethanol solution, sodium benzoate solutions and castor oil (Balasubramaniam et al., 2008). Food products that undergone HPP can operate in batch or semi continuous process.

During the operation of HPP, the pressure is uniformly and simultaneously applied in all direction to the products. The food product did not crushed during the treatment because of the isostatic pressure applied. So HPP becoming major advantaged compared to common thermal methods where temperature of product is

increased gradually (Balasubramaniam et al., 2008). Once the product is loaded and tightly closed, the vessel then filled with a pressure transmitting medium. Then air is removed from the vessel with an automatic deaeration valves means that of a low pressure fast fill and drain pump. High hydrostatic pressure then being generated by direct and indirect compression or by heating the pressure medium (Mertens, 1995).

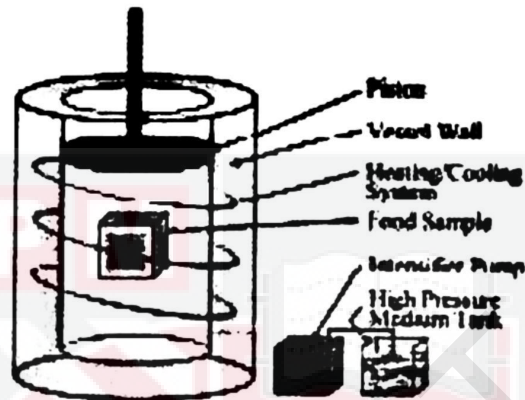


Figure 2. 2 : Basic components of HPP

Referring to these principles, the phase transition and chemical changes phenomenon are following by the decrease in volume, favoured by pressure and vice-versa. The pressure is transmitted instantaneously and uniformly independent of the size and geometry of food. Resultants pressure regulates most of the subsequent biochemical reactions that occurred in the treated products.

In the biological systems, the changes brought by the volume-decrease of High Pressure Processing include the denaturation of proteins, hydrophobic reactions, gelation, phase changes in lipids and increasing in the ionization of dissociable molecules due to electrostriction (Heremans, 2003). Three parameters could be characterized by the high pressure process which were temperature (T), pressure (P) and exposure time (t) when compared with heat preservations. Pressure applied to food range typically from 300-600MPa as shown in Table 2.1.

Table 2. 1: Products and salient results

Conditions	Product and Salient results	References
200-250 MPa	The combination of high pressure with bacteriocin such as lacinin resulted in synergetic effect in controlling microbial flora of milk without significantly influencing the cheese making properties.	Morgan et al.,(2000)
100-600 MPa/ 0-30min at 20°C	Rennet coagulation time of heated milk decreased with increasing pressure and treatment time. the strength of the pressure treated coagulum from heated milk was considerably greater and the yield of cheese curd also found 15% greater than that from unheated/ unpressurized milk, the protein content of the whey was 30% lower	Huppertz et al.,(2002)
200-400 MPa	Pressure treatment of cheese milk increased the yield of low fat cheese by improving protein and moisture retention. Pressurization of pasteurized milk improved its coagulation properties. Cheese made from pressurized and pasteurized milk showed increased protein and moisture retention as well as improved coagulation properties. The protein	Molina et al. (2000)

	degradation and development of texture and flavour was also rapid and the product had lower hardness and cohesiveness and higher sensory scores.	
200-500 MPa / 60min, 20°C	Periodic oscillation of pressure was very effective for the destruction of pathogen such as <i>Listeria monocytogenes</i> , <i>Escherichia coli</i> and <i>Salmonella enteritidis</i> .	Vachon et al., (2002)
300-600 MPa	Increase in cheese yield by high pressure treatment of cheese milk due to denaturation of whey proteins and increased moisture retention was also found. Higher moisture content of cheese made from high pressure treated milk due to the fact that casein molecules and fat globules may not aggregate closely and may allow moisture to be trapped or held in cheese	Drake et al., (1997)

2.2.3 HPP on ice cream

HPP induces fat crystallization. The time required to achieve a desirable solid fat content been shorten. Therefore, the aging time of ice cream was reduced. High pressure treatment effects the functional properties of whey proteins (Durnay et al. 1996). High pressure treatment used 300MPa in 15 minutes enhanced the foaming properties of whey protein concentrate, which when added to low fat ice cream to

improve body and texture of the ice cream. Results showed an increased overrun, foam stability and hardness the ice cream compared ice cream added with untreated whey protein (Lim et al., 2008).

A studied on the applications of High Pressure Processing in ice cream manufacture is carried out. Ice cream mixes were undergo HPP in range about 200 to 500MPa for one seconds until 20 minutes. It is showed that the mix viscosity increased when the HPP conducted at 400 or 500MPa for time as low as one second. The researchers attributed to the formation of a proteinaceous network of micellar fragments in the mix by reduction in solubility of calcium phosphate on decompression during HPP cycle. Results showed that ice cream has a strong resistance to meltdown, textural characteristics is greatly improved, such as creaminess and mouth feel (Huppertz et al., 2011).

All of these finding noticed that high pressure processing treatment leads to beneficial changes in proteins assist manufacturing of low-fat and stabilizer-free ice creams with improved mouth feel. Freezing process that assist the pressure may be a good area of research for high pressure processing treatment of ice cream.

2.2.4 The effect of HPP on the chemical composition of food

During HPP treatment, some temperature increases naturally occur due to adiabatic heating. However, it is depend on the chemical composition and target pressure of the food. Water temperature increases approximately 3°C per 100MPa, but for more compressible food ingredients such as fats the temperature can increase significantly higher. Therefore, during the HPP temperature increase higher for foods with higher fat content.

There is minimal effect of HPP treatment on molecules with low molecular weight. It shows that pigments, vitamins and flavour compounds that survive in HPP treatment processing are undamaged compared to thermal processing. Therefore, the quality of the food and the nutritional value can be preserved.

During HPP treatments, there are some compounds that are irreversibly changed. If pressure increases rather than temperature increases, gelatinization of carbohydrate occurred. Protein can denature at high increasing temperature.

Figure 2.3 shows a representation of pressure and temperature of a common HPP treatment (Ferstl, 2013).

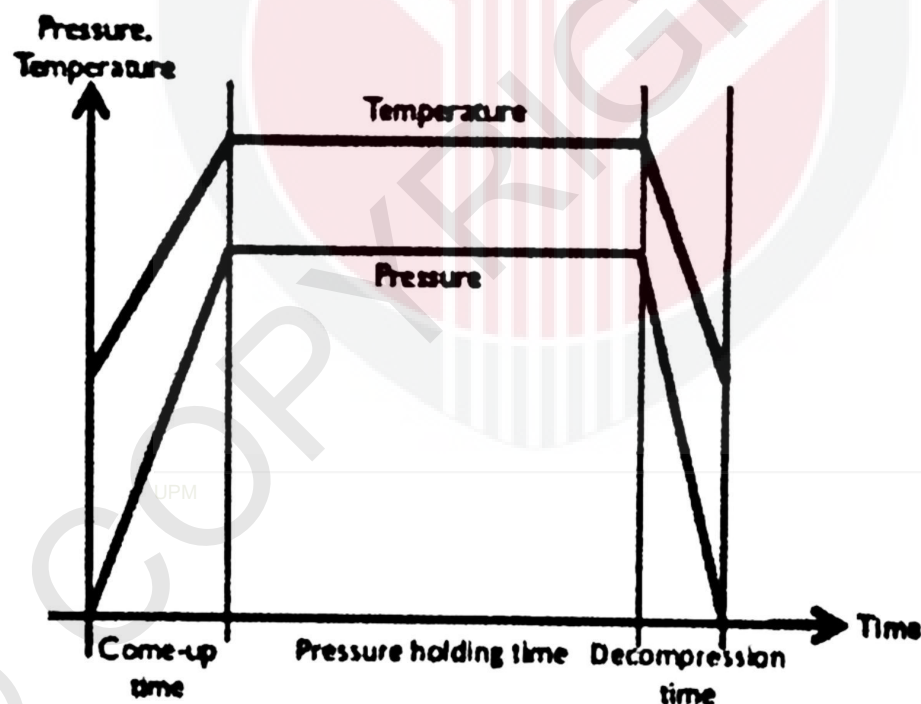


Figure 2. 3 : Pressure, temperature and time during a HPP process.

(Source: Ferstl, 2013)

2.2.5 Overrun ice cream

In ice cream, air is an important component that affects the physical and sensory properties as well as storage stability. Ice cream has around 100% overrun normally, meaning that air makes up 50% of the ice cream volume. The amount of air occupied into the mix determined the sensory attribute or properties of the ice cream. The resulting ice cream is dense, heavy and more cold eating if lower amount of air is applied. While, if a higher amount of air is used, resulting the texture of ice cream to become lighter, creamier and more warm eating. The overrun in production of ice cream is very important for the cost saving but the perceived quality by the consumer has to be the priority. The sensory attributes like smoothness, creaminess, resistance to shrinkage and melting cannot be compromised because the properties are very closely linked to consumer demands. The distribution of air cells in the ice cream involved creaminess as well as the melting resistance. Air cells that uniformly distributed in the ice cream results in a slower melting ice cream and creamier. Emulsifiers such as mono and diglycerides are well known for their positive influence in this respect (Hanne.k, 2011)

CHAPTER 3

METHODOLOGY

In chapter 3, methodology was discussed and described steps involved conventional pasteurization process and High Pressure pasteurization process.

3.1 Experiment details

The following are the steps in the manufacturing of ice cream for conventional pasteurization process. Preparation of the mix ingredients, mixing, pasteurization, homogenization, aging the mix, freezing, and hardening were showed on figure 3.5. For the first samples, it was produced in the Food processing Quality Lab, Faculty of Engineering, Universiti Putra Malaysia (UPM). Firstly, the ingredient for the ice cream was prepared as shown in table. Next, the ingredients were mixed using the mixer in the lab under the room temperature. The mix then was batch pasteurized at 80°C and hold for 15 seconds and immediately undergoes two-stage homogenized by using the laboratory scale homogenizer. Then, to prevent contamination and to improve the whipping qualities of mix and body and texture of the ice cream, the mix rapidly cooled at 4°C and aged for minimum 4 hours. The aged mixes were then frozen using a batch ice cream machine, hardened and stored in a deep freezer under quiescent freezing conditions at -20°C. Lastly, the ice cream will be divided equally and undergoes test for overrun, viscosity, melting rate and hardness. The procedures

were repeated by replacing the pasteurization process with the high pressure pasteurization (HPP) process. The process of HPP is done at the High Pressure Process Lab in the MARDI, Serdang. The following figures 3.1 and 3.2 shows the steps in manufacturing of ice cream for conventional pasteurization process and high pressure pasteurization process.

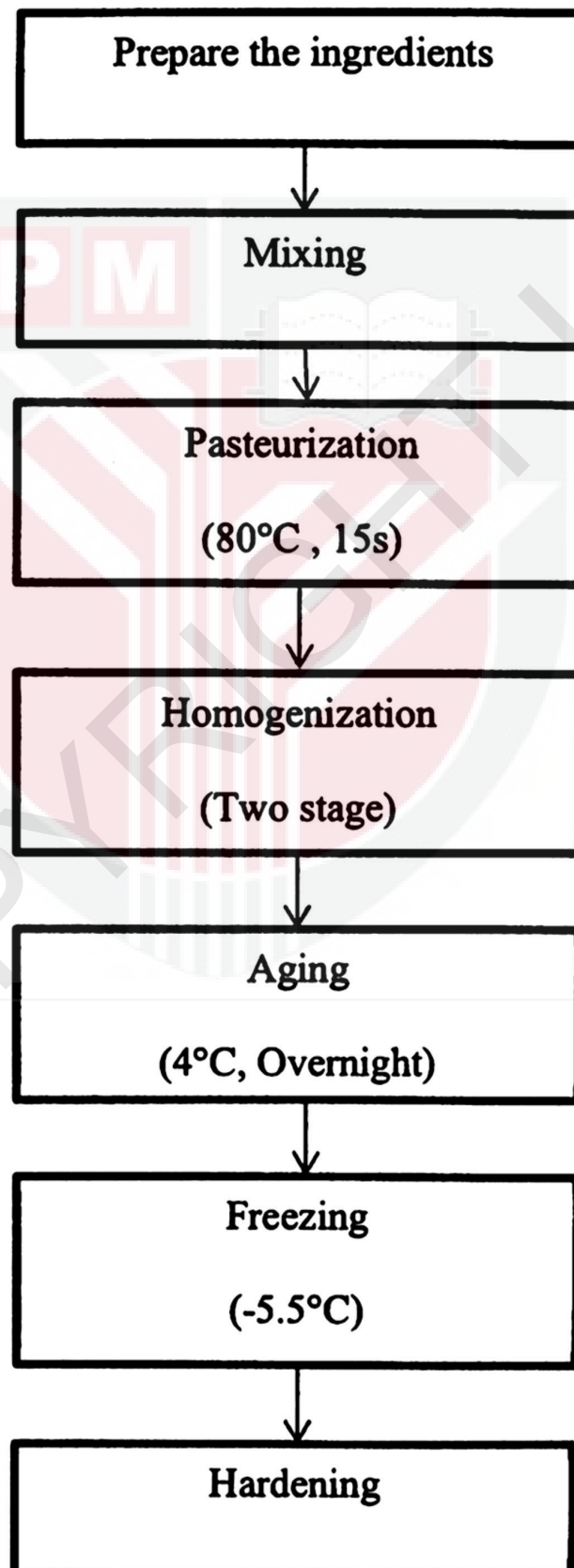


Figure 3. 1 : Flow diagram for sample preparation

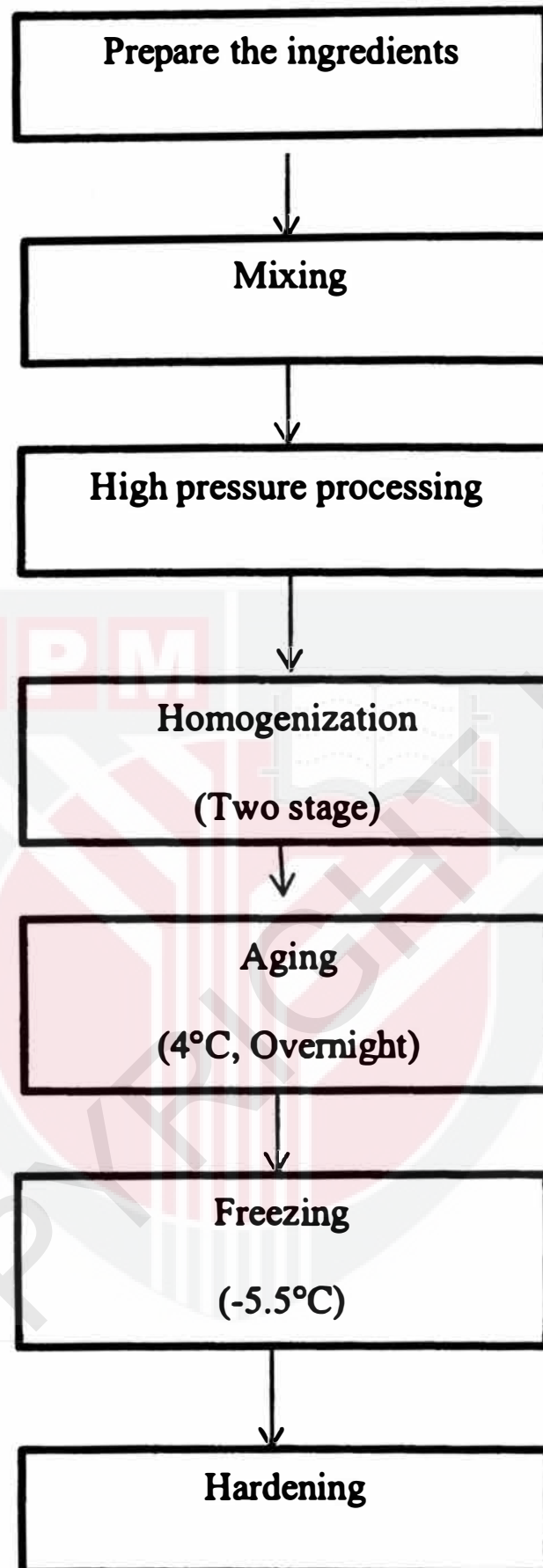


Figure 3. 2 : Flow diagram for sample preparation by replacing pasteurization process with HPP

3.1.1 Experiment location

Preparation of ice cream samples were conducted in the Food Processing Quality Lab, Faculty of Engineering, University Putra Malaysia (UPM) and High Pressure Processing Lab in MARDI, Serdang.

3.1.2 Materials and equipment

The materials that were used for the formulation of the ice cream are sugar, water, stabilizer, creamer, flavouring, whey powder, water and Dutch Lady Full Cream Milk. Equipment involved for the formulation of ice cream are mixer (Model 5K5SS, KitchenAid, St Michigan, USA), laboratory scale homogenizer (Success Technic Industries, Model WT500, Malaysia), stove for pasteurization process, ice cream machine (Breville, Model BC1600, Australia) and chiller. For the analysis equipment, texture analyser (TA.XT Plus, Stable Microsystem, England) is used to determine the firmness of ice cream. Rheometer (AR-G2, TA instrument) is used to check the viscosity of the ice cream mix. Weighing balance is used to check the overrun, density, and melting rate of the ice cream mix.

3.2 Preparing The Sample

3.2.1 Ice cream formulation

The ingredients for the samples were follow as the table 3.1 below (Parid et al, 2018):

Table 3. 1 :Formulation used to prepare hard ice cream

Ingredients	Weight composition (%)	Mass of each batch of 500g (g)
Water	60.9	304.5
Skimmed milk powder	14.5	72.5
Sugar	16.3	81.5
Whey powder	3.6	18
Creamer	3.6	18

Emulsifier	0.4	2
Stabilizer	0.3	1.5
Flavouring	0.4	2

Example to calculate the mass of the sample shown in eq 3.1:

$$\begin{aligned}
 \text{Skimmed milk powder} &= 14.5\% \\
 &= 14.5\% \times 500\text{g} \quad (\text{eq 3.1}) \\
 &= 72.5\text{g}
 \end{aligned}$$

3.2.2 Weighing ingredients

The percentages of the ingredients were calculated into gram to make it easier for weighing process. The weigh basis was 500g. Figure 3.3 shows the weighing balance used to weight the ingredients. After the beaker was put into the weighing balance, tare it to have the net weight of the ingredients.

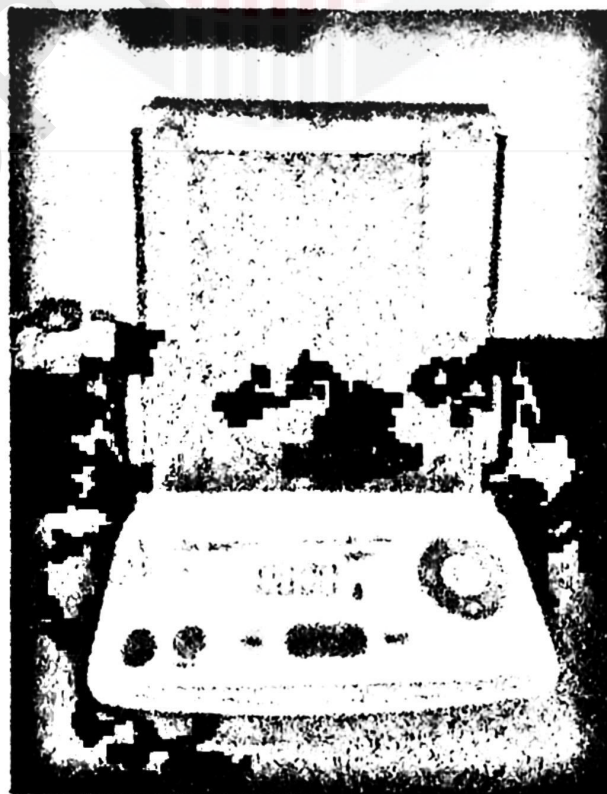


Figure 3. 3 : Weighing ingredients

All the ingredients that have been weighed will be mixed using the mixer (Model 5K5SS, KitchenAid, St Michigan, USA). The mixing process is shown in figure 3.4. The process of mixing was set for 5 minutes to complete. The 5 minutes was to ensure that the ingredients mix as well as possible. Mixing step is very important to have a smoother texture of the mixture.



Figure 3. 4: Mixing process

3.2.4 Pasteurization

Pasteurization process is functional process to keep the quality of the mixture of ingredients and mainly to destroying the microorganisms such as pathogen that might be presents in the ingredients. Pasteurization process is also help in making solids into solutions, aid in blending by melting the fat and decreasing the viscosity thus increases the uniformity of products. The mixture of the ingredients was been pasteurized using economical stove as shown in the figure 3.5 below. This process does not have specific time duration. The thermometer is inserted in the process to get the temperature of the mixture. The mixture must been stir uniformly using the dip. When the temperature of the mixture reached 80°C, hold the mixture for 15 second. Then the pasteurization processed stopped.



Figure 3. 5 : Pasteurization process

3.2.5 High pressure treatment of samples

For high pressure pasteurization treatment, samples of ice cream mix 500g were packaged in 3 sanitary bottles volume of 250ml as shown in figure 3.6. In one research found, Huppertz et al 2011 suggest that ice cream mixes were undergo HPP in range about 200 to 500MPa for one second until 20minutes. It is showed that the mix viscosity increased when the HPP conducted at 400 or 500 MPa for time as low as on second. High pressure treatment was performed for 20 minutes with the pressure set was 500MPa for each samples based on the suggested treatment by the research. The data was produced on the computer. Figures 3.7 show the high pressure processing machine (High Pressure Processing Machine 55L, HQ2932-Avure Techonologies, USA) used.

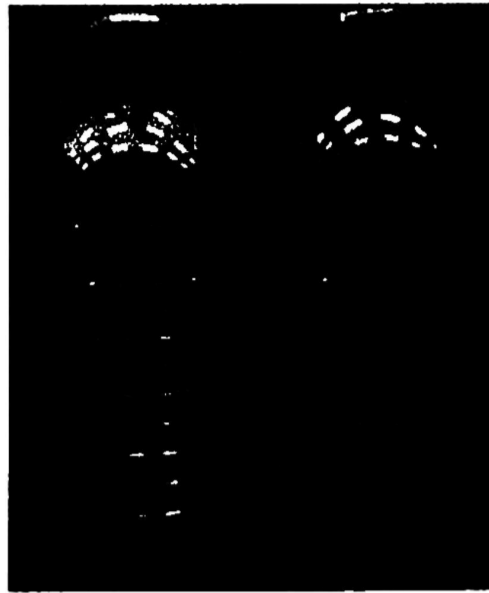


Figure 3. 6 : Sample prepared in sanitary bottles



Figure 3. 7 : High pressure processing machine

3.2.6 Homogenization

The function of homogenization is to forms the fat emulsion found in milk or cream by breaking down or reducing the size of the fat globules less than 1 μ m. After pasteurization, the mixture will undergo homogenizing process using the laboratory scale homogenizer (Success Technic Industries, Model WT500, Malaysia). The

process will go through two stages of homogenizer which are mode number 2 and then mode number 1. Each stage will be done for 2 minutes. Figure 3.8 below shows the set up for the homogenizing process.



Figure 3. 8 : Lab Scale homogenizer set up

3.2.7 Aging process

After homogenization, the ice cream was then stored in the chiller for aging process. The temperature of the chiller is 5°C. The aging process of the ice cream must be done minimum for 4 hours or more but the maximum of aging process is 24 hours. The aging process must be done because crystallization of the fat in the emulsified state occurs more slowly than when it is in the bulk state (not emulsified). Figure 3.9 shows ice cream mixture after aging process.



Figure 3. 9 : Ice cream mix after aging process

3.2.8 Ice cream maker machine

Next, the well mixed ice cream solution will go through ice cream maker machine (Breville, Model BC1600, Australia) to make it into hard ice cream. The machine aims to turn the ice cream mixture into hard ice cream texture. The machine was set in pre-cool to cool down to -30°C which gives the ice cream a head start. After the mixture of ice cream was totally turned into ice cream texture, the finish product was transferred to a small container and was kept into a freezer for further hardening process. Figure 3.10 shows the ice cream maker machine and figure 3.11 shows the ice cream mix after undergoes freezing process



Figure 3. 10 : Ice cream maker machine

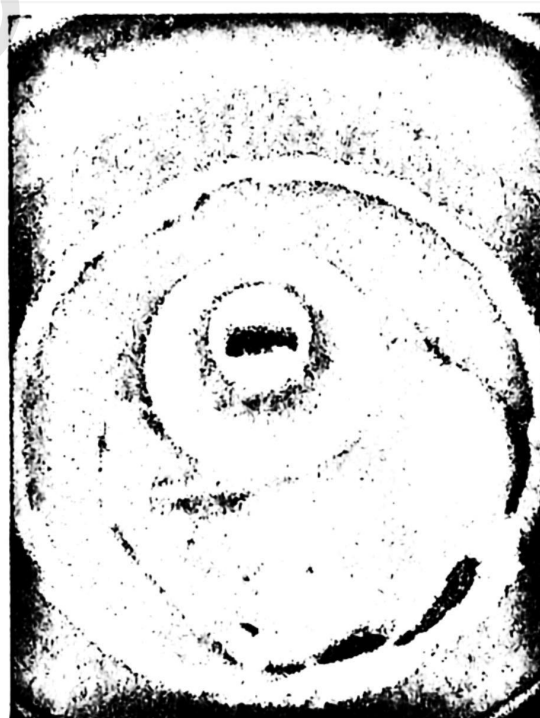


Figure 3. 11: Ice cream mix after undergoes freezing process

3.2.9 Hardening process of ice cream

The ice cream was then stored in the freezer for hardening process. The temperature of the freezer set is -18°C . The ice cream was stored in freezer at least 8 hours or more. The purpose of this process to ensure that ice cream is completely becomes hard and for further studies.

3.3 Analysis of physical characteristic of ice cream

Analysis was conducted to determine the physical characteristics of the ice cream sample for both high pressure pasteurization and conventional pasteurization process. The analysis involved are the melting rate, firmness, viscosity, density and overrun of the ice cream.

3.3.1 Analysis of firmness of ice cream

Texture analysis is an important test in determining the textural properties of food. The texture of any food is multi-faceted and connects with the consumer sensory attributes. Figure and shows the test conducted using texture analyser (TA.TX.plus, Stable Microsystems, England). The results will be shown on the computer. For each sample, three measurements were carried out using 45° Perspex cone probe. The test must be done as quickly as possible because to prevent the samples from melt down thus will affect the hardness of the ice cream. The texture analyser was run for this test by giving controlled force to the ice cream and respond taken is force versus time.

3.3.2 Analysis of melting rate of ice cream

Melting rate was measured for each sample. In this melting test, wire gauze, stopwatch, beaker and weighing balance were used. 200g samples of ice cream of already harden ice cream in the freezer were taken. The ice cream will be placed above the wire gauze and a beaker will be place on the weighing balance and the weight will be record. The duration of the experiments were depends on the samples, considering time needed for the total loss of the structure. The reading was taken and recorded for every 5 minutes. The weight of the melt ice cream was recorded and will be tabulated with time taken. The weighing must be tare to have net weight of the melted ice cream. Setup for this test is shown in figure 3.12.



Figure 3. 12 : Melting rate analysis

3.3.3 Analysis of viscosity of ice cream

Viscosity test must be done to all the samples to determine the differences of the viscosity between the samples. The samples used were the ice cream mix and the viscosity test was run by using the viscometer (AR-G2, TA instrument) as shown in figure 3.14 below. A small amount of ice cream mix about a scoop of spoon was used and then spread through the plate of the viscometer. The shear rate was set up to 0 until 300 1/s. Other settings were set by using the manual given. The duration of the test was not specified and were depends on the samples. The result will be recorded and tabulated.



Figure 3. 13: Rheometer (AR-G2, TA instrument)

3.3.4 Analysis of overrun reading

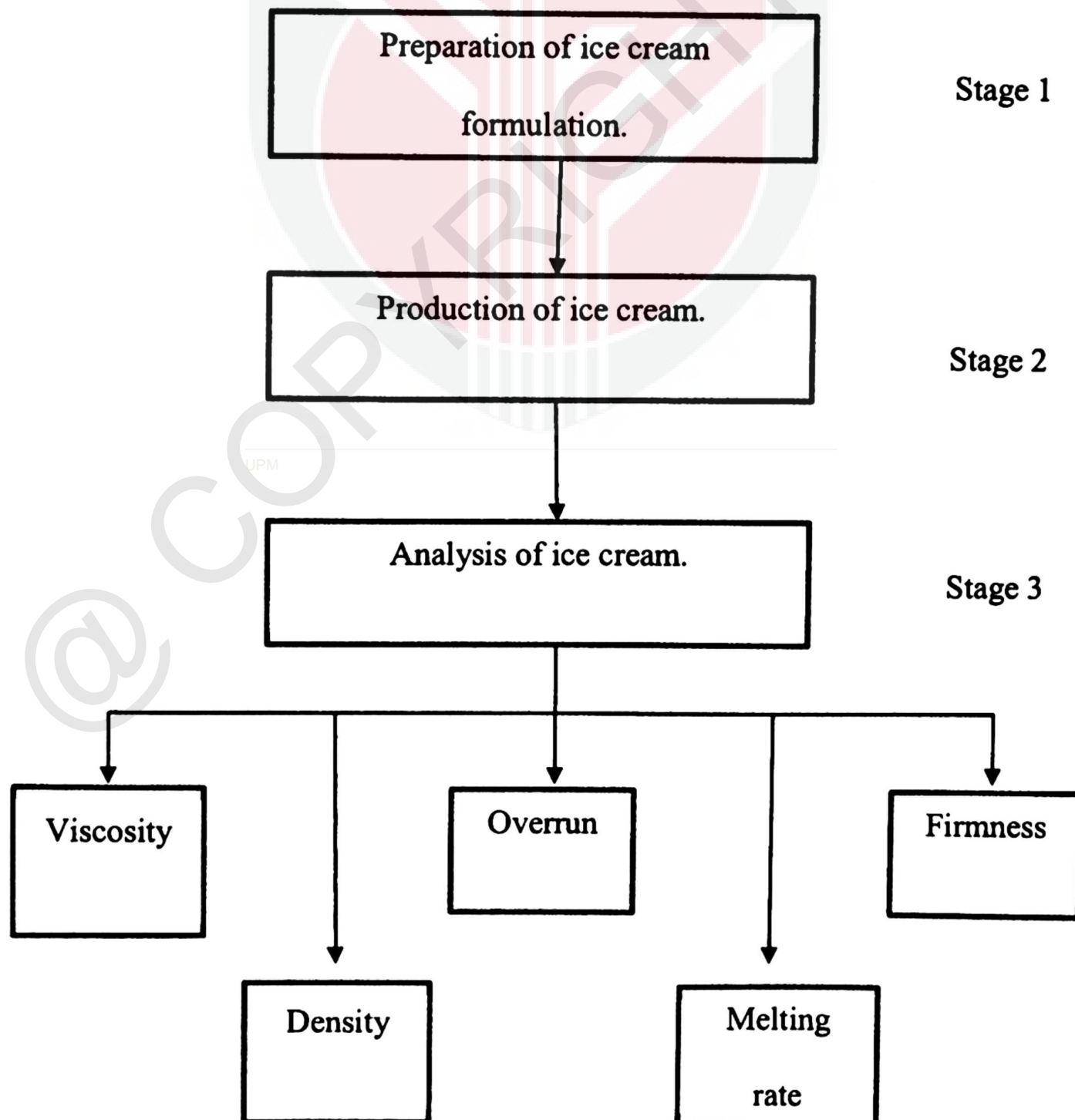
Overrun is the percentage of ice cream that is air incorporated in the product during the freezing process to expand & make more product with less materials (Slices Concession, 2017). Overrun can be calculated by weighing a container and making a note of it so it can be subtracted later. Note how much the container weighs filled with the liquid mix and subtract the container weight. Once noted both numbers can be used again whenever want to check your overrun. Fill the same container level

with frozen product and note its weight. Then, just plug it in to the formula (eq 3.2) below to get the overrun reading:

$$\text{Overrun (\%)} = \frac{\text{weight of ice cream mix} - \text{weight of the ice cream}}{\text{weight of the ice cream mix}} \quad (\text{eq 3.2})$$

3.4 Summary of methodology

Chapter 3 discussed on the methodology used in this study to produce ice cream with conventional pasteurization process and high pressure pasteurization process. Then, the method for the test required for analysis such as melting rate analysis, viscosity, overrun and firmness was explained.



CHAPTER 4

RESULT AND DISCUSSION

This chapter consist of the results obtained from the experiments, which are melting rate, firmness, viscosity, overrun and density of the ice creams. Comparison of results was done for different method for ice cream process which were conventional pasteurization process and high pressure pasteurization process (HPP).

4.1 Analysis on melting rate of ice cream

Melting rate is used to study the viability of ice cream by maintain its structure at room temperature. It is important to determine the melting rate of the ice cream for the consumer to consume the product without loss of its structure for a longer time. Consumer will having difficulties during eating the product if the ice cream melts too fast. Therefore, melting rate is more preferable, especially in the tropical countries. The melting test was carried out based on the methodology discussed in the previous chapter. A graph of mass of melted ice cream over time for ice cream mix by using conventional pasteurization and HPP treatment was plotted as shown in figure 4.1.

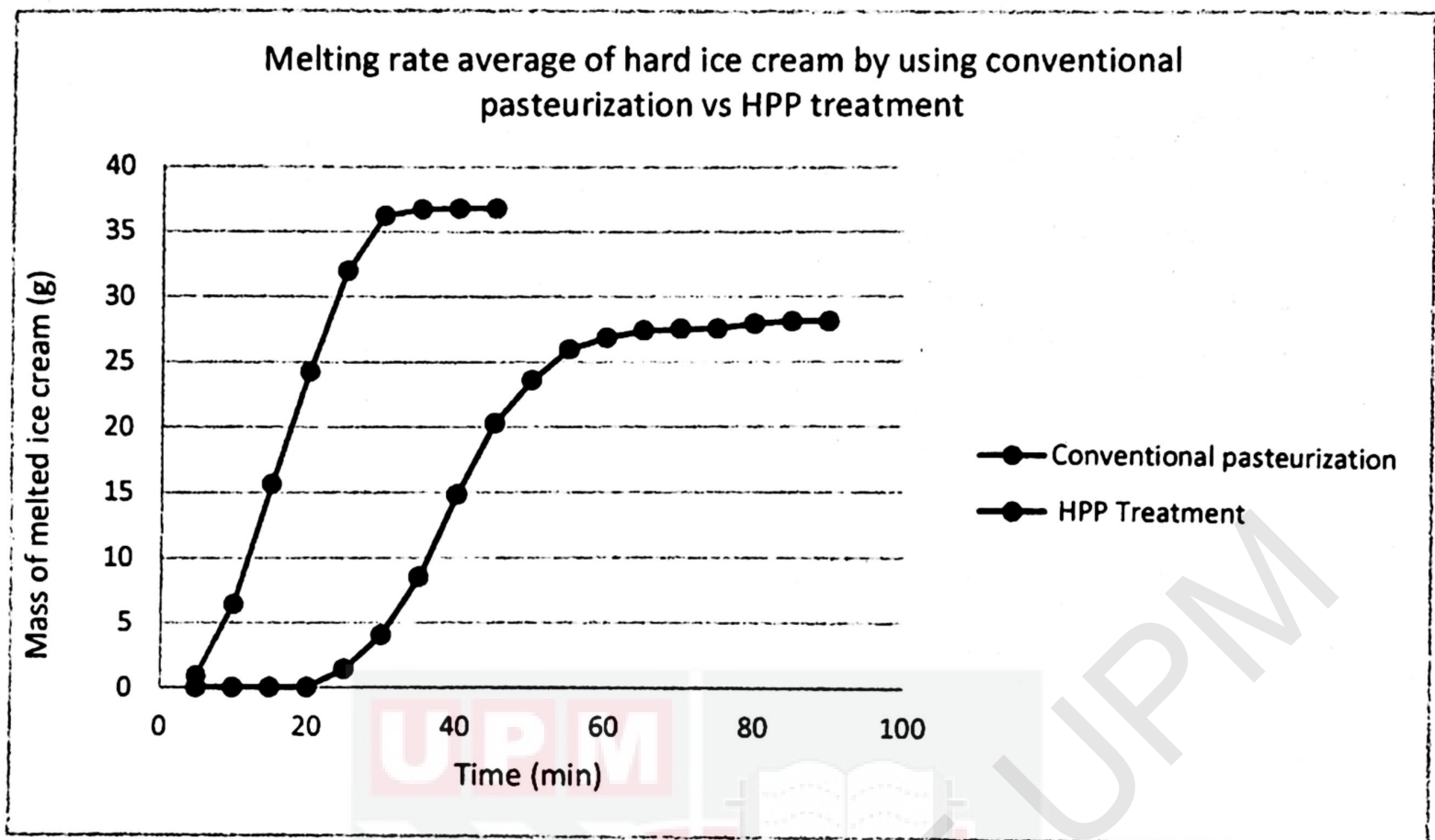


Figure 4. 1 : Graph of mass of melted ice cream over time

From Figure 4.1 shows the graph of mass of melted ice cream over time. It was found that as time increases, mass of melted ice cream also increases. It shows that ice cream mix that undergone HPP treatment melt longer compared to the ice cream mix undergone conventional pasteurization process. Figures below show the condition of ice cream with both processes of conventional pasteurization and high pressure pasteurization process after 45 minutes.

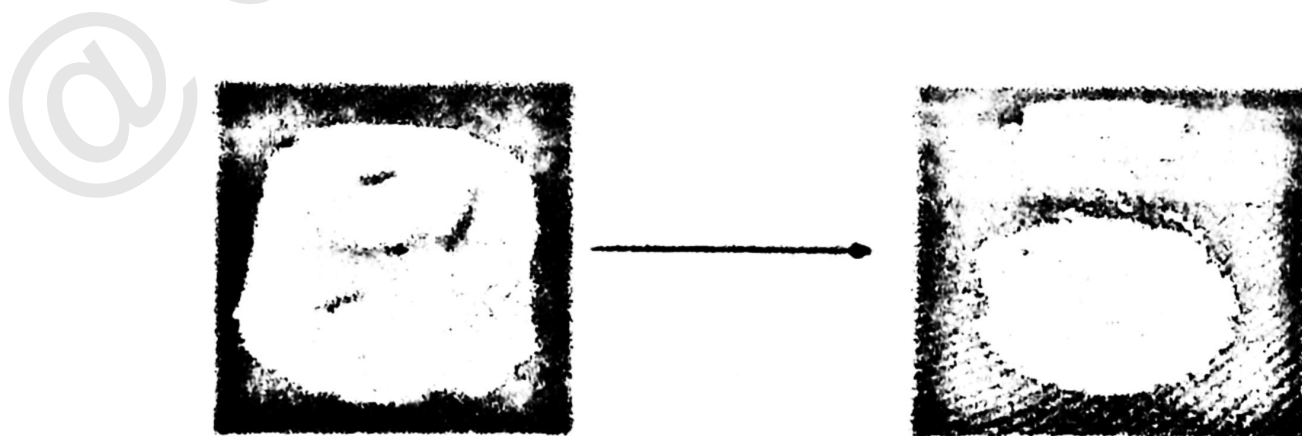


Figure 4. 2 : Melting rate of ice cream with conventional pasteurization after 45minutes

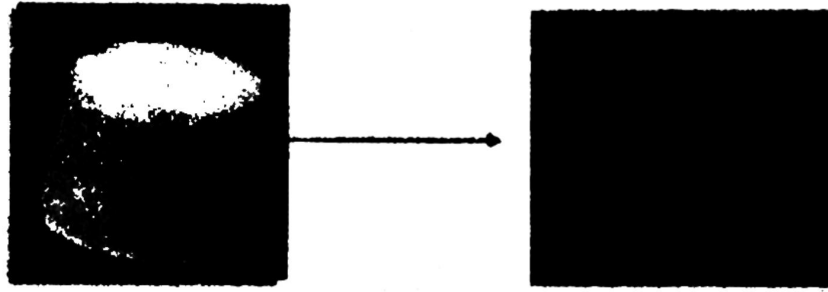


Figure 4. 3 : Melting rate of ice cream with high pressure pasteurization process after 45minutes

Ice cream undergone conventional pasteurization process have greater melting rate 0.817g/min compared to ice cream undergone HPP treatment process which have 0.312g/min. The melting rate of the samples was produced on equation 4.1 (Boonterm et al., 2012):

$$\text{Melting rate (g/min)} = \frac{\text{Weight of melted ice cream within total minutes (g)}}{\text{Total minutes (min)}} \quad (\text{eq 4.1})$$

Three mains structural components of ice cream are ice crystals, air cells and fat globules distributed throughout a continuous phase of unfrozen solution. Theoretically, heat is transfers from warm air surrounding the product into the ice cream to melt the ice crystals while the ice cream melts. In the early phase, ice melts at the exterior part of the ice cream and there is a local cooling effect. The water from the melting ice cream diffuse into viscous unfrozen serum phase and this diluted solution flows downwards through the structural elements such as air cells and remaining ice crystals to drip through the mesh wire on which the ice cream rest and then flow downwards to the beaker on the weighing balance. During melting, initially, flow of the diluted solution is over the exterior of the ice cream. It is found that when the sufficient heat penetration causes melting of the ice crystals in interior of the ice cream, the diluted solutions begin to flow from the interior as well (Muse

M., R., 2003). There are many factors can contribute to the meltdown rate such as nature of the ice crystals, amount of air incorporated and network of fat globules formed during freezing.

Emulsifiers are used in ice cream because they contribute greatly to smooth and creamy texture by promoting fat destabilisation. Fat destabilization could contribute to the largest effect on the melting rate of ice cream. Destabilized fat in ice cream takes the form of clumps of fat globules that coat and support the air cells and also chains of fat globules that build a fat network in the ice cream (Marshall et al., 2003). It is found that ice cream with lower level of destabilized fat had faster melting rates. Higher destabilized fat increase the resistance to flow of the serum phase as ice melted, led lower to slower meltdown (Hartel et al., 2003). High levels of destabilized fat could manage to retain the shape of ice cream well during the melting. The fat network in the ice cream helped maintain the ice cream on the screen (Tharp et al., 1998).

Huppertz T., et al (2011) proposed the comparison of ice cream that being treated with HPP process and untreated control ice cream mix. It is highlighted that there are presence of intact casein micelles whereas ice cream mix that treated with HPP processing contains few intact micelles. Regardless of fat and sucrose that presence in the ice cream mix, it is noticed that both micellar fragments as well as aggregates of such fragments notable in the results. It is found that ice cream prepared from ice cream treated with HPP melted more slowly from the untreated ice cream, suggesting that HP-induced thickening of the ice cream mix resulted the better able withstand melting ice cream. So, HPP treatment strongly affected the rheological properties of the ice cream mix with the presence of fat and sucrose. It proved that HPP treatments showed desirable functionalities, such as the better stability to

melting. Network of fragments of casein micelles is probably responsible for the increased in the viscosity of the ice cream mix and structure of the ice cream. The better resistance to melting contribute to improving the texture, mouthfeel of the ice cream and limit the ice crystal growth (Goff, 2003). So it is proved that ice cream mix that undergo HPP treatment have lower melting rate than ice cream undergo conventional pasteurization. Ice cream mix that undergo HPP treatment melt very slow compared to the ice cream mix undergo conventional pasteurization because of the fat destabilization factor and also presence of intact micelles in fat and sucrose.

4.2 Analysis on firmness of ice cream

Firmness test for ice cream is very important since it affect the difficulty of the scoop-ability of the ice cream. Harder ice cream has high scoop- ability difficulty while it is easier to scoop for lower soft ice cream. If the customer directly taken out the ice cream from the cold freezer, it is found that it is harder to scoop the ice cream because the firmness of the ice cream is very high at that condition. Therefore, customers should leave the ice cream for a while at room temperature to warm the ice cream. For easier scooping, surface ice has to be melted so that the firmness of ice cream can be reduced. The cold temperature indicates high phase volume, which can disturb penetration of the spoon into the product. From the figure 4.4, the high firmness value recorded from the sample of the conventional pasteurization process rather than sample for HPP treatment process.

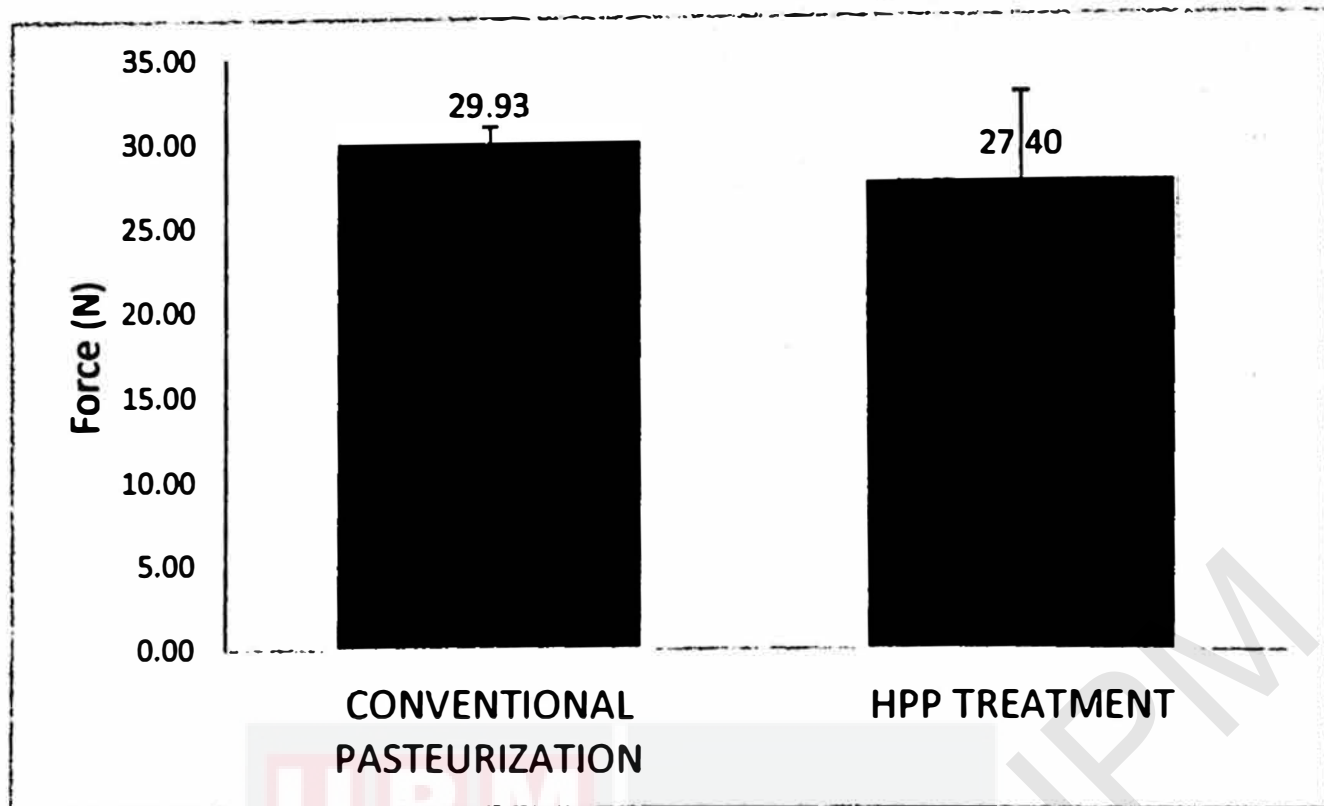


Figure 4. 4 : Firmness of ice cream

Firmness of ice cream is measured as the resistance of the ice cream to deformation when an external force is applied. The firmness of ice cream is affected by many factors such as ice crystal size, overrun and extent of fat destabilization. An inversed relationship between firmness and overrun has noted by many researches (Tanaka et al., 1972). High overrun of ice cream will increase the firmness of the ice cream thus slowing down the melting rate. The viscosity of the ice cream also will affect the firmness of the ice cream. Tharp et al (1998) suggest that firmness of ice cream also could be increase as the level of fat destabilization increase. Sakurai et al. (1996) found that large ice crystals of ice cream were high in firmness than ice cream that has fewer large crystals. Wilbey et al. (1998) states that firmness of ice cream was exponentially related to the ice phase volume.

Based on the figure 4.3 above, it shows that ice cream undergone conventional pasteurization process has greater firmness compared to ice cream undergone HPP treatment process. The result shows different from the previous studies. Based on the

viscosity analysis on the ice cream mix that undergone both process, it shows that ice cream mix that undergone HPP treatment process have high viscosity compared to ice cream mix that undergone conventional pasteurization process. Hartel et al. (2003) propose that high viscosity and percentage of ice during freezing process, led to enhance fat destabilization and promote high shear force. Bolliger et al. (2000) states that ice cream with low level of destabilized fats had faster melting rates and vice versa. So the higher level of destabilized fats, the higher the viscosity thus the greater the firmness of the ice cream.

The results from the graph show different where the ice cream mix that undergone HPP treatment process that have a higher viscosity have a lower firmness compared to ice cream mix that undergone conventional pasteurization process. The most likely reason why the firmness did not appear to be significant in this study was because the usage of the batch freezer. The use of the batch freezer in this study also affects the firmness if the tests due to it non consistent temperature because of its old condition. The temperature sometimes is adjusted manually so that it cannot retain a constant temperature thus it will affect the firmness test of the both samples. Moreover, the test on impact of air cell size on the size of the ice cream was also not been conduct. So the firmness test was not showed the correct results.

4.3 Analysis on overrun of ice cream

Overrun is an important aspect in producing ice cream. Air in ice cream influenced the melting rate and hardness of the ice cream. Figure 4.5 below shows overrun data for ice cream mix under pasteurization conventional process and ice cream mix under HPP treatment process.

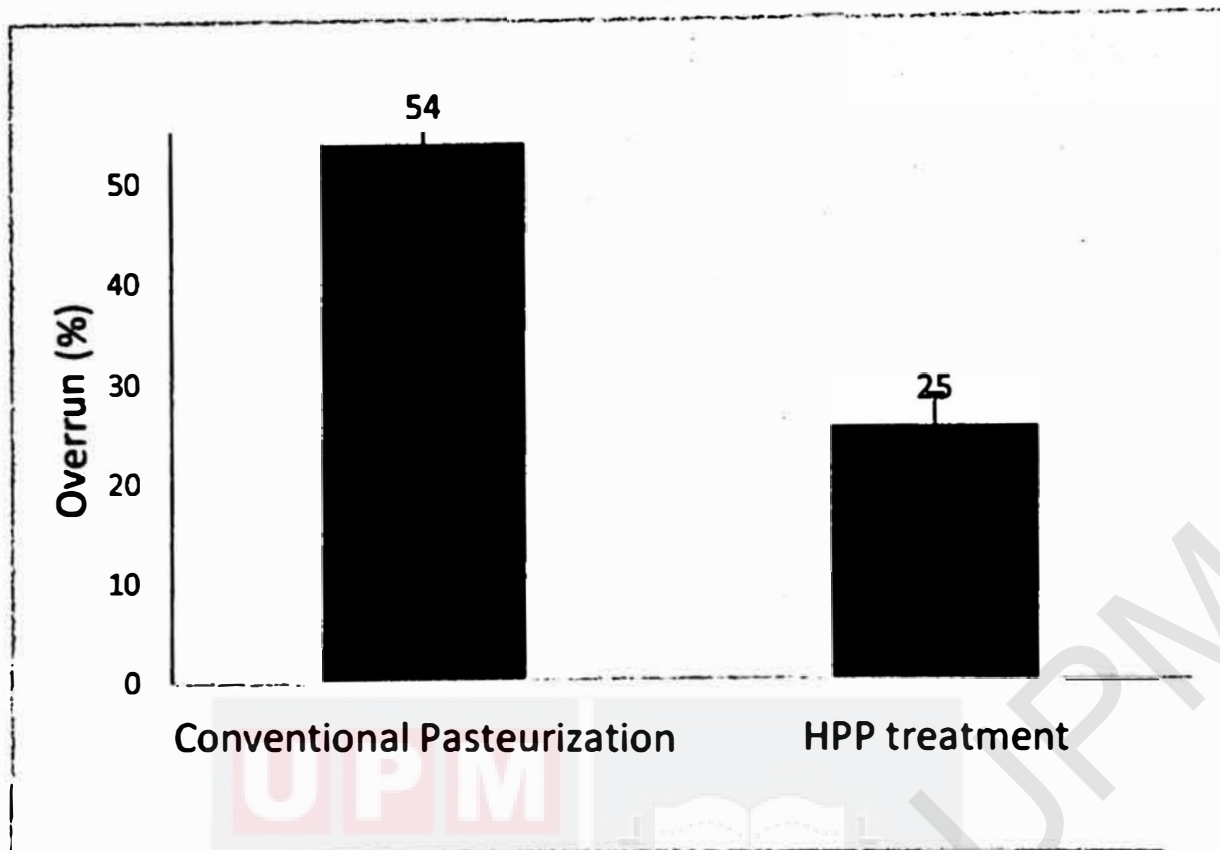


Figure 4. 5 : Overrun of ice cream

High overrun ice cream melted slowly and has a good melting resistance compared to ice cream with lower overruns that melted very quickly. The high overrun with slower melting rate of ice cream was because of the reduced rate of heat transfer due to larger volume of air but may also due to the more tortuous path which the fluid must flow. Figure 4.5 above shows that ice cream mix using HPP treatment has lower overrun compared to ice cream mix using conventional pasteurization process. Overrun can determine the hardness of the ice cream. Willbey et al (1998) suggests that ice cream with high overrun is softer. The study shows that the hardness of ice cream decrease as the overrun increased in agreement with the results of (Willbey et al., 1998). The larger volume of compressible dispersed phase led to less resistance to an applied force (Hartel et al., 2003). Overrun also effect the melting rate. Sakurai et al (1996) and Sofjan (2002) in their research showed that ice cream with lower overruns had faster melting rates.

However, this study showed that the lower overrun of ice cream with HPP treatment has lower melting rates of the ice cream with conventional pasteurization. Besides,

based on the test, data shows that high overrun of ice cream mix for conventional pasteurization produce harder ice cream. Although many factors have been shown to influence the melting rate and firmness of ice cream, the understanding of these factors is not complete. Theoretically, high overrun of ice cream will produce harder ice cream thus have lower melting rate. The overrun in this study did not appear to have a significant effect on melting rate and firmness of the ice cream. Previous studies show that overrun has been found to affect the melting rate of the ice cream, but it did not appear as the factor in this study because of the error of the overrun mainly due to the gelation of the ice cream mix after done the HPP treatment. Further discussion of the ice cream was discussed detail in the hardness, viscosity and melting rate analysis section.

4.4 Analysis on density of ice cream

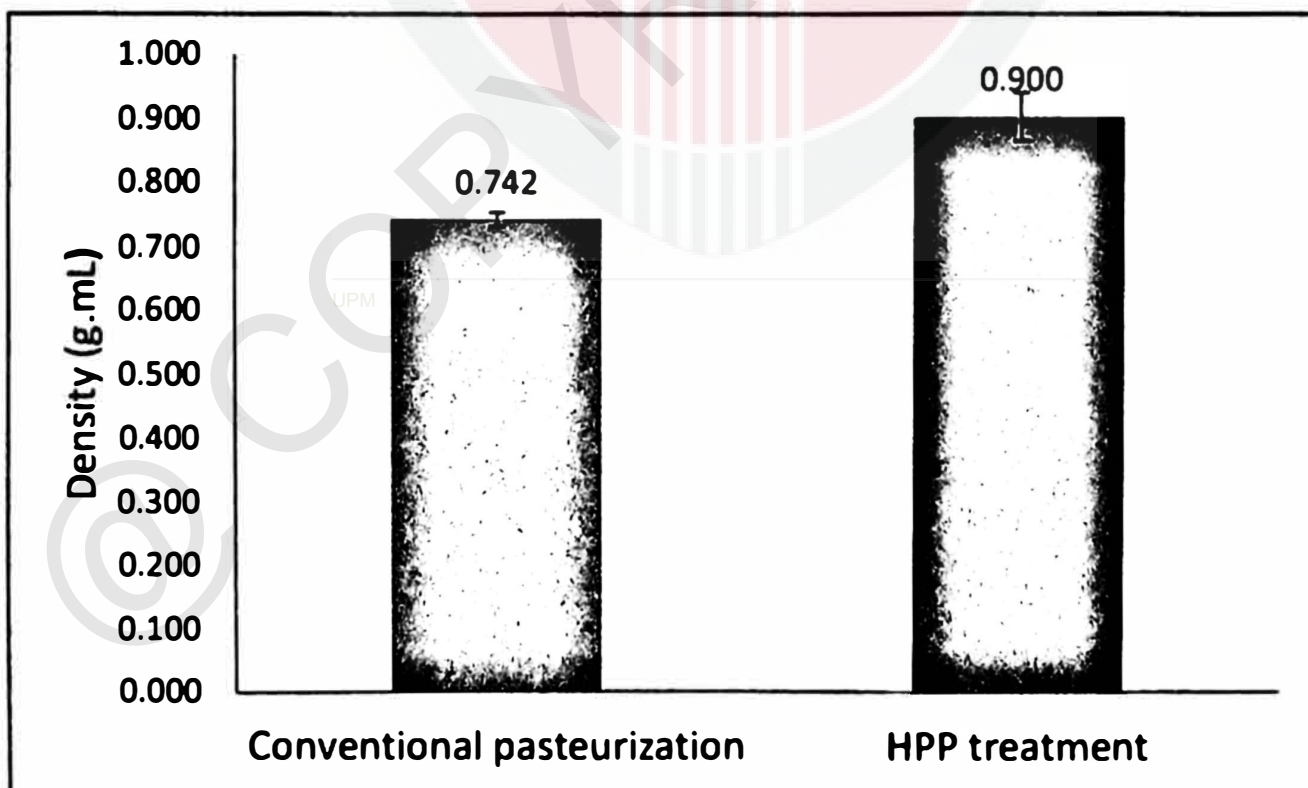


Figure 4. 6: Density of the ice cream

The density of both sample are shown in figure 4.6 above. The density for ice cream mix that undergone HPP treatment is higher compared to density of the ice cream mix that undergone conventional pasteurization. From the results, ice creams that

undergo HPP treatment have a density of 0.900 g/ml while ice creams with conventional pasteurization process have 0.742 g/ml. It was assume that density was affected by the weight after the HPP treatment.

The results show was affected by the amount of fat content of ice cream for both ice cream samples. Fat destabilization was discussed on the melting rate. Increased levels sugar and stabilizer increased the density while increased fat decreases mix density (Bajad et al., 2016). So it shows that ice cream mix undergone HPP treatment has higher density than ice cream mix undergone conventional pasteurization. The amount of air also has a huge effect on the density of ice cream. The overrun of the ice cream will affect the density reading. So, the reading of the density was not accurate enough due to the non-consistent reading of the overrun.

4.5 Analysis on viscosity of ice cream mix

Viscosity of ice cream is one of the important attribute from the engineering and consumer viewpoint. Fat is important in the ice cream structure stabilization especially as partially coalesced fat is responsible for its foam structure and for stabilizing the air bubbles (Koxholt et al., 2001). Figure 4.7 below shows the results of average for viscosity of ice cream mix by the conventional pasteurization process and HPP treatment process.

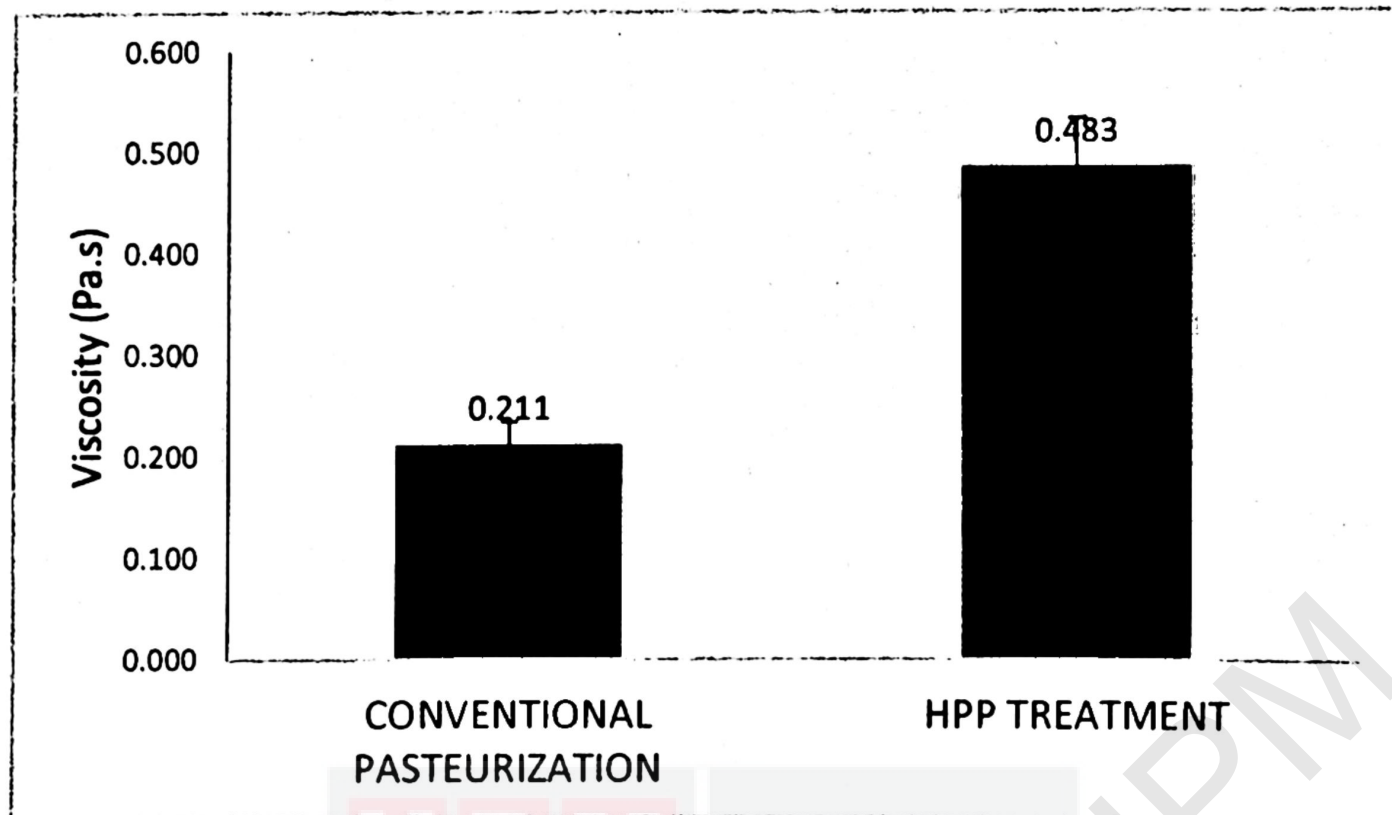


Figure 4. 7: Viscosity of ice cream

Based on the figure 4.4 above, it shows that ice cream mix undergone HPP treatment has a higher viscosity compared to ice cream undergone pasteurization conventional process. HPP treatment increased the viscosity of the ice cream although it only had little effect on the milk globules. With the increasing time and increasing pressure, the viscosity of ice cream mix that treated with HPP will also increase. It is also found that ice cream mix that treated with HPP treatment increased with the increasing fat, sucrose content of the mix and milk solids non-fat (Huppertz et al, 2011). Generally, the high viscosity and percentage of ice freezing can be attributed by the high level of destabilized fat in ice cream which can led to enhance high shear forces and enhanced fat destabilization.

HPP treatment also affects casein micelles that can be found in the whey protein which is the whey powder. The formation of protein network presence in the ice cream mix is responsible for the HPP induced increases in ice cream mix viscosity, which also increase with the increasing protein content. This is because caseins micelles and whey proteins are strongly affected by the HPP treatment. The whey

protein in the mix denatures during the HPP treatment and in systems comparable with ice cream mix (Considine et al., 2017). The micelles size in HP treated mix may be increased or decreased depend on the temperature, time and treatment pressure. Results show that both ice cream mix viscosity and whey protein denaturation increase with the increase in the pressure and treatment time. HP treatment will affect the hydration of casein micelles thus affects the results where the viscosity of the mix increase. Aggregation of casein is the mechanism behind the induced gelation of the mix. The micelles disrupted when the milk is pressurized in the HPP vessel. The extent and rate of micellar disruption increased with pressure and decreased with concentration of the milk solids. The induced of micellar disruption can be reduced by adding sucrose, glucose or corn syrup (Huppertz T., & Kruiff D., 2011). Treatment at 200-500MPa only causes partial disruption of casein micelles in ice cream mix. Keenan et al (2001) suggested that for induced gelation of skim milk, large number of micellar fragments in HPP treated affect micellar disruption and contribute strongly to the HP induced increases in the viscosity of the milk. The longer the treatment time with high pressure will follow the disruption of micelles under pressure thus will produce the gelation in the mix. The disruption is not complete if subsequent aggregation and reformation is observed. Figure 4.8 below shows the gelation on the ice cream mix occurred after the high pressure pasteurization process.



Figure 4. 8 : Gelation occur after high pressure pasteurization process

CHAPTER 5

CONCLUSION AND RECOMMENDATION

This chapter summarizes the project work done. The main objectives to determine the effects of high pressure pasteurization of ice cream mixture on viscosity and compare with the one pasteurized conventionally and to determine the effects of high pressure pasteurization of ice cream mixture on the overrun, melting rate, firmness and density of the ice cream produced. Different test were done to study the differences between ice cream that undergo conventional pasteurization and ice cream undergo high pressure pasteurization including melting rate test, firmness test, viscosity test, density test and overrun test. The recommendation is also included in this chapter.

5.1 Conclusions

High pressure pasteurization processing treatments leads to beneficial changes in proteins structure which helps to improve the mouthfeel. High pressure pasteurization of the ice cream mixture produced dense ice cream with slower melting rate, low overrun, and reduced firmness. These properties resemble the properties of premium ice cream.

High pressure processing gave impact to the quality of the ice cream. The results showed that ice cream mix that undergone conventional pasteurization and high

pressure processing gave a different result. For this research, ice cream mix had undergone high pressure pasteurization process for 20 minutes with pressure of 500 MPa. This main operation led to the differences between the results for ice cream mix.

For melting test, it was found that ice cream using conventional pasteurization have higher melting rate than ice cream using HPP treatment process. While, for viscosity the results showed that ice cream mix undergone HPP treatment have high viscosity compared to ice cream mix undergone conventional pasteurization. Next for the overrun test, using the calculation provided, overrun is higher for ice cream than undergone conventional pasteurization rather than ice cream that undergone HPP treatment. Furthermore, for hardness test, high hardness was recorded for the sample of conventional pasteurization. Lastly, the density in this research showed that ice cream mix undergone HPP treatment is denser than ice cream mix undergone conventional pasteurization.

To summarize, based on previous researches, ice cream that undergone HPP should be denser, viscous, high in hardness and have high overrun because of the low melting rate. The results for this research are mostly proved relating to the previous researches.. Ice cream undergone HPP treatment had a huge different physical properties compared to ice cream mix undergone conventional pasteurization that were commonly used. This research did not achieve the accurate results due to many external factors including the availability of the freezer, limited time for using the high pressure processing equipment and the availability of other equipment for testing in the lab. The formation of gel after the HPP treatment may be the biggest contribution to the results shown in this study.

5.2 Recommendation

Future studies - HPP can be utilized on the improvement of reduced-fat ice cream with varying treatment time and pressure of the processing which may help to alter protein structure without compromising texture and mouthfeel of the ice cream produced. By varying the treatment time and pressure, it could produce better ice cream and better understanding to study the difference of the physical characteristics of ice cream. Besides, the project also can be improved by using the specialized freezer for the ice cream. The used of many other samples for different project in the freezer will affect the quality of the ice cream especially when playing with the temperature. As shown in the result, it is difficult to determine the hardness with non-consistent temperature of the samples. Lastly, other test should be done in order to get the specific result of the physical characteristic of ice cream such as the ice crystal test, test for the fat globule size and the air bubble size test. Therefore, many recommendations especially by varying the treatment time and pressure should be done to study more about the ice cream properties using HPP treatment and conventional pasteurization because the gel produced after the HPP treatment process is the major contribution to the results of this study.

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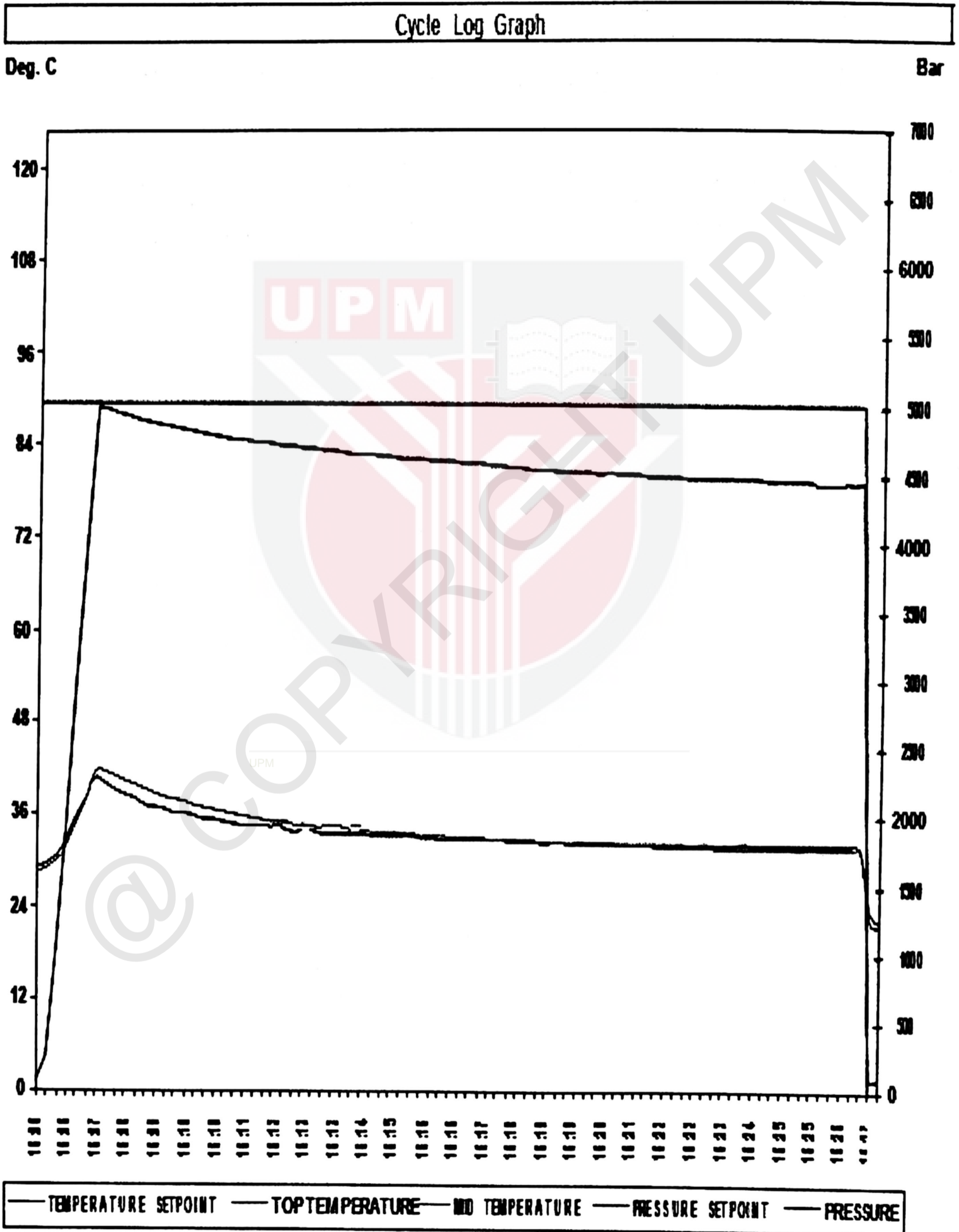
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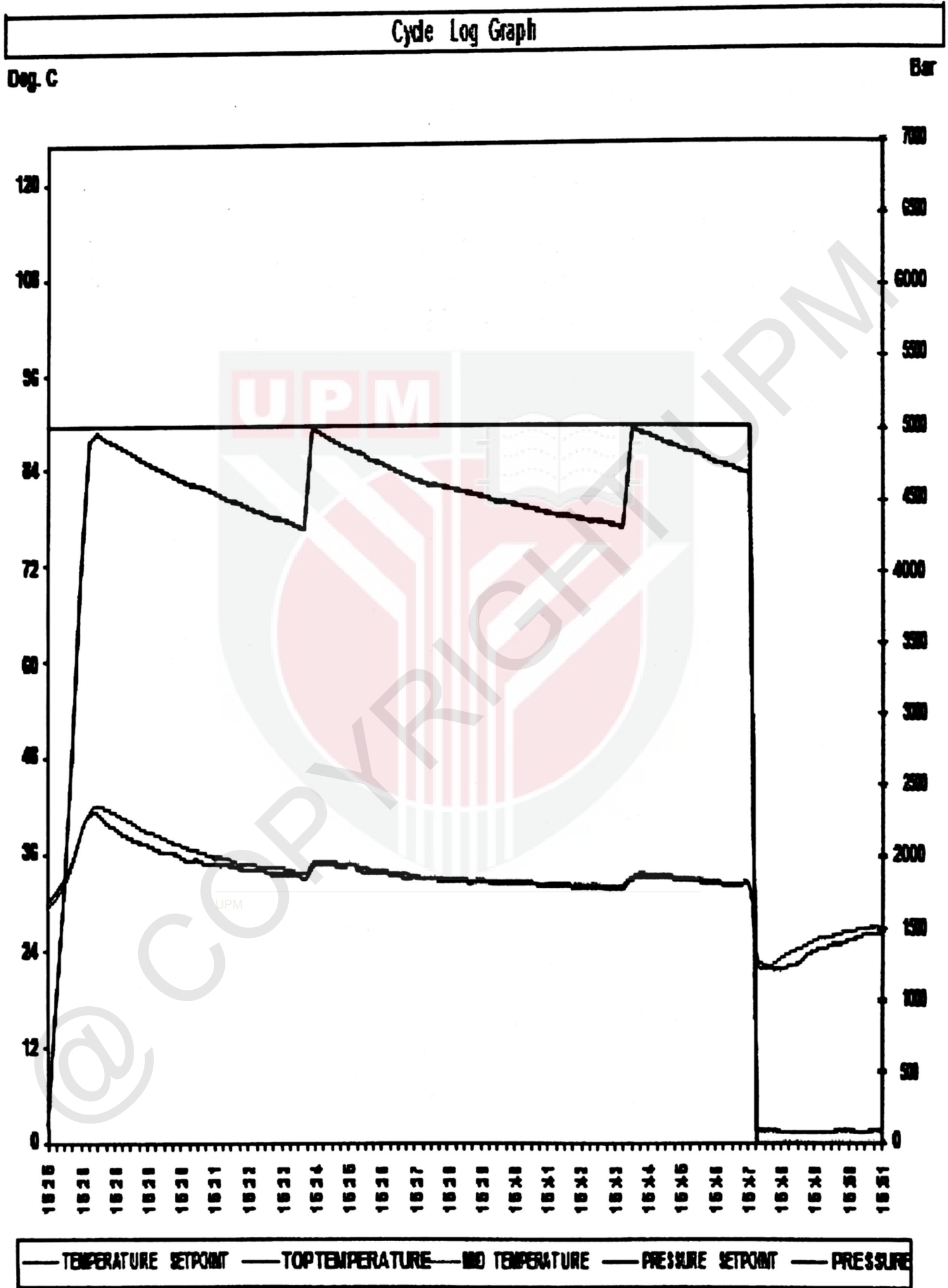


APPENDICES

HPP sample A



HPP sample B



HPP sample C

