Development of watermelon rinds jelly and its textural properties.

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DECLARATION

I am hereby declared that the work embodies in this report is the original research and has not been submitted for a higher degree of any universities or institutions.

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DEVELOPMENT OF WATERMELON RIND JELLY AND ITS TEXTURAL PROPERTIES

ABSTRACT

Watermelon (*Citrullus lanatus*) is an agricultural product that commonly been used by the majority of food manufacturers as the main source of various types of watermelon based product including jam, gummy and jelly products. The development of various type of watermelon based product has led to the increase of watermelon waste since manufacturers usually used the watermelon pulp only in order to produce the product whereas the watermelon by-product, the watermelon rind was discarded as it was often viewed and misunderstood as an inedible part of the watermelon. Some studies showed that 36 million tonnes of watermelon rinds, the watermelon waste were generated in 2013 and the situation might be worse over the years as the production of watermelon has increased. In this study, freeze-drying process has helped to preserve pectin content in watermelon rind and enzymatic process able to extract pectin (0.013%, 00.016% and 0.031%) from watermelon rind thus influenced the development of watermelon rind jellies. Textural profile analysis (TPA) has performed on watermelon rind jellies using Texture Analyzer. The produced watermelon rind jellies exhibited lower values in hardness (28.83±4.37, 168.25±2.50, 210.17±43.00) N, cohesiveness (1.84±0.17, 1.25±0.12, and 0.85±0.19), springiness (3.6±3.87, 0.33±0.095, 0.76±0.56) cm, chewiness (3.6±3.87, 3.83±1.72, 6.17±2.06) mJ and gumminess (39.67±18.50, 133.00±10.82, 195.33±41.6) g compared to the commercial jelly. For commercial production, the textures of the watermelon rind jellies can also be modified with additives to get better jellies consistency.

Keyword: *Citrullus lanatus*, watermelon rind, pectin, freeze-drying, Texture Profile Analysis (TPA)

PEMBANGUNAN JELI KULIT TEMBIKAI DAN SIFAT-SIFAT TEKSTURNYA

ABSTRAK

Tembikai (*Citrullus lanatus*) merupakan hasil pertanian yang biasa digunakan oleh majoriti pengeluar makanan sebagai sumber utama pelbagai jenis produk berasaskan tembikai termasuk produk jem, gula-gula getah dan jeli. Pembangunan pelbagai produk berasaskan tembikai telah menyebabkan peningkatan sisa tembikai kerana pengilang biasanya menggunakan pulpa tembikai hanya untuk menghasilkan produk manakala hasil sampingan tembikai, kulit tembikai telah dibuang kerana ia sering dilihat dan disalah ertikan sebagai bahagian buah tembikai yang tidak boleh dimakan. Beberapa kajian menunjukkan bahawa 36 juta tan kulit tembikai, atau sisa tembikai telah dihasilkan pada tahun 2013 dan keadaan mungkin menjadi lebih teruk selama bertahun-tahun kerana pengeluaran tembikai telah meningkat. Dalam kajian ini, proses pengeringan beku telah membantu mengekalkan kandungan pektin dalam kulit tembikai dan proses enzimatik mampu mengekstrak pektin (0.013%, 00.016% dan 0.031%) daripada kulit tembikai sekali gus mempengaruhi perkembangan jeli kulit tembikai. Analisis profil tekstur (TPA) telah dilakukan pada jeli kulit tembikai menggunakan Penganalisis Tekstur. Jeli kulit tembikai yang dihasilkan menunjukkan nilai kekerasan yang lebih rendah (28.83±4.37, 168.25±2.50, 210.17±43.00) N, kepaduan (1.84±0.17, 1.25±0.12, dan 0.85±0.19), dan 0.85±0.19, 0.76±0.56) cm, kenyal (3.6±3.87, 3.83±1.72, 6.17±2.06) mJ dan gumminess (39.67±18.50, 133.00±10.82, 195.33±41.6) g. Untuk pengeluaran komersil, tekstur jeli kulit tembikai juga boleh diubah suai dengan bahan tambahan untuk mendapatkan konsistensi jeli yang lebih baik.

Kata kunci: *Citrullus lanatus*, kulit tembikai, pektin, pengeringan beku, Analisis Profil Tekstur (TPA)

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Symbols/Abbreviations	Refers Meaning
%	Percent
^{0}C	Degree Celsius
∈	An element of
WRP	Watermelon Rind Powder
g	Gram
kg	Kilogram
cm	Centimetre
mJ	Millijoule
mm	Millimetre
N	Force
TPA	Texture Profile Analysis

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays, there are varieties of ready-to-eat products has been introduced to the market all around the globe and serve people with numerous kinds of choices. Since food is necessary as a substantial choice in our lives, most of the consumers tend to choose food that is easy to eat such as jelly fruit products. Jelly is known as a semi-solid or intermediate moisture product that is usually prepared from fruit pulp and required the addition of sugar, pectin and citric acid in order to enhance the total soluble solid (TSS) to more 65% (Shinwari & Rao, 2018). Jelly is very famous in having unique chew and soft texture that is encouraged by adequate fruit acidity and pectin content that can be extracted during cooking. Most of manufacturers turn fruits, particularly those with poor shelf life and contain high in bioactive compound into jelly products form so that it can be preserved well.

There are various types of fruits that have been utilised, where their pulp is commonly used by the manufacturers as the main source to generate jelly products and the jelly development was produce into numerous kind of types, relying on the creativity of the manufacturers.

In this study, watermelon was chosen as the main fruit whose by-products would contribute to the jelly production. Watermelon or *Citrullus lanatus* is a fruit that comes from the family of cucumber *(Cucurbitace)* (Hdider, Tlili, & Ilahy, 2020). It is very famous in many countries as it is well-known as large edible fruit consisting of a hard-green rind and a watery reddish or yellowish pulp. It is also recognized as a fruit that has smooth skin with dark green rind. Mostly, United States is the place where watermelon is commonly grown, however, the South and West countries such as Florida, California, and Texas are the huge watermelon producers, where the warm production season runs much longer (Wehner, 2008). Watermelon is an agricultural product that has been eaten by most people in the worldwide either in fresh or watermelon-based product forms since it is commonly been utilized by the manufacturer during this century to generate numerous food products such as candy, juices and even cocktails. Figure 1.0 shows the picture of watermelon rinds that has been used in this research.

Figure 1.0 Watermelon rinds.

Since watermelon is very high in vitamin content and acts as a good source of phytochemicals, it is frequently used as an essential source in food production. Watermelon-based products are usually made from watermelon pulp whereas their rind is usually discarded. Majority of people may not be aware that watermelon rind is actually edible and small number of people, especially those who live in remote areas have consumed the rind as vegetable. This situation led to the idea of the study to convert discarded rind into a jelly product.

1.2 Problem statement

Nowadays, watermelon rinds have always been discarded by the consumers, thus, this situation leads to food waste. Since watermelon rind is part of the watermelon peel, most people especially the young generation today think that the watermelon rinds are useless and inedible. This situation occurs when most people are still unaware of the uses of watermelon rinds and they are not exposed to watermelon rinds as an edible food and the benefits that watermelon rinds offers to our health. The watermelon rind is a part of the peel that it makes people think it needs to be discarded and has no direct value. So, this final year project is all about using watermelon waste which is the watermelon rinds to produce a valuable product so that people can consider watermelon rinds as an inedible part and non-disposable part.

1.3 Objectives

- To produce a jelly product that can be consumed and commercialize from watermelon rinds powder
- To determine texture properties of watermelon rinds jelly.

1.4 Research questions

- What is the essential aspect in order to produce watermelon rind jelly?
- What is the textural properties of watermelon rind jelly?
- What the differences of the texture of watermelon rind jelly and other commercial jelly product?

1.5 Hypothesis of study

Hypothesis Null

$H_{0:}$ There were no significant different of hardness, cohesiveness, springiness, chewiness `and gumminess of textural properties in the watermelon rind jelly as the amount of pectin in jelly increased.

Hypothesis Alternative

H_1: There were significant different of hardness, cohesiveness, springiness, chewiness `and gumminess of the textural properties in the watermelon rind jelly as the amount of pectin in jelly increased.

1.6 Scope of study

This study focused on the jelly development from watermelon rind, a by-product from watermelon. The samples were obtained from the local market in Tanah Merah, Kelantan and the whole research was conducted in the Food Lab and Biology Laboratory of University Malaysia Kelantan (Jeli Campus). The rinds of *C. lanatus* initially went through a drying method which involved freeze-drying in order to turn the rinds into watermelon rind powder (WRP) before pectin extraction to form jelly.

1.7 Significance of study

The rind of C. *lanatus* was commonly discarded by the consumers since the rind has been known to be an inedible part among most consumers over the past few years. Moreover, people also believe that watermelon rinds has no value especially most consumers have less knowledge about the benefits of watermelon rinds. This statement even can be reinforced as nowadays it is so difficult to find any products produced from watermelon rinds. Thus, this is the reasons it is discarded and contributes to the increases in fruit waste statistics. This study aimed to develop watermelon rind jelly as a measure to reduce watermelon waste that has happened over decade. This study also necessarily encourages consumers not to discard watermelon rinds and make it as an edible food. The results of this study provide a great opportunity to introduce food products from watermelon rinds in the market.

CHAPTER 2

LITERATURE REVIEW

2.1 Fruit influences food wastage

The last few years, the waste of food increased all around the world and this issue became the most concern problem by a lot of people in the worldwide where food supplied for human consumption is wasted for about one quarter of it (Stancu, Haugaard, & Lähteenmäki, 2015) and contributed approximately 1.3 billion tonnes of food per year (Schanes, Dobernig, & Gözet, 2018). According to European Union, food waste is known as food, including the cut parts from all stages of the food distribution chain or food that have been discarded due to the oversupply as well as eating or household-related activities (Schanes et al., 2018). Fruit processing residues are recognised as a major environmental concern, and landfilling is the most common means of disposing of trash with a high moisture content. The landfilling of biomass, on the other hand, has severe environmental consequences since it results in the creation of greenhouse gases, particularly methane, as a result of anaerobic decomposition (Thu Dao, Webb, & Malherbe, 2021).

Based on the report that has been generated by Food and Agriculture Organization (FAO), it once stated that among more than 1 billion tonnes of food wastage per year that hit the global, the highest wastage rate was determined came from the fruits (Petkowicz, Vriesmann, & Williams, 2016). The huge solid wastes commonly produced by majority of the restaurants, cottage fruit juice producers as well as industry of food all around the world was the fruit rinds.

2.2 The statistic production of *Citrullus lanatus*

Watermelon or *Citrullus lanatus* is known as the world's biggest fruit crop with a huge worldwide production that reached around 109 million tonnes in 2013 (Petkowicz et al., 2016) and the production was increased by 2016 to 2017 as most of the countries, especially in Africa, Europe and North America started to produce watermelon in a large scale that contributed million tonnes of watermelon per year. Moreover, Asia is also said contribute around 80% of the watermelon production, where 67.6% of the production was conquered by China (Dube, Ddamulira, & Maphosa, 2020). Watermelons are produced widely because they are well-known as fruits that are rich in vitamin (A, B, C and E), mineral salts (K, Mg, Ca and Fe), free amino acids (Citrulline and Arginine), carotenoids (lycopene) and phenolic compounds (Tlili et al., 2011). These nutrition facts of watermelon encourage the development of that fruit globally in order to ensure people can easily consume the fruit to treat various health complication such as digestion problem, skin diseases, high blood pressure (Abu-Nasser, Bassem S, & Samy, 2018).

2.3 The wastage of *Citrullus lanatus* rinds

Normally, watermelon pulp and juice are consumed by humans, whereas the rind and seeds, which account for 30% of the total weight of the fruit, are major solid wastes (L.-H. Ho & Che Dahri, 2016). In 2013, around 36 million tonnes of watermelon rinds, the watermelon waste were generated when considered its production (Petkowicz et al., 2016) and they are always discarded (Al-Sayed & Ahmed, 2013). This situation is worse day by day as the production of watermelon is increased, thus contributed to more wastage and disposal problem. According to a study conducted by the United States Department of Agriculture's Agricultural Research Service, only half of a watermelon fruit is edible, while the other half, consisting of approximately 35% rind and 15% peel are discarded (Liu, Ngo, & Guo, 2012). Even though some studies stated that watermelon rinds are used as vegetable in some countries, especially those in rural areas and as pickles in Southern US (Dube et al., 2020), they are still considered as waste that has no commercial value. This perception occurs because the majority of people nowadays especially the new generation do not expose with the use of watermelon rinds due to the limited research of activities that focusing on the possible transformation of waste to another value-added product. Because the rind accounts for 30% of the total weight (Hoque & Iqbal, 2015), it is critical to figure out how to use watermelon rinds which also known as "wastes" in the formulation of various food products. By drying, water melon rind can be converted into a value-added product.

2.4 The watermelon rinds composition

Despite contributing to the increases of disposal problems, most of people also don't usually aware that watermelon rinds contain mineral salts, protein, carbohydrates, vitamin phytochemical and citrulline (Petkowicz et al., 2016). In this case, the foremost watermelon rind compound is carbohydrate and it was stated that it can be utilized as an important material in pectin extraction. Pectin is actually the polysaccharides that usually found in the cell walls of most living plants. Pectin consists of D-galacturonic acid joined by α-(1-4) glycosidic linkages (Gawkowska, Cybulska, & Zdunek, 2018) and act as the adhesive role between cells. Interestingly, pectin is widely utilized as gelling, thickening and stabilizing agents in the food industry. Pectin within watermelon rinds can be extracted by enzymatic and acid extraction that usually performed through convectional heating extraction and microwave-assisted extraction (Petkowicz et al., 2016).

Pectin from fruit wastes is known as a valuable by-product because it consists essential nutritional and technological characteristics, particularly due to its ability in gels forming. Moreover, pectin is used in numerous products development such as jams, jellies and marmalades in a global scope. Thus, this situation showed that by-product from fruit waste especially those that contain pectin can improve economics of processing units besides of reducing the environmental pollution problem. From Madhav et al. (2006), it has stated that about 80-90% of 7 million kg of commercial pectin around the globe is utilized to produce jelly as well as their similar kind of products, thus made pectin as the single largest use of ingredient in jellies production.

2.5 Pectin utilization for jelly development

Since *Citrullus lanatus* rinds contain high in pectin, it has good potential to be converted and developed into an innovative value-added product in the market as pectin offers great scope for utilization, especially in jelly production. In order to decrease rind waste that influence the disposal problems over the past decades, the new production of jelly from watermelon rinds is definitely the great step since this new development not only able to manage in solving the wastage problem but able to be the new focus of possible conversion of waste to enhance the commercial value of watermelon rinds which commonly discarded and underestimated its value in economics before consumers. Jelly is a kind of enjoyable product that is widely consumed by all stages of age and it's definitely suitable to be developed using watermelon rinds due the presence of pectin in the rinds.

As the information, pectin is placed under dietary fibers and have positive effect on digestive processes in order to reduce cholesterol level and with the development of jelly from watermelon rinds, it is able to help many people to consume pectin that has various benefits in much interesting and easy way. In fact, biopolymers, particularly pectin, which has an annual global usage as an addition of roughly 60 thousand metric tonnes in 2018, are abundant in the waste generated by the agro-food industry. Pectin can be obtained either from fresh watermelon rinds (FW) or dried (lyophilized) watermelon rinds (LW). Both conditions will produce different results of pectin yield. In this study, the focused is more into the pectin extraction from lyophilized watermelon rinds (LW) in order to develop jelly. Watermelon rind in the dried form offer more stability, thus increase its storage period.

2.6 Technology for watermelon rind powder production

Fresh watermelon rind may not be available for eating all year, and long-term preservation of fresh watermelon rind may be difficult due to high water content, a lack of cold-storage facilities, especially in developing and undeveloped nations, and the risk of nutritional deterioration. In this case, the drying of such foods may allow them to be consumed for longer periods of time while also making handling, transportation, and storage easier. Commonly, one of the most frequent processes for making powders from fresh fruits is dehydration and drying (Jiang, Zhang, & Adhikari, 2013). Drying is one of the oldest methods of food preservation, as it prevents microbial decomposition and enzyme activity, as well as extending the shelf life of food goods (Waghmare, Perumal, Moses, & Anandharamakrishnan, 2021).

According to Maisnam et al. (2017), drying is a process in which moisture is removed from food through simultaneous heat and mass transfer. Heat is delivered through conduction, convection, and radiation to cause water to vaporise, while forced air is used to remove the vapours. Fruits rind such as watermelon rind have a high that cause spoiling. By lowering water activity, dehydration keeps watermelon rind in a stable and safe state, allowing it to last far longer than fresh product.

Drying processes can be divided into two categories: natural and artificial. The natural technique of drying uses sun energy to eliminate moisture from food, but it has the problem of being weather dependent and having low operating effectiveness. In addition, artificial technologies have the ability to efficiently remove significant amounts of moisture and offer advantages over natural drying processes as well as involves mechanical or electrical equipment. As a result, dryers with the capacity for more efficient and dependable drying procedures are being developed such as freeze drying

2.6.1 Freeze drying process

Freeze drying, also known as lyophilization, has become one of the most essential methods for preserving food goods among the numerous drying techniques. Freeze drying is often regarded as the most effective process for removing water, approximately 90% of the water in the fruits is removed in the first phase of freeze drying from heat-sensitive materials like fruits and vegetables and obtaining dried products (Jiang et al., 2013). Freeze drying relies on the sublimation of a product's solvent, which can be either water or an organic solvent. At low temperatures, the solvent crystallises and then transitions directly from the solid to the vapour phase. In general, freeze drying is done at lower temperatures, which helps to preserve food quality while also decreasing the harm caused by thermo labile chemicals (Waghmare et al., 2021). The fundamental goal of freeze drying is to produce a material with a long shelf life that retains its quality after being reconstituted with water. When compared to traditional drying methods, freeze drying has various advantages including the preservation of morphological, biochemical, and original features, high volatile recovery, and structure and surface preservation (Waghmare et al., 2021).

Freeze-drying was performed for the drying stage since freeze-drying itself is reviewed as one of the most advanced drying methods and able to produce good characteristics products compared to conventional techniques as freeze-drying has the ability to preserve more nutrients (Ho et al., 2016) and produce a fresh-like product. In this context, freeze drying or lyophilization is a process that usually performed to remove solvent (water), which typically used to preserve perishable foods like fruits. Freeze-drying is worked by freezing the material followed by the pressure reduction and heat

addition involvement to let the frozen water in the material to change directly to a vapor or sublimate.

2.6.2 Fundamental principles of freeze drying

Freeze drying has 3 main phases that are known as freezing, sublimation (primary drying) and adsorption (secondary drying). The phases in freezing drying method is done to preserve the physical form and involves the conversion of water to ice (crystalline phase). Freezing is a crucial step in the freeze-drying process because it determines ice crystal morphology and size distribution, which affects a variety of significant factors such as drying rates, product crystallinity, specific surface area, and dried product reconstituability (Waghmare et al., 2021). Freezing rate influence the crystal growth which subsequently defined the sublimation efficiency.

During primary drying or sublimation phase, heat and mass transfer are involved and the frozen product is vaporized without passing through liquid phase before the vaporized solvent turn back to a solid during adsorption phase (Ratti, 2013). Moreover, in order to begin the sublimation process, a vacuum is applied and the shelf temperature is raised until the product temperature is 2-3 C below the collapse temperature. During the freeze drying process, the collapse temperature is the temperature above which the product risks losing macroscopic structure (Bhatta, Stevanovic Janezic, & Ratti, 2020). After that, the unfrozen solvent is removed using a desorption process (secondary drying).

Secondary drying begins while sublimation is still in progress, and it is a slow component of the freeze-drying process that can take up to 30 percent longer than sublimation to finish. This final stage could be done at a higher shelf temperature to desorb the residual unfrozen or bound water more efficiently (Bhatta et al., 2020). As a result, the two equally important primary activities that take place during a freeze-drying process are freezing and drying (Waghmare et al., 2021). These phases make freeze drying as the most accepted process in fruit drying since the involvement phase during freeze-drying help to retain the maximum bioactive activity. Moreover, the absence of liquid water and oxygen under vacuum as well as the use of low temperatures during freeze-drying process encourage the minimization or partially stopped of deterioration reactions such as flavor reduction, aroma losses and nutrient retention maximization.

Freeze drying which operated under vacuum involves lack of liquid water, oxygen-free atmosphere and low operating temperatures, thus make this process as the best method for dehydrating fruits and vegetables to maintain optimal bio component content in the final goods. Figure 2.0 below illustrates the involvement of heat and mass transfer during freeze drying process.

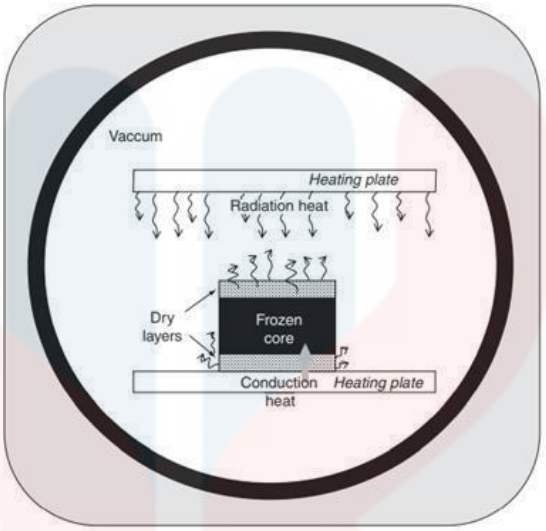


Figure 2.0 Heat and mass transfer involvement during freeze drying process.

Source: Ratti (2013)

As a result, freeze drying is recommended for high-value items such as fruits, and extracts. However, most freeze dryers on the market now require a longer drying period, resulting in significant energy consumption and a hefty initial investment (Waghmare et al., 2021). In addition, product temperature must be considered during freeze-drying process, which product quality might be deteriorated once it stays below particular limits. Despite the long drying time and high cost, freeze-drying is frequently employed to make high-value food items because it maintains food quality better than other drying procedures.

2.7 Enzymatic extraction

Generally, pectin is commercially made utilising a thermal technique that involves a high temperature and an acidic medium such as nitric acid, hydrochloric acid, and others. Those acids are utilized in pectin extraction particularly to produce thickening agent in food production due to their cheap price and their capability to generate pectin from the fruits (Maran et al., 2014). However, the wastewater generated by this method is not environmentally friendly and contributes to environmental problems. As a result, various green chemical approaches have been developed to address these issues, including microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), and supercritical fluid extraction (SFE). In this situation, microwave-assisted extraction (MAE) is known as a good method for pectin extraction since it has advantages such a shorter time, less solvent, less power and energy consumed, and a greater extraction rate (Kazemi, Khodaiyan, & Hosseini, 2019).

According to Veggi et al., (2012), the high extraction yield and process acceleration in microwave-assisted extraction (MAE) could be due to a synergistic combination of two transport phenomena including heat and mass gradients that moving in the same direction. The extraction process is divided into three stages that stars with an equilibrium phase, which solubilisation and partition phenomena are present. Then, a removal phase which the substrate is removed from the particle's outer surface at a constant velocity and followed by an intermediate transition phase to diffusion. Resistance to mass transfer appears at the solid–liquid interface, and mass transfer through convection and diffusion takes precedence during this time. The solute must next overcome the interactions that link it to the matrix and permeate into the extracting solvent in the final phase.

Microwave-assisted extraction (MAE) may use both polar and nonpolar solvents, with solvents like ethanol, methanol, and water being sufficiently polar to be heated by microwave energy. Moreover, small amounts of water in the extraction solvent allow water to diffuse into the matrix's cells, resulting in improved heating and thereby aiding component transport into the solvent at higher mass transfer rates. To boost the extraction efficiency of poor microwave absorbers like hexane, ethanol or water might be added.

Another significant thing to consider in microwave-assisted extraction (MAE) is the heating period. In comparison to conventional procedures, microwave-assisted extraction (MAE) extraction periods are very short, ranging from a few minutes to a half-hour, minimising probable thermal degradation and oxidation. The high dielectric characteristics of the solvent like ethanol and methanol, promote overheating, as doe's further dilution with water, which enhances the heat capacity of the solvent mixture. In microwave-assisted extraction (MAE), higher extraction time typically increases extraction yield, and solvents such as water, ethanol, and methanol may become extremely hot after extended exposure, endangering the future of thermo labile constituents.

Microwave-assisted extraction (MAE) is becoming more widely utilised in the of natural products extraction as a substitute for conventional extraction techniques for a variety of reasons, including reduced extraction time and solvent consumption as well as less environmental pollution as a result of increased efficiency and clean energy transfer to the matrix, resulting in enhanced extraction yield and quality of product (Michel, Destandau, & Elfakir, 2011).

CHAPTER 3

METHODOLOGY

3.1 MATERIALS AND METHODS

3.1.1 Chemicals and Reagents

Ethanol was purchased from Sigma-Aldrich (New Jersey, USA) whereas another chemical including citric acid was obtained from Merck (Darmstadt, Germany) and all the chemicals and reagents utilised were of analytical grade.

3.1.2 Apparatus and equipment

The apparatus used in the laboratory were measuring cylinder 100 mL, beaker 200 mL and 500 mL, stainless steel spatula, aluminium foil. Freeze dryer Model CoolSafe 4-15 L was supplied by LaboGene (Bjarkesvej, Lillerød, Denmark) while Ultra-low temperature freezer Model MDF-U55V-PE was supplied by Panasonic (Osaka,Japan)

were used. Durable & Lightweight Blender (Dry Mill) Model MX-M210SSL was obtained from Panasonic (Petaling Jaya, Selangor, Malaysia). Branson 2800 Ultrasonic Cleaner Model CPX2800H that was obtained from Fisher Scientific (Massachusetts, USA) and Saffron Laboratory Balance Model SES623 was supplied from Saffron Scales (Gujrat, India).

3.1.3 The collection and preparation of the sample.

Watermelon or *Citrullus lanatus* was purchased from the market in Tanah Merah, Kelantan. The watermelon was cut and the watermelon rinds were collected. The green part of the rind or watermelon peel was removed and the rind was kept. Then, watermelon rind was clean with running tap water to get rid of any dirt. The collected watermelon rind was weighed and the weight of watermelon rind was recorded.

3.1.4 The production of watermelon rinds powder (WRP)

Watermelon rind was placed in airtight plastic and kept in -18°C for 24 hours in Ultra-low temperature freezer (MDF-U55V-PE) by Panasonic. Then, the sample of watermelon rind was freeze-dried for 72 hours by using Freeze dryer Model CoolSafe 4-15 L that was supplied by LaboGene (Bjarkesvej, Lillerød, Denmark). The freeze-dried watermelon rind was transferred into an airtight plastic and the watermelon rind was subsequently grounded using durable & Lightweight Blender (Dry Mill) Model MX-M210SSL from Panasonic. The sample was saved a little bit for further analysis.

3.1.5 The production of watermelon rind jellies

Jelly formulation was consisted of 80 g of sugars, 1 g of citric acid and 10-30 g of watermelon rinds powder (WRP). At first, 10 g of watermelon rinds powder (WRP) was weighed and put into a 500 mL beaker. Then, about 60 mL of distilled water was added to the watermelon rind powder (WRP) and it was heated in a water bath to 80 ^{0}C for 20-30 minutes in order to extract pectin. Meanwhile, sugar was dissolved in 100 mL of boiling water with the involvement of 1 g of citric acid (pH 3.2) for 20 minutes. Then, the addition of dissolved sugar with citric acid to the watermelon rind powder (WRP) dispersion at 121^{0}C was done and the dispersion was then warmed up again for approximately 30 minutes at 80 ^{0}C. After that, the dispersion was filtered and the filtrate was poured into petri dish and it was let to be cooled for 48 hours at room temperature to develop jelly. The processes were repeated for 20 g and 30 g of watermelon rind powder (WRP).

Jelly	**1**	**2**	**3**
Amount of WRP (g)	10	20	30
Amount of sugar (g)	80	80	80
Amount of citric acid (g)	1	1	1

Table 3.0 The composition of watermelon rind jelly

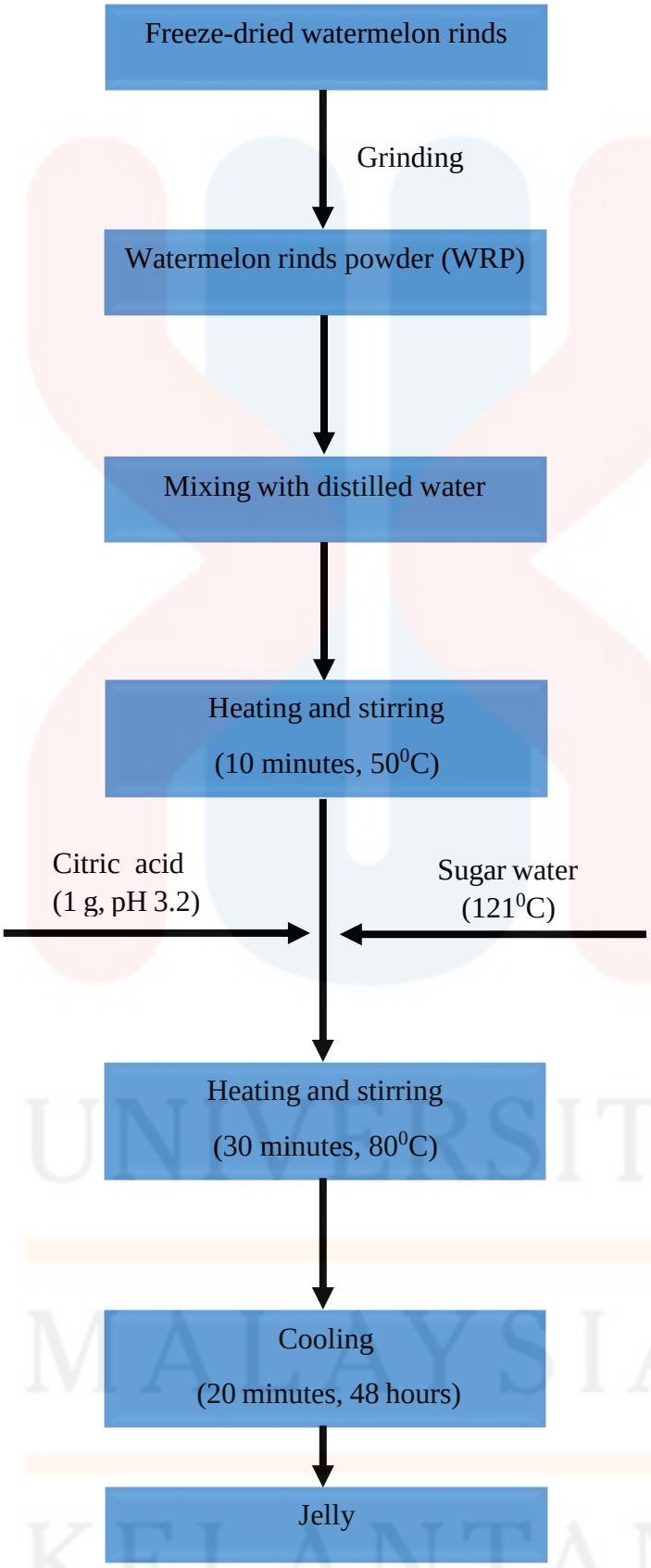


Figure 3.0 Watermelon rinds-based jelly

3.1.6 Textural Properties Analysis (TPA) of watermelon rind jellies.

Texture profile of watermelon rind jellies were analysed with Texture Analyzer (Broofield, MA, USA). The test involved a 2-cycle compression. In this analysis, 2 mm diameter rod probe (TA39) was used. The time elapsed between cycles was 5 s with a load cell of 10000g. The jellies were compressed by 5 mm with a crosshead speed of 10 mm/s and the trigger force considered was 0.1 N. Each test was replicated 3 times. The watermelon rind jellies were analysed based on parameter hardness (N), cohesiveness, springiness (cm), chewiness (mJ), gumminess (g).

3.1.7 Statistical analysis

In this study, statistical analysis (SPSS) Version 23.0 was used to analyse the data from the analysis that was carried out. The method was completed with the Tukey Honestly Significant Difference post hoc test, which allows for the detection of differences. Each experiment was performed 3 times and the data was expressed in the form of mean, standard deviation and one-way variance of ANOVA. In this condition, $p<0.05$ was considered as significant value for the textural properties.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Pectin extraction from watermelon rind

The watermelon rind contains mineral salts, fat, protein, carbohydrates, vitamins, phytochemicals, and citrulline and carbohydrate act as the main compound in watermelon rind, and it has been suggested that it could be used as a raw material for pectin extraction. Pectins are polysaccharides that are widely employed as gelling, thickening, and stabilising agents in the food industry. Commercial pectins are mostly extracted from citrus peels and apple pomace, both of which are waste products from the juice industry, using diluted mineral acid. According to a prior study, watermelon rind might be used as a source of pectins, and pectins from watermelon rind can be extracted using enzymatic and acid extraction methods, as well as conventional heating and microwave-assisted extraction methods. In this study, the extraction yield of pectin from watermelon rind was calculated using formula below:

% of pectin extraction from watermelon rind powder (WRP)

$$= \frac{\text{total weight of extract (g)}}{\text{total weight of WRP (g)}} X\ 100$$

Table 4.0. The percentage of pectin obtained from 10 g, 20 g and 30 g of watermelon rind powder

Amount of WRP (g)	10	20	30
Percentage (%) of pectin extracted	1.30%[a]	1.60%[b]	3.05%[c]

*[a-b]All values represented the percentage of pectin extraction. Different letters in same row indicates significant differences at $p \leq 0.05$

Table 4.0 showed the percentage of pectin extraction obtained from watermelon rind powder (WRP). Based on the result, 10 g, 20 g and 30 g of watermelon rind powder (WRP) produce approximately 1.30%, 1.60% and 3.05% of pectin respectively. Based on the result, all the samples of watermelon rind powder (WRP) contained different amount of pectin extracted showed significant different ($p \leq 0.05$). This condition illustrates the increased of watermelon rind powder (WRP) content had increased the pectin content. In this analysis, watermelon rind powder (WRP) was heated in the water bath at 80^0C in order to extract the pectin to develop watermelon rind jellies.

According to Veggi, Martinez et al (2012), the high water bath power had raised the temperature of the system and resulting in an increase in extraction yield until it became insignificant or drops thus made the power and temperature of the water bath are linked. The previous study had stated that the temperature of the solvent may rise much above its boiling point, resulting in improved extraction efficiency due to desorption of solutes from active sites in the matrix. In this case, the efficiency increases as the temperature rises until it reaches an ideal temperature, at which point it begins to decline as the temperature rises further. This is due to the fact that the ideal extraction temperature is strongly related to the stability and, as a result, yield of the target molecule.

However, high water bath power also can result in low extraction yield due to the destruction of thermally sensitive chemicals, it is important to control the power of the water bath to ensure the temperature is not damaging the extraction yield. This is because the rapid rupture of the cell wall occurs at a higher temperature when utilising more power thus contaminants can be leached out into the solvent with the desired solute (Veggi et al., 2012). Based on the study, the yield grew dramatically as the temperature increased from 50°C to 70°C, while yields increased slowly and even dropped at 70°C (Yan et al., 2010). As a result, it's critical to choose the extraction power carefully to reduce the time it takes to reach the desired temperature and avoid temperature which can damage the pectin yield during the extraction.

4.2 Textural properties of jelly from watermelon rind

Texture is the sensory measurement of the structure or known as an inner makeup of foods and substances, where the skin's *tactile sense* and the muscles' *sense of forces* are the two distinct pathways that texture can be "felt" through. The skin's tactile sense, which also called as somesthesis, perceives fat and moisture and geometrical particles as it moves across the surface of a food. The muscles' sense of forces, also called as kinesthesis, measures a food's mechanical properties and reactions to applied forces in chewing and manipulation. Basically, texture combines these physical measures of tactile and mechanical perceptions (Civille, 2011).

Commonly, food texture originates from its structure or microstructure including from the molecular level to the microstructure and macroscopic level. The sensation of food texture depends highly on how the structure deforms and breaks when handle. Any factor that influences the structural properties of the food such as ingredient interactions, processing conditions, storage and packaging will affect its texture. According to food texture sensation, it could be made through two very different physical principles including oral rheology and oral tribology. Rheology-originated such as firmness, springiness, cohesiveness is known as texture associated with bulk deformation whereas tribology-originated is a texture associated with relative surface movement such as smoothness and roughness. The other categorization of texture properties is those sensed through combined rheology and tribology mechanisms such as slipperiness and creaminess. Food texture was commonly accepted as a key quality factor and was recognised as an important research area of the food science and technology discipline (Cheng et al., 2008).

In this research, mechanical parameters including hardness, cohesiveness, springiness, chewiness and gumminess was measured. The mechanical instrument that was used for the measurement was CT3 Texture Analyzer. The probe that was used are TA11/100 Cylinder, 38.1 mm D, 35 mm L. The watermelon rind jelly samples that used during this analysis were produced by 10 g, 20 g and 30 g of watermelon rind powder.

Table 4.1 Hardness of watermelon rind jellies

Sample	**Hardness**
Commercial jelly	269.00±6.24[c]
Jelly[1] (1.30% pectin)	28.83±4.37[a]
Jelly[2] (1.60% pectin)	168.25±2.50[b]
Jelly[3] (3.05% pectin)	210.17±43.00[b]
Correlation coefficient (R^2) with WRP content	0.9133

Commercial fruit pectin jelly was included for comparisons. J^1, jelly was made with 10 g WRP, J^2, jelly was made with 20 g WRP, J^3,jelly was made with 30 g WRP.

[*a-b]All values represented as mean±SD (*n*=3), Different letters in same row indicates significant differences at $p \leq 0.05$

Table 4.1 shows the hardness parameter of watermelon rind jellies enriched with 10 g, 20 g and 30 g of WRP which produced different amount of pectin content to produce the jellies. Overall, the hardness of commercial watermelon jelly had the highest value 269.00±6.24 N and the hardness of the watermelon rind jellies had increased as the amount of WRP and pectin content was increased. Based on the result in Table 4.1, 10 g of WRP content was used to produce the jelly containing 1.30% pectin, which was the lowest pectin content produced by watermelon rind in this analysis thus producing the lowest hardness of watermelon rind jelly (28.83±4.37) N. The WRP amount of 20 g was used to produce the jelly containing 1.60% of pectin, thus producing the watermelon rind jelly with the hardness value of (168.25±2.50) N whereas 30 g of WRP containing 3.05% pectin produced watermelon rind jelly with the hardness value of (210.17±43.00) N. The results obtained for the hardness of both 20 g and 30 g (Figure 4.1) watermelon rind jellies showed no significant differences between the samples, which $p \geq 0.05$. However, 30 g of WRP content contained high pectin content (3.05%) and further increased the hardness (210.17±43.00) N between watermelon rind jellies. In this situation, the hardness of the watermelon rind jelly produced from 10 g of WRP content showed significantly different ($p \leq 0.05$) from the commercial jelly. The result of hardness of watermelon rind jellies were illustrated in the bar graph in Figure 4.1.

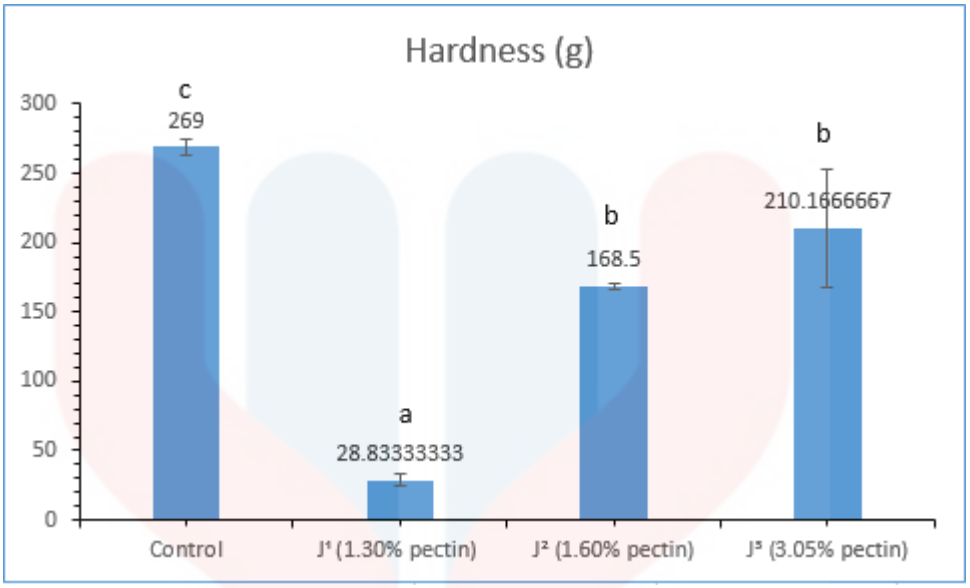


Figure 4.1 Hardness of Commercial jelly, J^1Jelly (10 g of WRP), J^2Jelly (20 g of WRP), J^3Jelly (30g of WRP)

High content of watermelon rind powder (WRP) brings more pectin level which support gelification of watermelon rind jellies. Pectin is a gelling ingredient that causes gels to develop during the production of jellies in the presence of sucrose. In this analysis, correlation of WRP content with hardness of watermelon rind jellies was strong ($r \in 0.9$). However, raising the concentration of pectin supposedly increases the amount of active polymer chains in the gel network, making the structural network inside the gel tougher (Basu, 2010). Moreover, sugar and pectin content within WRP probably influenced the texture properties, particularly, the hardness of the final product. In this case, the hydrogen bond between polyhydric sucrose and water molecules left over from pectin's strong gel network is destabilised by high sugar concentration (Basu, 2013). The decrease in hardness can be attributed to the weakening of pectin gel and the release of a considerable amount of water into the jam, which softens and lowers its hardness

(Nourmohammadi et al., 2021). Commercial jelly had the highest hardness value among all the samples because the food producer commonly had added the commercial pectin into their jelly product. The concentration of high- ester pectin will increase the final gel strength of the system due to the increase in the number of junction zones thus produce a harder jelly. In general, the results showed that adding pectin increased the hardness of the jellies, whereas high sucrose concentrations decreased the hardness of the jellies. For comparison, there was no significant difference ($p \geq 0.05$) between commercial jelly and 30 g of WRP indicated a formulation of using 30 g of WRP can be used to be commercially comparable to commercial jelly.

Table 4.2 shows the cohesiveness values of commercial jelly and watermelon rind jellies that were produced from 10 g, 20 g and 30 g of WRP which contained different amounts of pectin. According to Raquel et al., (2020), the forces inside the meal that keep the mass together and prevent it from dissolving are referred to as cohesiveness.

Table 4.2 Cohesiveness of watermelon rind jellies

Sample	**Cohesiveness**
Commercial jelly	0.85±0.083[a]
Jelly[1] (1.30% pectin)	1.84±0.17[a]
Jelly[2] (1.60% pectin)	1.25±0.12[a]
Jelly[3] (3.05% pectin)	0.85±0.19[a]
Correlation coefficient (R^2) with WRP content	0.0005

Commercial fruit pectin jelly was included for comparisons. J^1, jelly was made with 10 g WRP, J^2, jelly was made with 20 g WRP, J^3,jelly was made with 30 g WRP.

[*a-b]All values represented as mean±SD (*n*=3), Different letters in same row indicates significant differences at p≤0.05

Figure 4.2 showed that cohesiveness relatively high for Jelly 1 (1.84±0.17) followed by Jelly 2 (1.25±0.12) and jelly 3 that has been produced from 30 g of WRP and contain 3.05% of pectin had lowest in cohesiveness value (0.85±0.19) among the samples of watermelon rind jellies. In this study, all the samples showed no significant difference (p≥0.05).

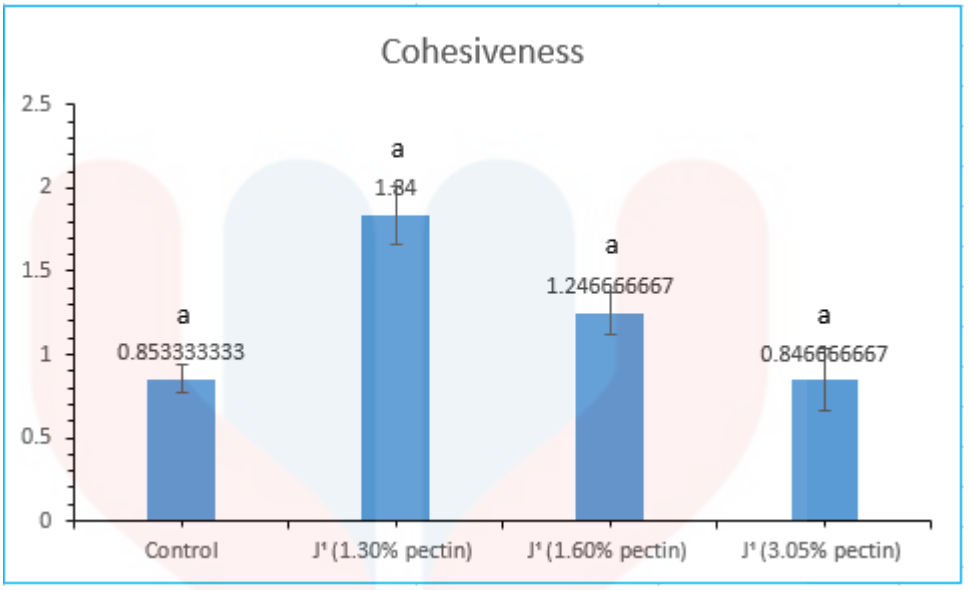


Figure 4.2 Cohesiveness of Commercial jelly, J^1Jelly (10 g of WRP), J^2Jelly (20 g of WRP), J^3Jelly (30g of WRP)

According to (Raquel et al., 2020), the following limits were considered as correlation interpretation such as, if r = 0 there is no correlation, if r ∈ [0.0, 0.2] the correlation is very weak, if r ∈ [0.2, 0.4] the correlation is weak, if r ∈ [0.4, 0.6] the correlation is moderate, if r ∈ [0.6, 0.8] the correlation is strong, if r ∈ [0.8, 1.0] the correlation is very strong and in the case of r = 1 the correlation is perfect.

The result obtained in this analysis showed that the cohesiveness of the jellies had decreased as the pectin content had increased thus making watermelon rind jellies had a very weak correlation (r ∈ 0.0) between WRP content with the cohesiveness. The cohesiveness of jelly has reduced as pectin concentrations has increased and that means when the pectin concentration has increased, the jellies texture became brittle (Nourmohammadi et al., 2021). When a strong gel is subjected to too much elastic stress, the permanent and temporary bonds are irrevocably broken, and the gel is broken, resulting in poor adhesiveness. The samples with weaker gel structures, on the other hand,

were more cohesive. The weak gel structure is primarily made up of transitory bonds that can be partially repaired after the applied tension is removed, resulting in high cohesiveness (Nourmohammadi et al., 202

Table 4.3 Springiness of watermelon rind jellies

Sample	Springiness (cm)
Commercial jelly	1.89±0.015[b]
Jelly[1] (1.30% pectin)	0.18±0.021[a]
Jelly[2] (1.60% pectin)	0.33±0.095[a]
Jelly[3] (3.05% pectin)	0.76±0.56[a]
Correlation coefficient (R^2) with WRP content	0.51

Commercial fruit pectin jelly was included for comparisons. J[1], jelly was made with 10 g WRP, J[2], jelly was made with 20 g WRP, J[3], jelly was made with 30 g WRP

[*a-b]All values are mean±SD (*n*=3), Different letters in same row indicates significant differences at $p \leq 0.05$

Table 4.3 showed the springiness (cm) values for commercial jelly and watermelon rind jellies that has been produced from 10 g, 20 g and 30 g of WRP content which contain different amount of pectin content. According to Cruz et al. (2015), the ability to recover shape after compression is represented by springiness, which is the rate at which the product returns to its original state when the force has been withdrawn. Overall, the springiness of control watermelon rind jelly had the highest value (1.89±0.015) cm and the springiness of the watermelon rind jellies had increased as the amount of WRP ad pectin content was increased. Based on the result in Table 4.3, 10 g of WRP content that

was used to produce the jelly contain 3.05% pectin, which was the lowest pectin content produced by watermelon rind in this analysis thus produced the lowest springiness of watermelon rind jelly (0.18±0.021) cm. The WRP amount of 20 g that was used in producing the jelly in this analysis contain 1.60% of pectin and produced the watermelon rind jelly with the springiness value of 0.33±0.095cm. However, 30 g of WRP content contain high pectin content (3.05%) and had increased the springiness (0.76±0.56) cm of watermelon rind jelly. In this situation, the springiness of the watermelon rind jelly produced from 10 g, 20 g and 30 g of WRP content show no significant different $p \geq 0.05$ compared to commercial jelly.

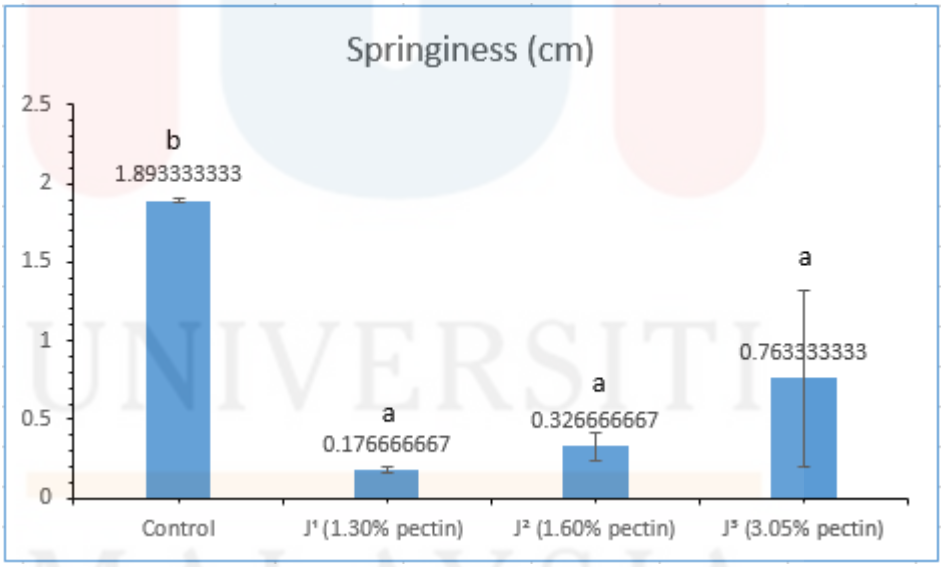


Figure 4.3 Springiness of Commercial jelly, J^1Jelly (10 g of WRP), J^2Jelly (20 g of WRP), J^3Jelly (30g of WRP)

In this analysis, it showed that there was a weak correlation ($r \in 0.5$) between WRP content with the springiness of watermelon rind jellies. Increased WRP level resulted in increased pectin content, which improved the structural integrity of watermelon rind jellies. This could explain why watermelon rind jellies with the increases of WRP concentration had high springiness values among the samples (Mojtaba et al., 2016). The high value of springiness in this situation necessitates more mastication energy in the mouth (Chandra et al., 2015).

Table 4.4 Chewiness of watermelon rind jellies

Sample	**Chewiness (mJ)**
Commercial jelly	18.83 ± 1.29^{b}
Jelly[1] (1.30% pectin)	3.6 ± 3.87^{a}
Jelly[2] (1.60% pectin)	3.83 ± 1.72^{a}
Jelly[3] (3.05% pectin)	6.17 ± 2.06^{a}
Correlation coefficient (R^2) with WRP content	0.8165

Commercial fruit pectin jelly was included for comparisons. J[1], jelly was made with 10 g WRP, J[2], jelly was made with 20 g WRP, J[3], jelly was made with 30 g WRP

*a-bAll values are mean±SD (*n*=3), Different letters in same row indicates significant differences at $p \leq 0.05$

Table 4.4 showed the chewiness (mJ) values for commercial jelly and watermelon rind jellies that has been produced from 10 g, 20 g and 30 g of WRP content which contain different amount of pectin content. According to Guiné, R., Correia, P. et al., (2020), chewiness is defined as the amount of energy required to dissolve a food into a state that allows it to be swallowed and because this textural property is so closely linked to hardness, it's likely that the observed trend will be comparable. Based on the result in Table 4.6, the chewiness of control watermelon rind jelly had the highest value (18.83±1.29) mJ and the chewiness of the watermelon rind jellies had increased along with the amount of WRP content as presented in Figure 4.4. Watermelon rind jelly from 10 g of WRP content which contain 1.30% pectin showed the lowest in chewiness characteristic (3.6±3.87) mJ among the sample of watermelon rind jellies. Jelly 2 from 20 g of WRP content had chewiness value of (3.83±1.72) mJ, much higher than Jelly 1 due to high pectin level within the WRP content (1.60%). However, watermelon rind jelly from 30 g of WRP content with 3.05% pectin produced the highest chewiness value (6.17±2.06) mJ among the three samples of watermelon rind jellies. All the watermelon rind jellies were not significantly difference ($p \geq 0.05$) with commercial jelly.

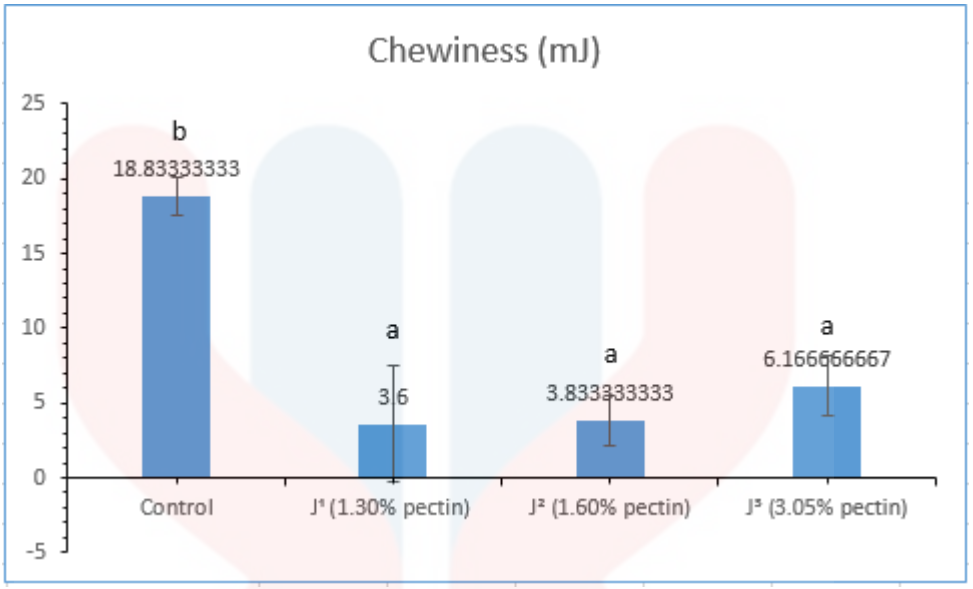


Figure 4.4 Chewiness of Commercial jelly, J^1Jelly (10 g of WRP), J^2Jelly (20 g of WRP), J^3Jelly (30g of WRP)

Based on the result, the correlation WRP content with the chewiness of watermelon rind jellies was strong, ($r \in 0.8$). In this analysis, it can be said that the chewiness of watermelon rind jellies had increased as the WRP content and pectin content had increased. In general, the progressive increase in sugar concentration appears to lower the amount of water in the pectin–sugar–acid mixture to some extent, reducing the chance of hydrogen bonding and other potential causes, reducing the softness of the jellies texture and increasing the chewiness rate (Nourmohammadi et al., 2021). Sugars diminish water activity, causing pectin interactions rather than pectin–water interactions, indicating that sucrose is the primary source of enhanced chewiness and improves sample texture quality. (Nourmohammadi et al., 2021)

Table 4.5 Gumminess of watermelon rind jellies

Sample	Gumminess (g)
Commercial jelly	280.00±39.74[c]
Jelly[1] (1.30% pectin)	39.67±18.50[a]
Jelly[2] (1.60% pectin)	133.00±10.82[b]
Jelly[3] (3.05% pectin)	195.33±41.62[b]
Correlation coefficient (R^2) with WRP content	0.987

Commercial fruit pectin jelly was included for comparisons. J^1, jelly was made with 10 g WRP, J^2, jelly was made with 20 g WRP, J^3, jelly was made with 30 g WRP

*a-cAll values are mean±SD (*n*=3), Different letters in same row indicates significant differences at $p \leq 0.05$

Table 4.5 showed the gumminess (g) values for commercial jelly and watermelon rind jellies that has been produced from 10 g, 20 g and 30 g of WRP content which contain different amount of pectin content. According to Delgado & Banon (2018), gumminess is known as the energy required to break down a semi-solid food ready for swallowing, the values being the result of multiplying hardness × cohesiveness. Based on the result in Table 4.8, the gumminess of control watermelon rind jelly had the highest value of (280.00±39.74) g and the gumminess of the watermelon rind jellies had increased along with the amount of WRP content as presented in Figure 4.5. Watermelon rind jelly from 10 g of WRP content which contain 1.30% pectin showed the lowest in gumminess characteristic (39.67±18.50) g among the sample of watermelon rind jellies. Jelly 2 from 20 g of WRP content had gumminess value of (133.00±10.82) g, much higher than Jelly 1 due to high pectin level within the WRP content (1.60%). However, watermelon rind

jelly from 30 g of WRP content with 3.05% pectin produced the highest gumminess value (195.33±41.62) g among the three samples of watermelon rind jellies. Jelly2 and jelly3 were both not significantly difference ($p \geq 0.05$) but Jelly 1 was significantly difference ($p \leq 0.05$).

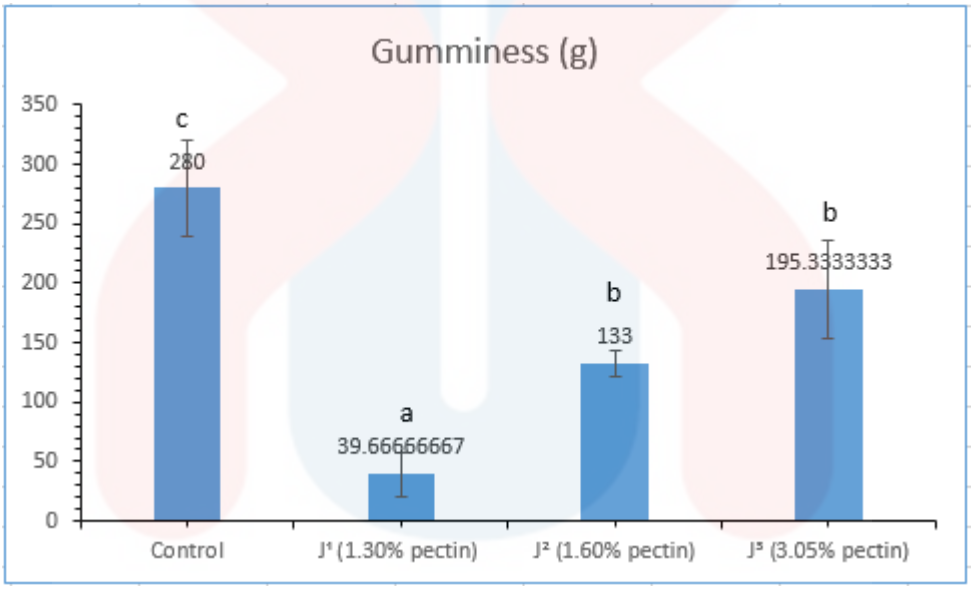
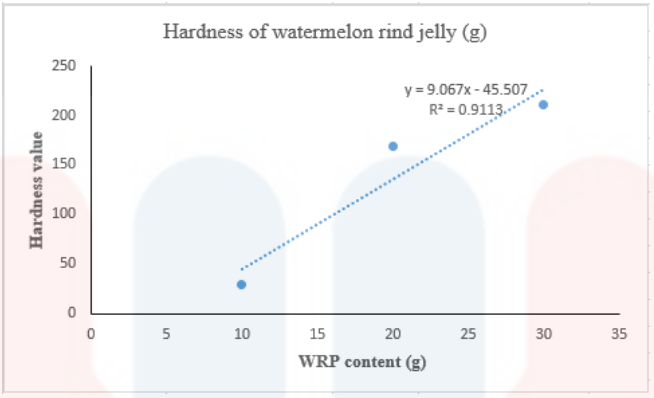
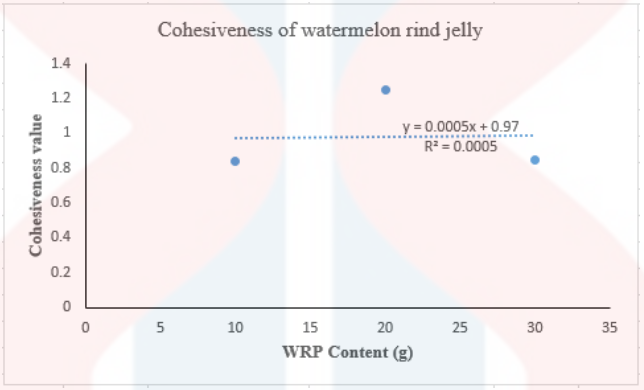


Figure 4.5 Gumminess of Commercial jelly, J^1Jelly (10 g of WRP), J^2Jelly (20 g of WRP), J^3Jelly (30g of WRP)

The correlation WRP content with the gumminess of watermelon rind jellies was strong ($r \in 1.0$). In this analysis, it can be said that the gumminess of watermelon rind jellies had increased as the WRP content and pectin content had increased. Based on the study, the gumminess of jelly has found increased as the value of hardness has increased. Gumminess is a property of semisolid foods that have a low degree of hardness but a high level of cohesion. Semisolids like gelatin have a more important textural parameter than solids like gumminess. The gelatin was visco-elastic and gumminess behaviour was seen at this concentration. Gelatin derived from grouper skin and commercial gelatin gel produced similar results (Chandra & Shamasundar, 2015).



(a)



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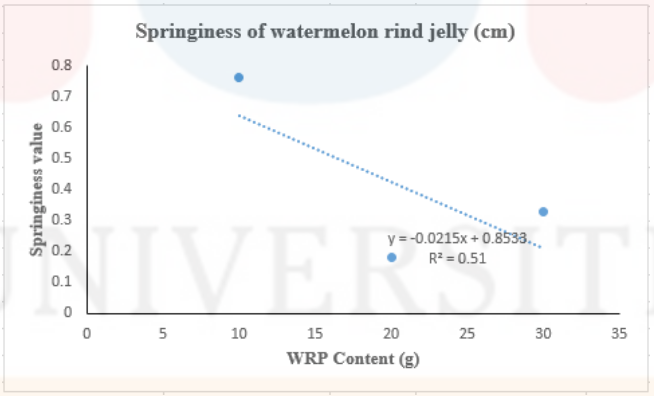
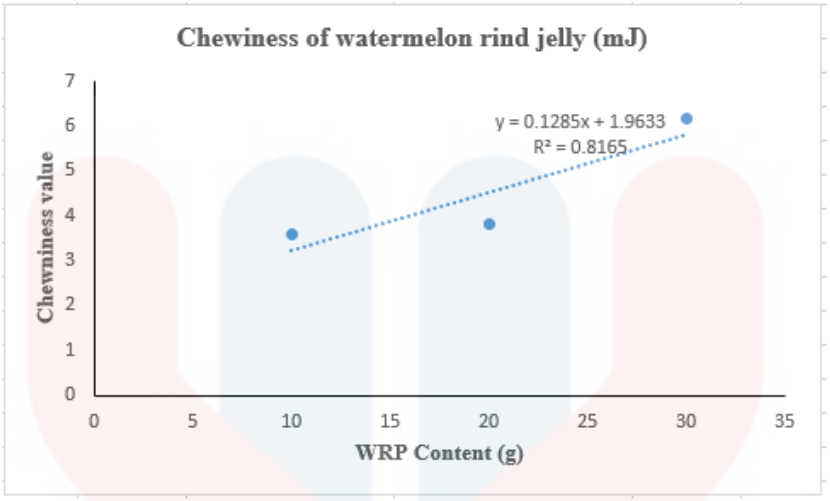
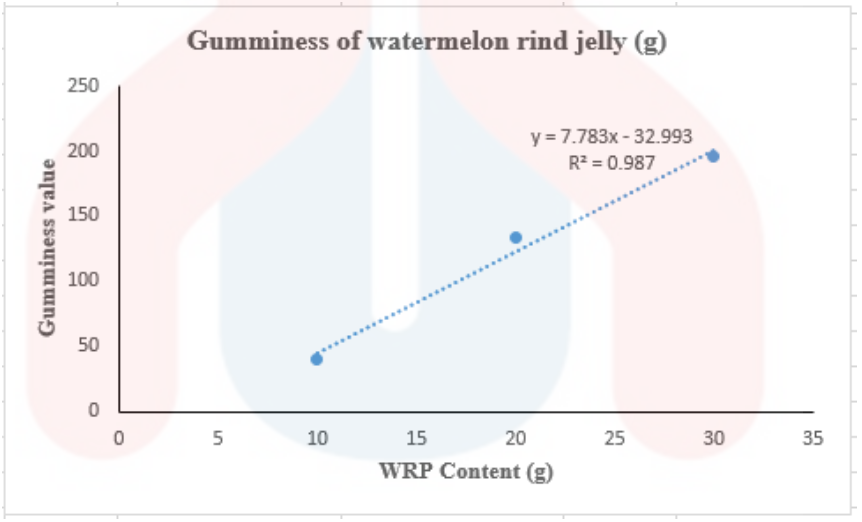


(c)



(d)



(e)

Figure 4.6. The correlation with WRP content. (a) Hardness, (b) Cohesiveness, (c) Springiness, (d) Chewiness, (e) Gumminess

CHAPTER 5

5.1 CONCLUSION

As a conclusion, watermelon rind is the watermelon by-product or waste that has good advantage which can be transformed into valuable product such as jelly. This measure will not only reduce the problem of fruit waste and disposal, but it also helps to increase the market of watermelon. Moreover, watermelon rind contains pectin which is able to act as a thickening agent and influence the development of jelly. The development of watermelon rind jelly involves a freeze-drying process as an initial phase to ensure the preservation of watermelon rind nutrient and was followed by enzymatic extraction process involving the use of citric acid to extract pectin. In this study, textural properties analysis (TPA) was performed on watermelon rind jelly and watermelon rind jelly produced in this study exhibited values of hardness (N), cohesiveness, springiness (cm), chewiness (mJ) and gumminess (g) lower than that of commercial jelly. This situation occurs probably due to the pectin content in the watermelon rind jelly and commercial jelly, for which the development of commercial jelly usually adds more commercial pectin to obtain the required jelly consistency. Overall, watermelon rind can be used in producing good jelly but the textures of watermelon rind jelly can also be modified with additives for commercial production if necessary.

5.2 RECOMMENDATION

There are a few recommendations that should be considered for future study. Firstly, add additives during the production of watermelon rind jelly in order to enhance the texture of the jelly. In this situation, jelly without additives and jelly with additives can be compared to see the differences of their texture. Moreover, the production of the watermelon rind jelly also is recommend to use different temperature during pectin extraction to determine the best pectin yield that can be produced. This condition can helps to determine what temperature is the best to extract pectin from watermelon rind in order to produce the jelly. However, to extract pectin from watermelon rind by using various temperatures will definitely take a long time because water bath provided is not much and must take turns with other students to use it.

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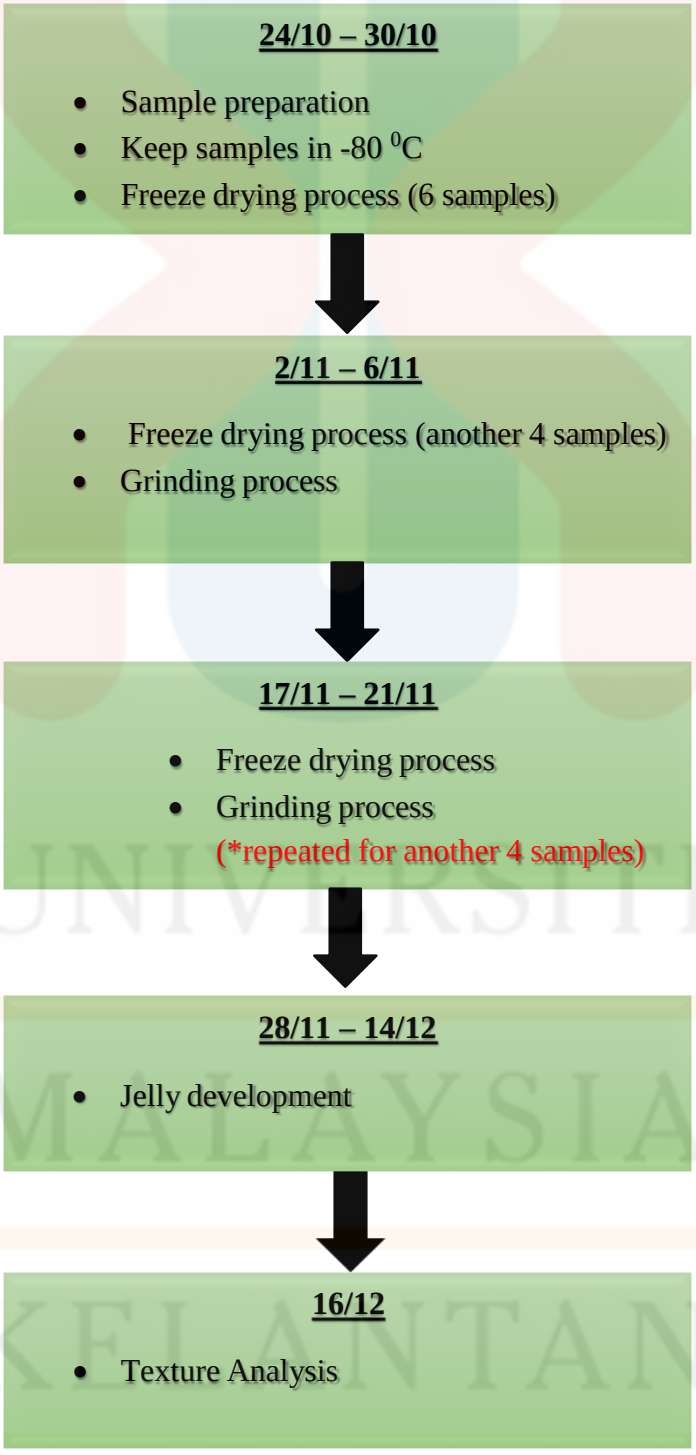
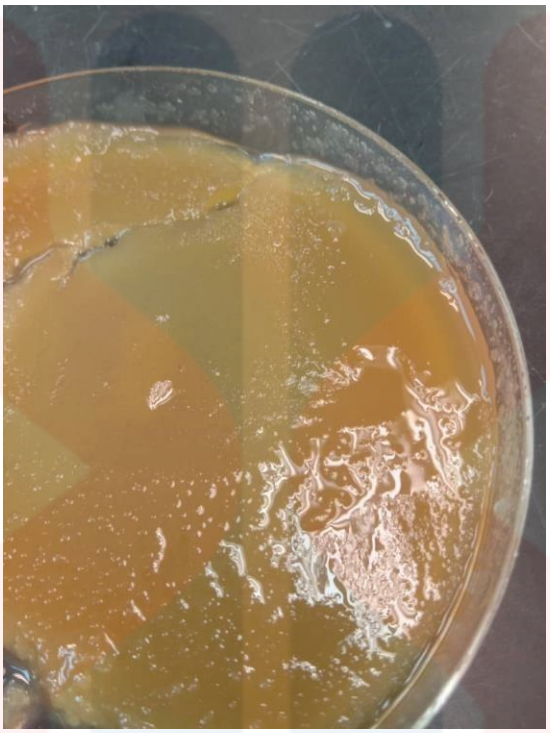
APPENDICES

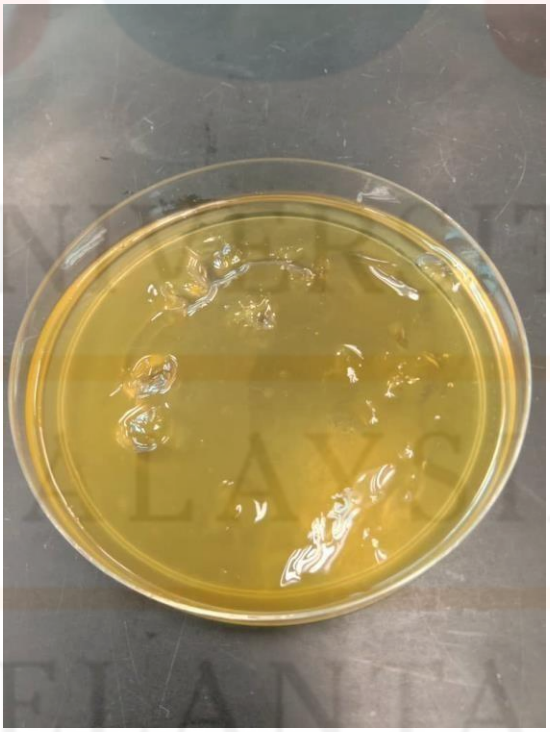
Flowchart of project



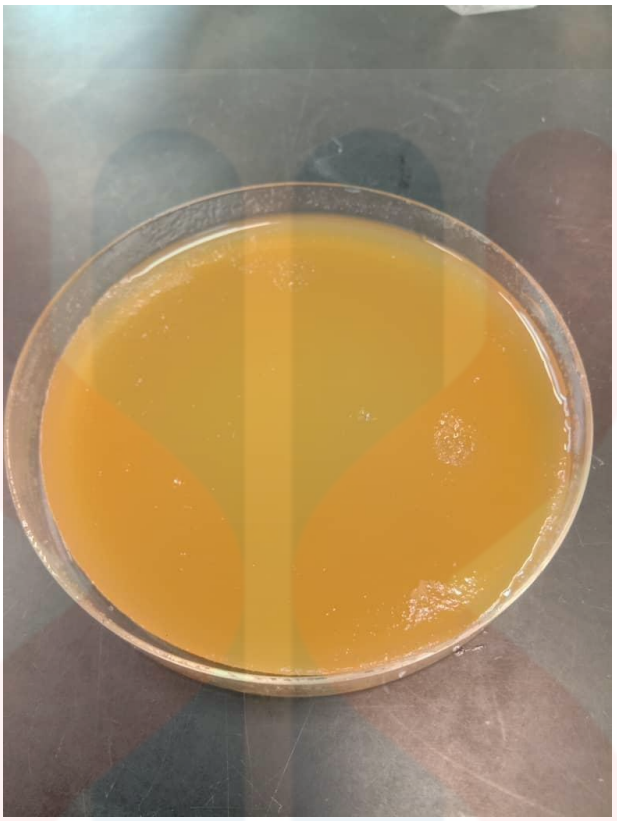
Watermelon rind jellies



Jelly 1



Jelly 2



Jelly 3

Oneway

Descriptives

Hardness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
control	3	269.0000	6.24500	3.60555	253.4866	284.5134	262.00	274.00
J1	3	28.8333	4.36845	2.52212	17.9815	39.6852	24.00	32.50
J2	3	168.5000	2.50000	1.44338	162.2897	174.7103	166.00	171.00
J3	3	210.1667	43.00097	24.82662	103.3463	316.9870	167.00	253.00
Total	12	169.1250	94.31647	27.22682	109.1992	229.0508	24.00	274.00

ANOVA

Hardness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	94024.729	3	31341.576	65.520	.000
Within Groups	3826.833	8	478.354		
Total	97851.562	11			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Hardness

Tukey HSD

(I) Formula	(J) Formula	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	J1	240.16667*	17.85785	.000	182.9795	297.3538
	J2	100.50000*	17.85785	.002	43.3129	157.6871
	J3	58.83333*	17.85785	.044	1.6462	116.0205
J1	control	-240.16667*	17.85785	.000	-297.3538	-182.9795
	J2	-139.66667*	17.85785	.000	-196.8538	-82.4795
	J3	-181.33333*	17.85785	.000	-238.5205	-124.1462
J2	control	-100.50000*	17.85785	.002	-157.6871	-43.3129
	J1	139.66667*	17.85785	.000	82.4795	196.8538
	J3	-41.66667	17.85785	.169	-98.8538	15.5205
J3	control	-58.83333*	17.85785	.044	-116.0205	-1.6462
	J1	181.33333*	17.85785	.000	124.1462	238.5205
	J2	41.66667	17.85785	.169	-15.5205	98.8538

***. The mean difference is significant at the 0.05 level.**

Homogeneous Subsets

Hardness

Tukey HSD[a]

Formula	N	Subset for alpha = 0.05		
		1[a]	2[b]	3[c]
J1	3	28.8333		
J2	3		168.5000	
J3	3		210.1667	
control	3			269.0000
Sig.		1.000	.169	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Oneway

Descriptives

Cohesiveness

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	Between-Component Variance
						Lower Bound	Upper Bound			
control		3	.8533	.08327	.04807	.6465	1.0602	.76	.92	
J1		3	1.5067	.56871	.32835	.0939	2.9194	.88	1.99	
J2		3	1.2467	.12423	.07172	.9381	1.5553	1.17	1.39	
J3		3	.8467	.18771	.10837	.3804	1.3130	.63	.96	
Total		12	1.1133	.39262	.11334	.8639	1.3628	.63	1.99	
Model	Fixed Effects			.30864	.08910	.9079	1.3188			
	Random Effects				.16104	.6008	1.6258			.07198

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Cohesiveness	Based on Mean	4.607	3	8	.037
	Based on Median	1.306	3	8	.338
	Based on Median and with adjusted df	1.306	3	3.400	.403
	Based on trimmed mean	4.264	3	8	.045

ANOVA

Cohesiveness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	**.934**	**3**	**.311**	**3.267**	**.080**
Within Groups	**.762**	**8**	**.095**		
Total	**1.696**	**11**			

Robust Tests of Equality of Means

Cohesiveness

	Statistic[a]	df1	df2	Sig.
Welch	**6.215**	**3**	**4.088**	**.053**
Brown-Forsythe	**3.267**	**3**	**2.736**	**.192**

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Cohesiveness

Tukey HSD

(I) Formula	(J) Formula	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	J1	-.65333	.25200	.118	-1.4603	.1537
	J2	-.39333	.25200	.449	-1.2003	.4137
	J3	.00667	.25200	1.000	-.8003	.8137
J1	control	.65333	.25200	.118	-.1537	1.4603
	J2	.26000	.25200	.737	-.5470	1.0670
	J3	.66000	.25200	.114	-.1470	1.4670
J2	control	.39333	.25200	.449	-.4137	1.2003
	J1	-.26000	.25200	.737	-1.0670	.5470
	J3	.40000	.25200	.436	-.4070	1.2070
J3	control	-.00667	.25200	1.000	-.8137	.8003
	J1	-.66000	.25200	.114	-1.4670	.1470
	J2	-.40000	.25200	.436	-1.2070	.4070

Homogeneous Subsets

Cohesiveness

Tukey HSD[a]

Formula	N	Subset for alpha = 0.05 1
J3	3	.8467
control	3	.8533
J2	3	1.2467
J1	3	1.5067
Sig.		.114

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Oneway

Descriptives

Springiness

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	Between-Component Variance
						Lower Bound	Upper Bound			
control		3	1.8933	.01528	.00882	1.8554	1.9313	1.88	1.91	
J1		3	.7633	.56128	.32405	-.6310	2.1576	.34	1.40	
J2		3	.1767	.02082	.01202	.1250	.2284	.16	.20	
J3		3	.3267	.09452	.05457	.0919	.5615	.22	.40	
Total		12	.7900	.74321	.21455	.3178	1.2622	.16	1.91	
Model	Fixed Effects			.28488	.08224	.6004	.9796			
	Random Effects				.38826	-.4456	2.0256			.57592

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Springiness	Based on Mean	10.149	3	8	.004
	Based on Median	1.608	3	8	.262
	Based on Median and with adjusted df	1.608	3	2.113	.398
	Based on trimmed mean	8.925	3	8	.006

ANOVA

Springiness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	**5.427**	**3**	**1.809**	**22.289**	**.000**
Within Groups	**.649**	**8**	**.081**		
Total	**6.076**	**11**			

Robust Tests of Equality of Means

Springiness

	Statistic[a]	df1	df2	Sig.
Welch	**3383.901**	**3**	**3.958**	**.000**
Brown-Forsythe	**22.289**	**3**	**2.122**	**.038**

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Springiness

Tukey HSD

(I) Formula	(J) Formula	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	J1	1.13000*	.23261	.006	.3851	1.8749
	J2	1.71667*	.23261	.000	.9718	2.4616
	J3	1.56667*	.23261	.001	.8218	2.3116
J1	control	-1.13000*	.23261	.006	-1.8749	-.3851
	J2	.58667	.23261	.130	-.1582	1.3316
	J3	.43667	.23261	.309	-.3082	1.1816
J2	control	-1.71667*	.23261	.000	-2.4616	-.9718
	J1	-.58667	.23261	.130	-1.3316	.1582
	J3	-.15000	.23261	.914	-.8949	.5949
J3	control	-1.56667*	.23261	.001	-2.3116	-.8218
	J1	-.43667	.23261	.309	-1.1816	.3082
	J2	.15000	.23261	.914	-.5949	.8949

***. The mean difference is significant at the 0.05 level.**

Homogeneous Subsets

Springiness

Tukey HSD[a]

Formula	N	Subset for alpha = 0.05	
		1	2
J2	3	.1767	
J3	3	.3267	
J1	3	.7633	
control	3		1.8933
Sig.		.130	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Oneway

Descriptives

Chewiness

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	Between-Component Variance
						Lower Bound	Upper Bound			
control		3	18.8333	1.28970	.74461	15.6295	22.0371	17.40	19.90	
J1		3	3.6000	3.87427	2.23681	-6.0242	13.2242	.70	8.00	
J2		3	3.8333	1.72434	.99555	-.4502	8.1168	2.30	5.70	
J3		3	6.1667	2.05508	1.18650	1.0616	11.2718	4.20	8.30	
Total		12	8.1083	6.87505	1.98466	3.7401	12.4765	.70	19.90	
Model	Fixed Effects			2.44285	.70519	6.4822	9.7345			
	Random Effects				3.62165	-3.4174	19.6340			50.47630

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Chewiness	Based on Mean	2.214	3	8	.164
	Based on Median	.447	3	8	.726
	Based on Median and with adjusted df	.447	3	3.575	.734
	Based on trimmed mean	2.014	3	8	.191

ANOVA

Chewiness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	472.189	3	157.396	26.376	.000
Within Groups	47.740	8	5.968		
Total	519.929	11			

Robust Tests of Equality of Means

Chewiness

	Statistic[a]	df1	df2	Sig.
Welch	47.975	3	4.260	.001
Brown-Forsythe	26.376	3	4.473	.003

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Chewiness

Tukey HSD

(I) Formula	(J) Formula	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	J1	15.23333*	1.99458	.000	8.8460	21.6207
	J2	15.00000*	1.99458	.000	8.6127	21.3873
	J3	12.66667*	1.99458	.001	6.2793	19.0540

J1	**control**	**-15.23333***	**1.99458**	**.000**	**-21.6207**	**-8.8460**
	J2	**-.23333**	**1.99458**	**.999**	**-6.6207**	**6.1540**
	J3	**-2.56667**	**1.99458**	**.595**	**-8.9540**	**3.8207**
J2	**control**	**-15.00000***	**1.99458**	**.000**	**-21.3873**	**-8.6127**
	J1	**.23333**	**1.99458**	**.999**	**-6.1540**	**6.6207**
	J3	**-2.33333**	**1.99458**	**.661**	**-8.7207**	**4.0540**
J3	**control**	**-12.66667***	**1.99458**	**.001**	**-19.0540**	**-6.2793**
	J1	**2.56667**	**1.99458**	**.595**	**-3.8207**	**8.9540**
	J2	**2.33333**	**1.99458**	**.661**	**-4.0540**	**8.7207**

***. The mean difference is significant at the 0.05 level.**

Homogeneous Subsets

Chewiness

Tukey HSD[a]

		Subset for alpha = 0.05	
Formula	**N**	**1**	**2**
J1	**3**	**3.6000**	
J2	**3**	**3.8333**	
J3	**3**	**6.1667**	
control	**3**		**18.8333**
Sig.		**.595**	**1.000**

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Oneway

Descriptives

Gumminess

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	Between-Component Variance
						Lower Bound	Upper Bound			
control		3	280.0000	39.73663	22.94196	181.2887	378.7113	243.00	322.00	
J1		3	39.6667	18.50225	10.68228	-6.2955	85.6288	21.00	58.00	
J2		3	133.0000	10.81665	6.24500	106.1299	159.8701	121.00	142.00	
J3		3	195.3333	41.62131	24.03007	91.9403	298.7264	152.00	235.00	
Total		12	162.0000	95.37772	27.53318	101.3999	222.6001	21.00	322.00	
Model	Fixed Effects			30.70288	8.86316	141.5615	182.4385			
	Random Effects				50.69645	.6613	323.3387			9966.29630

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Gumminess	Based on Mean	1.350	3	8	.325
	Based on Median	.934	3	8	.468
	Based on Median and with adjusted df	.934	3	5.122	.488
	Based on trimmed mean	1.323	3	8	.333

ANOVA

Gumminess

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	92524.667	3	30841.556	32.717	.000
Within Groups	7541.333	8	942.667		
Total	100066.000	11			

Robust Tests of Equality of Means

Gumminess

	Statistic[a]	df1	df2	Sig.
Welch	29.776	3	3.981	.003
Brown-Forsythe	32.717	3	5.055	.001

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Gumminess

Tukey HSD

(I) Formula	(J) Formula	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	J1	240.33333*	25.06879	.000	160.0542	320.6124
	J2	147.00000*	25.06879	.002	66.7209	227.2791
	J3	84.66667*	25.06879	.039	4.3876	164.9458
J1	control	-240.33333*	25.06879	.000	-320.6124	-160.0542
	J2	-93.33333*	25.06879	.024	-173.6124	-13.0542
	J3	-155.66667*	25.06879	.001	-235.9458	-75.3876
J2	control	-147.00000*	25.06879	.002	-227.2791	-66.7209
	J1	93.33333*	25.06879	.024	13.0542	173.6124
	J3	-62.33333	25.06879	.137	-142.6124	17.9458
J3	control	-84.66667*	25.06879	.039	-164.9458	-4.3876
	J1	155.66667*	25.06879	.001	75.3876	235.9458
	J2	62.33333	25.06879	.137	-17.9458	142.6124

***. The mean difference is significant at the 0.05 level.**

Homogeneous Subsets

Gumminess

Tukey HSD[a]

Formula	N	Subset for alpha = 0.05		
		1	2	3
J1	3	39.6667		
J2	3		133.0000	
J3	3		195.3333	
control	3			280.0000
Sig.		1.000	.137	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.