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PRODUCTION AND OPTIMIZATION OF CHEWY MULTIVITAMIN FROM FISH GELATIN

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ABSTRACT

Multivitamin gummy confectionery is a chewable-based gelatin that provides a nutritional value to consumer to promote good health and well-being without compromising taste, texture or convenience since, the texture and mouth-feel of gelatin-based candy is already familiar among the consumers. However, in the available pharmaceutical industry, multivitamin gummy candies are produced from gelatin sources derived from the skin and bones of pigs and cows that are not acceptable to the Halal and Kosher food markets. In addition, the incidence of bovine spongiform encephalopathy (BSE) caused anxiety to bovine gelatin. As a result, fish products have become a new source of gelatin for the production of multivitamin gummy candy to overcome safety concerns and religious reasons. The main objective of this study to formulate and characterize the properties of multivitamin gummy candies prepared by fish and bovine gelatin with different concentrations of gelatin (9, 12, 15%) at different hydrating temperature (70, 80, 90°C). The effect on their physico-chemical, rheological and textural properties with different concentration of gelatin at different hydrating temperature also been studied. The result indicated the properties of multivitamin gummy candy of bovine gelatin were significantly greater even though their moisture content was 20% lower than with fish gelatin. They also had higher hardness (4656.76g±386.52) and gumminess (2375.16±267.88) compared to hardness (4095.14g±315.58) and gumminess (2287.54±271.26) with fish gelatin while other properties, such as springiness (0.854±0.05; 0.807±0.03) and chewiness (1875.68±289.01; 1889.0±50.66) for each gummy candies were close to each other. As the concentration of gelatin increased, there is no significant different in °Brix as while the moisture content would decreased from 25.34 to 23.97%. The pH increased ranging of 3.93 to 4.47 so the viscosity in solutions also increased around 0.34 to 0.99 Pa.s due

to the higher cross-linked between protein molecules and hydrogen bonds. The melting (38°C to 40.67°C) and gelling (30.67°C to 37.33°C) temperature increased when the concentration of gelatin increased from 9% to 12% (w/v). However, further increased of gelatin concentration would decreased the melting (40.67°C to 39.33°C) and gelling (37.33°C to 35.33°C). The increased concentration of gelatin also increased hardness and gumminess parameter but decreased in springiness (0.89±0.03 to 0.81±0.03) and cohesiveness (0.67±0.07 to 0.46±0.03). In addition, there is no major difference in °Brix, pH and moisture content at different hydration temperatures. The studies discovered the melting (38°C to 41.5°C) and gelling (30.67°C to 32.67°C) temperature, viscosity (0.25±0.05 to 0.34±0.19Pa.s) and hardness (2723.38g±296.24 to 2925.18g±204.32) parameter increased when hydration temperature increased from 70°C to 80°C. However, at 90°C, these properties was consistently reduced. Other textural parameter such springiness (0.90±0.03 to 0.89±0.02), cohesiveness (0.67±0.07 to 0.41±0.03), gumminess (1828.16±129.69 to 1143.73±60.89) and chewiness (1319.54±256.69 to 1025.57±73.25) also consistently decreased when hydration temperature increased from 70°C to 90°C. Based on the optimization of the production process of multivitamin gummy candies, the ratio of gelatin concentration(%) and hydrating temperature(°C) were 9:79.9 and 9:72.5 respectively for each production of multivitamin gummy candies by fish and bovine gelatin to obtain the final product with desired textural properties. Since the present of multivitamin in formulation increased the value of candies, sensory analysis was conducted. Based on the sensory analyses conducted, it showed that commercial multivitamin gummy candies is preferable choice. However, both bovine and fish gelatin were also ideal choice for use in confectionery products because it has similar textural properties to commercial multivitamin gummy candies.

ABSTRAK

Multivitamin gummy confectionery adalah gula-gula kunyah berasaskan gelatin yang memberikan nilai pemakanan kepada pengguna untuk meningkatkan tahap kesihatan dan kesejahteraan tanpa menjejaskan rasa, tekstur atau kemudahan kerana tekstur dan rasa gula-gula berasaskan gelatin sudah biasa di kalangan pengguna. Walau bagaimanapun, dalam industri farmaseutikal sekarang, *multivitamin gummy candies* dihasilkan dari sumber gelatin yang berasal dari kulit dan tulang babi dan lembu yang tidak dapat diterima dalam pasaran Halal dan Kosher. Selain itu, insiden *bovine spongiform encephalopathy* (BSE) menyebabkan gelatin lembu tidak selamat untuk dimakan. Oleh itu, ikan menjadi sumber gelatin baru untuk pengeluaran *multivitamin gummy candies* bagi mengatasi masalah ini. Objektif utama kajian ini untuk merumuskan dan mencirikan sifat *multivitamin gummy candies* yang disediakan oleh gelatin ikan dan lembu dengan kepekatan gelatin yang berbeza (9, 12, 15%) pada suhu penghidratan yang berbeza (70, 80, 90°C). Kesan terhadap sifat fisiko-kimia, rheologi dan tekstur pada kepekatan gelatin yang berbeza dengan suhu penghidratan yang berbeza juga telah dikaji. Hasil kajian menunjukkan sifat *multivitamin gummy candies* oleh gelatin lembu jauh lebih tinggi walaupun kandungan kelembapannya 20% lebih rendah daripada gelatin ikan. Mereka juga tinggi *hardness* (4656.76g ± 386.52) dan *gumminess* (2375.16 ± 267.88) berbanding dengan *hardness* (4095.14g ± 315.58) dan *gumminess* (2287.54 ± 271.26) oleh gelatin ikan, sementara sifat lain, seperti *springiness* (0.854 ± 0.05 ; 0,807 ± 0,03) dan *chewiness* (1875,68 ± 289,01; 1889,0 ± 50,66) untuk setiap *multivitamin gummy candies* berdekatan antara satu sama lain. Apabila kepekatan gelatin meningkat, tiada perubahan yang besar pada kandungan Brix manakala kadar kelembapan semakin berkurangan dari 25.34 ke 23.97%. pH juga meningkat dalam lingkungan 3.93 ke 4.47 begitu juga dengan kelikatan yang meningkat dari 0.34 ke 0.99. Suhu lebur (38°C to 40.67°C) dan gel (30.67°C to 37.33°C) meningkat apabila kepekatan gelatin meningkat dari 9% ke 12% (w/v). Walaubagaimanapun, peningkatan kepekatan gelatin yang lebih tinggi dapat menurunkan suhu lebur (40.67°C to 39.33°C) dan gel (37.33°C to 35.33°C). Peningkatan kepekatan gelatin juga meningkatkan *hardness* dan *gumminess* parameter tapi mengurangkan *springiness* (0.89±0.03 to 0.81±0.03) dan *cohesiveness* (0.67±0.07 to 0.46±0.03). Tambahan juga, tiada perubahan pada °Brix, pH and kadar kelembapan pada suhu hidrasi berbeza. Suhu lebur (38°C to 41.5°C) dan gel (30.67°C to 32.67°C), kelikatan (0.25±0.05 to 0.34±0.19Pa.s) dan *hardness* (2723.38g±296.24 to 2925.18g±204.32) parameter meningkat apbila suhu hidrasi meningkat dari 70°C ke 80°C. Pada 90°C, parameter ini menurun dengan sejajar. Tekstur parameter yang lain seperti *springiness* (0.90±0.03 to 0.89±0.02), *cohesiveness* (0.67±0.07 to 0.41±0.03), *gumminess* (1828.16±129.69 to 1143.73±60.89) dan *chewiness* (1319.54±256.69 to 1025.57±73.25) juga sejajar menurun apabila suhu hidrasi meningkat dari 70°C ke 90°C. Berdasarkan pengoptimuman proses pengeluaran *multivitamin gummy candies*, nisbah kepekatan gelatin (%) dan suhu penghidratan (°C) masing-masing adalah 9:79.9 dan 9:72.5 untuk setiap pengeluaran *multivitamin gummy candies* oleh gelatin ikan dan lembu bagi memperoleh produk akhir dengan sifat tekstur yang diingini. Oleh kerana penambahan multivitamin dalam formulasi meningkatkan nilai gula-gula, analisis deria telah dilakukan. Berdasarkan analisis sensori yang dilakukan, ia menunjukkan bahawa *commercial multivitamin gummy candies* adalah pilihan yang terbaik. Namun, gelatin ikan dan lembu juga merupakan pilihan yang ideal untuk digunakan dalam produk gula-gula kerana mempunyai sifat tekstur yang serupa dengan *commercial multivitamin gummy candies*.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Chewy flavoured candy or gummy confections is one of confectionery product that currently available on all marketplaces. They are products derived from gel substances such as gelling agent combined with water, sweeteners, colouring and flavouring (Marfil et al., 2012). By mixing these different ingredients together, they can have different characteristics of gummy candy, such as texture, taste and appearance. Nowadays, gummy candy with a soft and sticky texture is popular worldwide. People generally consume it regardless of age, gender or place of living because of the unique semi-solid complex gel texture (Utomo et al., 2014).

In confectionery product, the texture depends mainly on the formation of a gel network, which may be strongly affected by the presence of the biopolymers in the formulation (Marfil et al., 2012). The unique texture of the product is based on the choice of gelling agent that can have the biggest impact on final product quality and attributes such as suitable hardness and transparency that are desirable by consumers. Gelatin a degraded type of collagen is the common gelling agent used in gummy formulations due to its multi-functionalities that are complemented by numerous characteristics that make it irreplaceable in the confectionery applications (Burey et al., 2009). With strong functionalities and properties, gelatin help to create innovative gummy candy while preserving their flavour, texture and shelf stability.

When used at the sufficient concentration, the gels take on the texture of the chewy candies (Caecar et al., 2019). But, since these gels are thermoreversible, which means that they get thinner as they are heated, candies have a "melt in the mouth" characteristic (Gudmundsson, 2002). Both the texture and the amount of time it takes for the candy to melt in the mouth can be regulated by the amount of the gelatin used in the formulation. With the of sugars in formulation, gelatin systems can easily form gel networks as they can contribute to the formation and rheological behaviour of confectionery gels (Burey et al., 2009).

Because people's attitudes and habits have now changed towards a healthy lifestyle, the consumption of these gummy candy confections is not good for the diet, and the overconsumption of confectionery products among children continues to increase slowly (Jiamjariyatam, 2018). So these problems have raised concerns for parents and adults searching for something that is so easy to eat but has a nutritional value for the health. To order to overcome these issues, the addition of healthier ingredients such as multivitamins to the formulation introduces some improved health characteristics to products that are typically devoid of nutrition.

1.2 Problem Statement

In available pharmaceutical industry, multivitamin gummy candies are produced from sources of gelatin are that derived from the skin and bone of pig and cow which are not acceptable for the Halal and Kosher food markets. In addition, the incidence of Foot and Mouth Disease (FMD) or Bovine Spongiform Encephalopathy (BSE) caused anxiety about bovine gelatin (Chancharern et al., 2016). Thus, seafood product have become a new option of gelatin source for production multivitamin gummy candy as to overcome the safety concerns and religious reasons. Along with that, most gelatin allergic patients have been reported to develop allergic reactions to bovine and porcine gelatin, but do not react to fish gelatin (Ardekani et al., 2013).

In order to overcome the problem, multivitamin gummy candies are produced by using fish gelatin. However, the multivitamin of gummy candies with fish gelatin are still new and limited in nowadays industry as the texture of fish gelatin product is much soft and sticky which is different compared to bovine gelatin. The properties of gelatin defined its commercial value because the acid amino content of different gelatin sources will have different physico-chemical and rheological properties. Even though, in general the acid amino content of fish gelatin is lower than bovine gelatin but their characteristic behaviour in the gelling system is relatively same.

Besides, the main differences in the properties of bovine and fish gelatin are that fish gelatin has lower gelling and melting temperatures, but relatively higher viscosities. Due to lower melting temperature, the product with fish gelatin tends to have more desirable release of flavour and aroma than the same product produced with bovine gelatin (Karim & Bhat, 2009). So the fish gelatin could have some potent as alternative to bovine gelatin in production of gummy candy. After all, the quality of the final gummy candy product is determined mainly by their rheological and textural characterizes based on the type and the quantity of gelatin used (Chandra & Shamasundar, 2015). Also during processing of gummy candies, the most important step is hydration of gelàtin as the hydration of gelatin also causes an increase in the viscosity and a decrease in fluidity of the candy mass that modifies the appearance, texture and sensory properties of the final product.

Though, the production of multivitamin gummy candy still have some challenges in regard to long-term stability, off-taste and textural properties. Since the multivitamin is some sort of vitamin so the degradation of multivitamin may occur as they are easily affected by different parameters including time, temperature and pH that may lead to to formation of undesirable flavour compounds and discolouration.

1.3 Objectives

The objectives of this study are:

1. To formulate and characterize the physico-chemical and rheological properties multivitamin gummy candy solutions that prepared with fish and bovine gelatin with different concentration of gelatin at different hydration temperature.

2. To study the textural properties of multivitamin gummy candies of different type and concentration of gelatin at different hydration temperature.

3. To determine the optimal condition of the concentration of gelatin and the hydration temperature for the formulation of multivitamin gummy candies and its effects on sensory acceptability.

1.4 Scope Of The Study

This study focuses on the formulation for the production of the multivitamin gummy candies that prepared using fish gelatin at different concentration of gelatin. There are different hydration temperature were used during preparation of gelatin solutions. Then from the samples prepared, the analysis on the rheological and physico-chemical of multivitamin gummy candy solutions were conducted.

After that, the multivitamin gummy solutions were molded 24 hours before conducting the analysis on the moisture content, gel strength and texture profile analysis. Last but not least, the analysis on sensory properties and consumers acceptance were done to determine the effect of multivitamin present in the formulation. All analysis that tested were compared to the multivitamin gummy candies that prepared with bovine gelatin at certain concentration.

1.5 Organization Of The Study

The scope of this study consists of five chapters. Chapter 1 is about the general introduction of multivitamin gummy candy, the problems statement, the objectives and the scope of the study. Chapter 2 is an organized set of literature review consists of the formulations related in production of gummy confections, the role of each ingredients involved in the formulation. In gelling agent section, detailed explanation on gelatin source, production processes, also structural and chemical composition of gelatin. There is also explanation about the processing steps involved during production of gummy confections and their physical characteristic. Chapter 3 consist of method used to conduct the experiment with the procedure and equipment used. This include the formulation of multivitamin gummy candies and preparation of multivitamin at different hydration temperature and then analysis of the multivitamin gummy solution in term of their physicochemical, rheological and textural properties of multivitamin gummy product. Chapter 4 is the result and discussion of the experiments which contains figure, tables and graph while conclusion and recommendation of this study is stated in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Recent consumer preferences have moved towards the procurement of food products that provide phytonutrients to promote good health and well-being without compromising flavour, texture or convenience. Gummy confectionery is a chewable-based gelatin that provides a little or no nutritional value to the consumer. So incorporation of a multivitamin help to increase the value of the product in pharmaceutical industry since the texture and mouth-feel of gelatin-based candy is already familiar among the consumers. Besides, many people prefer gummy vitamin to tablet or pills due to their fruity flavour, candy-like taste and easy to chew. More importantly, the children and the picky eater person can consumed the product without any problem.

Generally, they were prepared from concentrated sugar solutions, gelatin and other ingredients. The mixed ingredients are then formed into a molten material that can be molded into specific shape. (Delgado & Banon, 2015). Among protein-based gelling agents, mammalian gelatin has been used in the development of multivitamin gummy confectionery due to its diverse functional properties, in particular its textural, gel-forming, foam-stabilizing and emulsifying properties (Louise et al., 2006). Indeed, mammalian gelatin derived from bovine or porcine sources is unacceptable for the vegetarian community and certain religious groups (Kai et al., 2017). Hence, fish gelatin was chosen as the new alternative to replace gelatin in the preparation of multivitamin gummy confections as the gelling agent that could be potentially marketed in the future.

In general, gelatin is one of the most versatile texturising ingredients for sugar confectionery and is ideally adaptable to most commercial sugar confectionery processes (Imeson, 2011). They helps to build the network to form this structure in order to provides a texture with a rubbery and elastic mouth feel (Benjakul & Kittiphattanabawon, 2019). They hydrates readily in warm or hot water to low-viscosity solutions that have good whipping and foaming properties. After cooling, the network of polypeptide chains associates slowly to form clear, elastic gels that are syneresis free (Mariod & Fadul, 2013; Hanani, 2016).

Gelatin is a heterogeneous substance relative to other protein sources, with a large molecular weight distribution and variations in isoelectric point depending on the raw material preparation process and origin (Mariod & Fadul, 2013). Therefore it is important to consider the type of gelatin, bloom value, viscosity, and percentage used as this can have a significant impact on the texture properties of the final product (Hanani, 2016).

2.3 Fish Gelatin As Gelling Agent

Gelatin is derived from the parent protein collagen by breaking down the secondary and higher structures of the polypeptide backbone with different degrees of hydrolysis (Benjakul & Kittiphattanabawon, 2019). Most commercial gelatins are sourced from cattle bone and hide, pig skin and bones which are restricted in certain religious regulations. Moreover, bovine spongiform encephalopathy (BSE) has become a concern for the consumption of cow-derived products. Such drawbacks and concerns encourage the development of alternative non-mammalian gelatins, and the use of fish gelatin appears to be an attractive option (Gudmundsson, 2002).

Fish gelatins are primarily extracted from skins, bones and scales, since the fish processing industry produces a large quantity of waste (Kamer et al., 2019). Around 30% of this waste consisting of skin and bones with a high content of collagen can be used to manufacture gelatin from fish. Thus the production of fish gelatin is considered as a better way of utilization of the processing wastes from the fishing industry (Karim & Bhat, 2009) because extraction fish gelatin can be included from fish skins, bones, fins, heads, scales, or swim bladder (Hanani, 2016).

In general, fish gelatin especially from cold-water have relatively low melting and gelling temperature, low gel strength and weaker structural stability that limits its application (Somboon et al., 2014) due to lower concentration of amino acid compositions and molecular weight of proteins with the approximate weight of 200 and 116 kDa in compared to bovine gelatin which the average around 171 kDa (Muyonga et al., 2004). Since amino acids such as proline and hydroxyproline play an important role in the gelling properties (Somboon et al., 2014) and gelatin with more α-chains have higher gel strength, while with more β and γ-chains will have lower values of viscosity, gelling and melting points (da Trindade Alfaro et al., 2015).

However, warm-water fish gelatin such as tilapia have the slightly same physical properties which make them have similar melting and gelation temperatures to bovine gelatins (Gudmundsson, 2002). Their gelatin properties are depend on the the characteristics of the initial collagen and the extraction process that related to the molecular weight distribution of gelatin (da Trindade Alfaro et al., 2015). Therefore, gelatin properties and quality are not only influenced by the species or tissue from which it is extracted, but also by the process of extraction, which depend on pH, temperature and time during both pretreatment and extraction (Karim & Bhat, 2009).

Besides, fish gelatin with lower temperatures of gel melting had a higher flavour release and gave a stronger taste. Therefore, gelatin from warm water fish source had found to be have a slightly similar quality to bovine gelatin and can be a possible alternative to bovine gelatin (Choi & Regenstein, 2000; Karim & Bhat, 2009).

In gummy confectionery, gelatin are commonly used at concentrations of 5–10% to create a solid, chewy gel. It functions as a gelling agent, providing food products with texture and water-binding properties (Dille et al ; Hartel et al., 2018).

The type of gelatin used, bloom strength and concentration of gelatin are determinant quality of gelatin gels in gummy confections (Hartel et al., 2018).

2.3.1 Production Of Gelatin

Gelatin production can be split into three main steps, pretreatment, extraction, and drying (Benjakul et al., 2012). After preparation of raw materials, they are conditioned either in acid or alkaline solution depending on the raw materials involved. There two types of gelatin produced such as type A and type B (Hanani, 2016).

2.3.1.1 Acid And Alkaline Pretreatment Of Gelatin

In this treatment, the washed raw materials were immersed in the acid or alkaline solution at the certain amount of time depending on the thickness and size of the raw materials. After treatment, the materials were washed using tap water and neutralized until extraction pH is reached (Haug & Draget, 2011). The purpose of the alkali or acid pretreatment is to weaken the structure of the collagen, solubilize non-collagen proteins and hydrolyze some of the peptide bonds, while preserving the strength of the collagen fibers (Sarbon et al., 2013).

The yield and properties of gelatin are generally influenced by type and concentration acid or alkaline used. A previous study by Gudmundsson and Hafsteinsson (1997) showed that high concentrations of alkali or acid increased the gelatin yield while decreasing gel strength. These results have also been confirmed by

Zhou and Regenstein (2005). Besides, among the acid and alkaline solution been used, acid sulfuric and natrium hydroxide respectively shown the highest yield value since both of solutions are strong reagent (Zhou & Regenstein, 2005).

However, the pH of gelatin solution from the pretreatment affects directly to the viscosity of gelatin. A study from da Trindade Alfaro et al (2015) observed the alkaline pH level (above 10) results in drastically decreases in viscosity, while the acidic pH level only results in a mild decrease. In addition, the acid pretreatment that partially inactivate the endogenic proteases involved in degradation. As a result, the enzymatic breakage of intrachain peptide collagen bonds during extraction can be minimized (Zhou and Regenstein 2005). Nalinanon et al. (2008) reported that gelatin extraction from large eye snapper skin using a pepsin-assisted process in combination with a protease inhibitor showed higher bloom intensity than gelatin extracted without pepsin aid, which had a major degradation of gelatin components.

Jridi et al. (2013) also proved that gelatin yield from the skins of bigeye snapper and cuttlefish when pepsin was added during the swelling process. Pepsin has been reported to cleave peptides in the telopeptide region of the native collagen containing intramolecular and intermolecular covalent crosslinks. Therefore, during the acid-swelling process, pepsin can solubilize the collagen in the skin matrix by attaching some peptide bonds, resulting in higher productivity in gelatin extraction (Nalinanon et al., 2008; Lassoued et al., 2014). A similar study done by Lassoued et al (2014) using thornback ray also showed the same result.

Acid treatment is highly advantages in compared to alkaline treatment because its important for the sensory aspects of gelatin, appearance and smell, as acid treatment effectively eliminates odours and colour from the raw material (Zhang et al., 2007, Boran & Regenstein 2009). In the certain study such as by Montero & Gomez-Guillen (2000) and Yang et al., (2007) had applied alkaline treatment and followed by acidic treatment because alkali treatment also necessary for removing potential impurities from the raw material and also for weakening the structure of collagen, resulting in higher yields and superior quality (Zhang et al., 2007).

Type A is obtained from the gelatin that undergo acidic treatment and Type B gelatin is extracted by alkaline treatment (Hanani, 2016). Acidic treatment is best suited to less covalently cross linked collagen found in pig or fish skins, whereas alkaline treatment is best suited to the more complex collagen found in cattle hides (Karim & Bhat, 2009).

In a highly acidic solution, gelatin becomes positively charged and migrates as a cation in the electrical field. It is negatively charged in a strongly alkaline solution and migrates as an anion. The intermediate point, where the net charge is zero and no migration occurs, is known as the isoelectric point (IEP) and is indicated in pH units. The IEP of gelatin is related to the functional groups of amino acids and terminal amino and carboxyl groups formed during hydrolysis (Benjakul & Kittiphattanabawon, 2019). The IEP value of type A gelatin is ranged from 7 to 9 while type B gelatin for gelatin type B ranges from 4.5 to 6.0 (Hanani, 2016). The higher IEP of type A gelatin is due to the limited hydrolysis of the side chains of glutamine and asparagine, whereas the side chains of these amino acids are easily hydrolyzed to aspartic and glutamic acids, resulting in the lower IEP of type B gelatin (Benjakul & Kittiphattanabawon, 2019).

In general, type A gelatin has a higher isoelectric point, and its use is beneficial for applications requiring a low pH at which gelatin can contribute to the formation of gel networks. Likewise, since type B gelatin has a low isoelectric point, it can be used in applications requiring a high pH at which gelatin is readily available for the formation of a gel network.

2.2 Gummy Confections

Gummy confections generally composed of high sugar systems, with one or more gelling components along with food acid, flavourings and colourings (Burey et al., 2009; Marfil et al., 2012). Their firm structure with a softness and chewiness conferred by the chosen of gelling agents used such as starch, pectin, gum arabic, and gelatin (Delgado & Banon, 2015). These polymers can be used by themselves or as in the form of mixtures for producing candies with different textures (Edwards, 2000). Habilla et al (2011) claimed that chewy candies made with various gelling agents and sweeteners have certain texture and eating properties since the structural properties of these molecules incorporate are different (Kasapis et al., 2003).

The network formation of the gelling in biopolymers system is determined by some important characteristics. First, the minimum critical concentration of gelling which is the minimum concentration of biopolymer that allows the formation of gel networks; and second is the concentration of coil overlap and entanglement of biopolymer chains, which affects the density of the network (Burey et al., 2009). The composition of gummy candy at the particular concentration and origin of gelling agents and sugars, has a significant impact on the rheological properties of the product (Čižauskaitė et al., 2019). In confectionery, gelatin commonly used and acts as a gelling agent to give a gummy texture characterized by adequate hardness and transparency (Normah & Fahmi, 2015). When increased levels of gelatin in the food matrix have been shown to increase the thickness of the substance along with a decrease in the perception of the taste (Čižauskaitė et al., 2019).

Gelatin are mainly used due to their melting point at the body temperature by absorbing water quickly that would results in the release of flavour. Gelatin is added to make candy more gummy and appetizing (Pabor, 2015). They have a distinct chewy texture, varying from soft to very hard, depending on the amount of gelatin used. Based on Scott Lennox (2002), gelatin is the major ingredient in confectionery to give strong flavour release and a clear translucent appearance. The addition of sugar in gummy confections can have a significant changed the structure of gelatin gels. Even though the main textural properties of gummy confections are determined by the gelling materials used, but present of sugar co-solutes can contribute significantly to the formation and behaviour of gel system in gummy confections (Burey et al., 2009).

Food acids such as citric acids is one of the important ingredients in gummy candies that primarily added to give a tart taste (Hartel et al., 2018). A 50% citric acid solution is commonly added in near the end of the processing of gummy candies to avoid the harsh combination of acid and high temperature affecting the other ingredients (Burey et al., 2009; Bartkiene et al., 2018). They have the ability to break down sucrose to invert sugar and reduced gelatin viscosity by causing coacervation of gelatin. The acidity pH from food acids have some preservative action to help the gels stabilize (Burey et al., 2009). Lastly, colouring and flavouring are added to make gummy confections more consumer-friendly (Jiamjariyatam, 2018). They are added in very small amount during at the last of production as they are unstable and can be influenced by high temperatures to promote the appearance and the sense of the flavour (Hartel et al.,, 2018).

After mixing of these ingredient together, the obtained mass was poured into the mould, and gummy candies were dried at 5°C for 24 h to get sufficient hard gummy candies with the moisture content is between 8-22% and the water activity is between 0.50-0.75 (Ergun et al., 2015). The moisture content of final product is very important as it determines the textural properties and shelf life of the product (Burey et al., 2009).

2.3.1.2 Extraction Of Gelatin

The pretreated raw materials were then extracted with either in mild acid, distilled water or hot water to remove gelatin (Haug & Draget, 2011; Mariod & Adam, 2013). The common method for the preparation of fish gelatin typically involve mild chemical pretreatment of the raw material and mild temperature conditions during the extraction process (Karim & Bhat, 2009).The extraction process can influence the length of the polypeptide chains and the functional properties of the gelatin .The degree of degradation of collagen into gelatin depends on the processing parameters, excessive damage to collagen fractions with longer heating. It is therefore necessary to balance both the extraction temperature and the period of the extraction.

When the higher temperature applied, more energy provided to disrupt bonding stabilizing the collagen structures and peptide bonds of α-chains. As a result, a large amount of gelatin could be extracted as the temperature was increased. In contrast, the gel strength was decreased when extracted at high temperature in long duration due to effect of heat that destroy gelatin structure (Chancharern et al., 2016). Muyonga et al (2004) reported that higher temperature extracted from Nile perch skin yielded lower gel strength, melting point, setting temperature, and longer setting time. Yang et al. (2007) also reported lower gel intensity from channel catfish skin as the extraction temperature rise from 60 to 75°C.

In addition, higher extraction temperature also caused lower amounts of hydroxyproline in gelatin extract (Gómez-Guillén et al.,2002) because the high quality gelatin is determined by average molecular weight and gel-forming properties, that are generated at lower temperature extractions as less polypeptide backbone hydrolysis occurs (Yang et al.,2007; Haug & Draget, 2011). After all, the raw material used in the production of gelatin also has a significant effect, mostly from variations in the amino acid composition of the parent molecule gelatin, collagen (Karim & Bhat, 2009) that will have different gelling properties and stability of viscosity in gelatin solution (Schrieber & Gareis,2007).

2.3.1.3 Post-Treatment Processes Of Gelatin

Based on the experimental procedure, the gelatins were filtered using filter paper after extraction to remove suspended or insoluble materials like fat, non-extracted fibers of collagen, and other residues (Zandi, 2008; Shakila et al., 2012). Certain studies have directly centrifuged the gelatin following extraction to obtain the supernatant (Mohtar et al., 2010; Yusof et al., 2017) or vacuum concentrated to obtain viscous gelatin solutions (Zeng et al., 2010; Keenan, 2012) before being dried for 24 hours (Zeng et al., 2010). The drying method applied is the major factor affecting the water content of gelatin products because high water content favour microbial spoilage during storage.

Heat drying and freeze drying are two of the most common methods used to remove water from gelatin preparations. Heat drying is generally done at low temperatures between 40 and 60 °C from several hours to several days (Hinterwaldner 1977; Zeng et al., 2010). Freeze dried might be a much faster and most common method (Jamilah et al., 2011) used compared to heat dried and may be able to remove water while causing less damage to the gelatin. Other advantages of freeze-dried is the gelatin showed the highest gel strength and foam formation ability, even though its foam stability was the lowest. Nevertheless, other method such as spray-dried gelatin exhibited the best emulsion capacities and contribute to lower fishy odour of fish gelatin among the three other methods (Benjakul et al., 2012; Sae-Leaw et al., 2015).

2.3.3 Rheological Behaviour Of Gelatin

The rheological properties of gelatin are related to their chemical characteristics. The gel strength, viscosity, setting behaviour and melting point of gelatin depend on their molecular weight distribution and the amino acid composition, the imino acids proline and hydroxyproline are important in the renaturation of gelatin subunits during gelling. As a result, gelatin with high levels of amino acids tends to have higher gel strength and melting point (Ahmed, 2017).

2.3.3.1 Gel Strength of Gelatin

Gel strength is one of the most important quality characteristics used in the gelatin industry to characterize gelatin (Zhou & Regenstein 2005). Generally, the gel strength or bloom strength is defines the gelatin quality to a measure of the hardness, stiffness, strength and compressibility of the gel at a particular temperature and is influenced by the average molecular weight, the chemical treatment of raw collagen involved, and type and concentration of gelatin (da Trindade Alfaro et al., 2015; Ahmed, 2017). Based on review by Ahmed (2017), the higher value of gel strength contribute to higher melting and gelling temperature of gelatin solutions. Also physical properties such as the colour of gelatin is much lighter and the odour more neutral.

The method of measurement gel strength is followed according to GMIA standard method. After preparation of gelatin sample at 6.67% (w/v) concentration, the maturation and temperature of measured were standardized at 16-18 hours and

10°C respectively using a specific container is used, called a "bloom jar," with approximately 10g gelatin (GMIA, 2012).

The properties of the gel strength are correlated to the components of α-and β-chain in gelatin (Ahmed, 2017) thus high α-chains would result high gel strength (Karim & Bhat). The gel strength also correlated with viscosity, which is an important property in the food industry as it is a good guide to the gel's behavior (Mariod & Fadul, 2013). Different gel strengths are used for different applications. In confectionery product, the common gel strengths used is between 125-250 as high gel strength of gelatin generally requires lower amount of gelatin to reach the desired gel strength in the final product, when compared with low bloom gelatin (GMIA, 2012).

In general, the wide range of gel strength values observed for the various gelatins that derives from variations in proline and hydroxyproline content in collagens of different origin of raw materials (Karim & Bhat, 2009). Since the composition imino acid of mammalian gelatin is higher than fish gelatin, so that could contribute to the higher gel strength (Haug & Draget, 2011). Apart from that, the gel strength also related to the habitat temperature of animal sources (Karim & Bhat, 2009). A study from Badii & Howell (2006) found the hydrophobic amino acid compositions in tilapia fish gelatin are higher in compared to cod fish gelatin and the higher hydrophobic amino acid composition could promotes to higher gel strength.

Besides, the extraction conditions also markedly affect the gel strength (Zhou & Regenstein 2005; Jamilah et al., 2011). The study done Jamilah et al (2011) reported the high gel strength value obtained for red tilapia skin due to extraction condition with liming solution for 14 days as results the pH of the gelatin close to its isoelectric point, where the proteins will be more neutral and thus the gelatin polymers are closer to each other. It was discovered the conditions of extraction affect the composition and distribution of hydrophobic amino acids, which affect the physical properties of gelatin, even more than the content of imino acids.

A research from Jamilah and Harvinder (2002) in comparison used of high concentrations of sulfuric acid, sodium hydroxide, and citric acid, has been reported to result in the lowest gel strength values for tilapia gelatin, indicating that the gel-forming ability of the gelatin was sensitive to acid and alkali hydrolysis, as both affect the degree of cross linking in the collagen. **Moreover, the used of gelatin with high gel strength in food production required shorter gelling time and lesser amount of gelatin to obtain a firm gel** (Normah & Fahmi, 2015).

2.3.3.2 Viscosity Of Gelatin

Viscosity is the second most important commercial property after gelatin gel strength (Schrieber & Gareis, 2007). The viscosity of gelatin solutions varies from source to source in terms of molecular weight and protein distribution of molecular chain. According to Cole (2000), the lower average molecular weight of gelatin, contribute to the lower gel strength and viscosity of the solution. Similar study done by Jamilah et al. (2011) proved that highest molecular weight gives highest viscosity value. This rheological behaviour of aqueous gelatin solutions can be described when dilute gelatin solution is a Newtonian fluid showing purely viscous behaviour by the formation of hydrophilic and hydrophobic interactions between the gelatin molecules. (Ahmed, 2017).

The different origin sources of gelatin that have different value of viscosity which is partly influenced by molecular weight and polydispersity (Jamilah et al., 2011). Fish gelatin is expected to have low viscosity compared to mammalian gelatin since they have low molecular weight and gel strength. However, gelatin samples with high gel strengths does not mean that their viscosity would also be high (GMIA, 2012). The study by Boran & Regenstein (2009) found the gelatin samples from fish skin gives unexpectedly high viscosity while giving low gel strength compared to pork skin gelatin due to carefully controlled extraction conditions and, consequently results higher molecular weight protein fractions.

Another study Zhou et al (2006) also stated with proper controlled of extraction conditions will results the presence of higher fat fractions of molecular weight, thus tilapia skin gelatin have higher viscosities while providing lower gel strengths than pork skin gelatin. However, increasing the extraction temperature and time also led to reduction of viscosity (da Trindade Alfaro et al., 2013). Therefore the processing condition need to be proper controlled to promote higher proportion of molecular weight (da Trindade Alfaro et al., 2015), thus result increased of viscosity.

Jamilah and Harvinder (2002) also claimed that the impact of pH on viscosity is small at the isoionic point of fish gelatin and maximum at pH 3 and 10.5. The same theory was confirmed by Shakila et al (2012) that the red snapper grouper fish showed higher viscosities at pH 3 and pH 10. Then, the quality of the gelatin with respect to gel strength and viscosity can be a result of the relationship between the concentration of alkaline solution, temperature and duration of conditioning process with stronger liming conditioning results in higher viscosity (Jamilah, 2011). The study Shakila et al

(2012) also claimed the pH of the gelatin solution also can be considerably related to the viscosity properties.

Thus, the variations in gel strength and viscosity between the two gelatins were likely due to intrinsic characteristics such as protein chain structure, molecular weight distribution, amino acid content and method of extraction procedure (Kuan eat al 2017). Since higher imino acid content contains is responsible for the stability of the triple helix of collagen structure through hydrogen bonding between free water molecules and hydroxyl groups, thus contributing to the higher gel strength and viscosity of bovine gelatin (Kuan eat al 2017).

Besides, at low viscosity of gelatin short brittle gels could produced, while high viscosity would give tougher more extensible gels (Wangtueai & Noomhorm, 2009). The different viscosities have created some significant difference in the perception of the sensory properties of food products with a gelatin sample since the viscosity is a crucial parameter for food products when gelatin is used as an ingredient.

2.3.3.3 Gelling And Melting Temperature Of Gelatin

Both melting and gelling temperatures are one of rheological methods that performed through temperature sweep test to determine gelatin quality (Sarbon et al 2013). During sol-gel transition, the storage modulus (G') representing the elastic energy accumulated during the process and the loss modulus (G'') reflecting the viscous energy dissipated during the cycle increased as the temperature decreased

(Tau & Gunasekaran, 2016). The frequency independence of the loss tangent that applied was commonly evaluated for chemical and physical gels in the range of the gelling point that was also used to assess the gelling point (Ahmed, 2017). The intersection between G' and G'' is determinant temperature of gelling and melting temperatures at which a gelatin solution changes from liquid to solid and vice versa (Tau & Gunasekaran, 2016). The gelling temperature,Tg is dependent on its thermal and mechanical history while melting temperature,Tm is the temperature at which a gelatin gel sufficiently softens due to maturing temperature and gelatin gel concentration (Mariod & Fadul, 2013).

Fish gelatin generally had poorer melting and gelling property than bovine and pig gelatins because it contains lower amount of of proline and hydroxyproline (da Trindade Alfaro et al., 2015) since the hydroxyl group of hydroxyproline especially plays a important role in the stabilization of the helix by interchain hydrogen bonding through a bridging water molecule as well as direct hydrogen bonding to a carbonyl group during gelling process (Benjakul et al., ; Shakila et al., 2012). In contrast, gelatin derived from warm water species have slightly similar thermal stability to bovine and pig gelatins compared to cold water species (Karim & Bhat, 2009).

Shakila et al (2012) observed the gelling and melting temperatures are also affected by variations in ion strength and pH of gelatin. These properties decreased with an increase in ion strength because the electrostatic interaction is reduced preventing attraction between inter-chain ion bridging and gelation of fish gelatin. From the same study also reported the ion strength and pH of gelatin influenced the time taken for fish gelatin formed a gel which is longer than mammalian gelatin.

Besides, Cho et al (2004) claimed that the increasing temperature of extraction from 60 to 75°C in the processing of gelatins would reduced the melting and gelling properties. Thus, this characteristic is also strongly related on the species, type of raw materials, processing conditions, average molecular weight, ionic strength and pH of the gelatin (Karim & Bhat, 2009).

Even though the lower melting temperature of fish gelatin is slightly had disadvantage impact but Choi and Regenstein (2000) found the lower melting point of fish gelatin have improves flavour release, stronger taste, and melting rate in water gel desserts. They also discovered that fish gelatin had similar physical and chemical properties compared to porcine gelatin and was considered preferable in the blind sensory test.

2.4 Role Of Sweetener In Gummy Confections

Sucrose needed in a bulk amount in gummy confections as they are primarily used to provide sweetness and body form to the gelatin gels (Hartel et al., 2018) that will contributed to the texture and sensory properties of the product (Burey et al., 2009; Kamer et al 2019). Sugar has been observed to increase gel strength although the magnitude of this increase depends upon the age and temperature of the gel (Fonkwe, et al., 2003). They have a ability to stabilize protein network and improve texture of gelatin gels (Porayanee et al., 2015) through a strengthening of hydrophobic interactions in the protein molecules (Choi et al., 2004). According the study done by Kasapis et al (2003), the addition of sugar to the gel system reduces haziness, improves thermal stability and promotes gel structure.

Other than that, sucrose also influenced the mechanical properties of gelatin gels (Kohyama et al., 2016). When the higher sucrose concentration is used, more harder of gelatins gels produced (Wang et al., 2014). The study by Kohyama et al (2016) observed the increased in the concentration of sucrose in agarose gels would result the increased of storage Young's modulus with decreased of the melting temperature, but the excessive addition of sucrose might lowered the elastic modulus because the amount of free water needed to form the junction zones is reduced. Normand et al. (2003) indicated that Young's modulus and stress and strain loss increased with an increase in sucrose concentration. They reported that the network structure had become less heterogeneous based on the experimental observation that result the increased number of junction zones with decreased the size of each junction zone when the concentration of sucrose increased.

Apart from that, there is a relationship between the concentration of water activity and sucrose concentration (Jiamjariyatam, 2018). Water is 1.0 and the increased concentration of sucrose decreases the activity of the water. Therefore, sucrose can be considered a depressor of water activity and it can decrease food microbial spoilage (Mathlouthi & Reiser, 1995). According to Ergun et al (2015), glass transition temperature,Tg of sucrose and water activity of sucrose has a correlation. Tg is the temperature that the sample changes the physical property from glassy state to rubbery state and a small addition of water decreases Tg more. A study from Ergun et al (2010), proved that as water activity increases, Tg will decreases. This relation is important as the sucrose and moisture content relation directly affect the physical properties of candies, mostly texture .

The addition of sucrose in gummy confections is often with the combination of glucose syrup (Porayanee et al., 2015) since glucose syrup is used to prevent crystallization of sucrose as well as stabilizes other ingredients such as sucrose or gelatin (Burey et al., 2009). The combination of sucrose and glucose syrup also generates a continuous process in gelatin which strengthens the gel of gelatin (Porayanee et al., 2015). Another studies by Tau & Gunasekaran (2016) observed the higher amount of glucose syrup would not alter the gelation property as long as the amount of glucose syrup is below its critical concentration that could cause the precipitation of gelatin. Due to the high dissolved solid content of glucose syrup, it also helps prevent microbial growth by reducing water activities. Thus, the addition of preservatives is not necessary (Porayanee et al., 2015).

2.5 Role Of Water In Gummy Confections

Water is an important component of foods product that promote the chemical reactions and serving as a reactant in hydrolytic processes. Thus reduced the water content by increasing the concentration of sugar in foods prevents help to slows the growth of microorganisms and helping to improve the food product's shelf life (Burey et al., 2009). According to Belton (1997), the swelling began in the gels upon the addition of water in biopolymer and the network will continue to extend to its maximum extent (Ziegler & Foegeding, 1990). The combination of improved mobility and expansion would allow more water to be consumed before saturation is reached.

In a gummy confections, the physical interactions of water have a ability to form hydrogen bonds with gelatin gels, sugars and other confectionery components (Schrieber & Gareis, 2007). In addition, the study by Vaca Chávez et al (2006) claimed the increase in the concentration of biopolymer results in a decrease in water activity due to a decrease in the chemical potential of the water due to electrostatic and non-covalent interactions with the polymer. During low water content, the diffusion of water is decreased and, where glass transitions occur, this reduction may be of several orders of magnitude. Under these conditions, water may be trapped in the bulk of the substance and may not be effectively removed (Djabourov et al., 1988).

According to Pinhas et al (1996), water acts as a plasticizer in a gummy confections to aid the gel formation (Burey et al., 2009). They reported the increased of water content will probably because the plasticizing effect of the water induced a greater mobility of the solid constituents. The water content also can affect glass transition temperature of the gelatin product from glassy to rubbery behaviour. Thus, high water content could reduced the glass transition temperature,Tg and affect the final moisture of the product (Mathlouthi & Reiser, 1995). Ergun et al (2015) also reported the final water content in gummy confections that have the significant affect on texture and shelf life as lower moisture content could result harder gummy confections with longer shelf life.

However, Rogers, Roos & Goff (2006) indicated the increased of Tg due to addition of gelatin in the sugar solution because slowing crystallization of amorphous sugars due to decrease free volume, molecular mobility, and diffusivity since gelatin has the maximum affinity for water when mixed with sucrose and therefore allows its integrity to be retained (Burey et al., 2009). Though, recrystallization of amorphous sugars due to increased molecular mobility also is an unacceptable defect in gummy-like candies because it produces a rough texture (Hartel, 1993).

Thus, water can influence the physical state of metastable foods based on the composition of water applied that causing them to be glassy, rubbery, or viscous and lead to moisture variations that will affect the quality changes such as premature crystallization, stickiness, accelerated rancidity, body shortage, chewing inconsistencies, stiffness, poor handling of forming and product flaws in texture (Burey et al., 2009).

2.3.2 Structural And Chemical Composition Of Gelatin

Amino acid composition of collagens in fish skins found typically more abundant than those of mammalian collagens. However their hydroxyproline and proline contents are lower than those of mammalian collagen, and this is compensated for by higher levels of serine and threonine (Karim & Bhat, 2009). In general, fish collagens have a lower imino acid content than mammalian collagens (Haug & Draget, 2011), and this may be the explanation for denaturation at low temperatures. However, warm water fish gelatin, extracted such as tilapia, has a higher content of proline and hydroxyproline than gelatin from cold water fish species (Haug & Draget, 2011). Gómez-Guillén et al (2002) stated the lower amounts of hydroxyproline in gelatin also due to high temperature applied during extraction process.

On the comparative study conducted by Shakila et al. (2012) stated that the main difference between fish and mammalian gelatins is the content of the imino acids, proline and hydroxyproline, which stabilize the ordered conformation when gelatin forms a gel network (Haug et al., 2004a). The lower content of proline and hydroxyproline lead to the low gel strength and low gelling and melting temperatures of fish gelatin. Besides, proline and hydroxyproline is important to play a role in stabilizing triple helical structures due to its hydrogen bonding ability between its hydroxyl group and free water molecules (Ktari et al., 2014; Chandra & Shamasundar, 2015).

In addition to the amino acid composition, the functional properties of gelatin are also affected by the distribution of the molecular weights, structures and compositions of its subunits (Karim & Bhat, 2009). The gelatin produced has a lower molecular weight than the native collagen (Nikoo et al., 2014) because during the production of gelatin, the conversion of collagen to gelatin creates molecules of various mass due to inter-chain covalent crosslinking and unfavorable breakage of some intra-chain peptide linkages (Zhou et al., 2006). Review from Karim & Bhat (2009) stated the molecular weight of mammalian gelatin is higher than fish gelatin due to different source of gelatin raw material. And the high molecular of gelatin also due to condition of extraction process with shorter treatment time and lower extraction temperature (Zhou and Regenstein 2005) that may influenced the viscosity of gelatin solution (Karim & Bhat, 2009).

2.6 Role Of Multivitamin In Formulation

Multivitamin is the combination of many different vitamins such as Vitamin A, B group, C, D and E used to prevent vitamin deficiencies caused by illness, poor nutrition, digestive disorders and many other conditions (Macpherson et al., 2016). The study from Major et al (2008) stated the multivitamin can be taken as dietary supplement as to increase the appetite that often accompanies with body-weight loss and the consumption of multivitamin may help to maintain and promote health by preventing various diseases.

Multivitamin is a diverse group of molecular compounds that be added in gummy formulation because they can increased the value of gummy candies as the vitamins are nutritiousness product (Dille et al., 2018). However, unlike most vitamins, gummy vitamins required constant temperatures and refrigeration to prevent spoilage. They required as proper storage as they tend to melt in high heat. In addition to affecting the portion size, high temperatures can cause formulation of vitamins to disintegrate. Basically, the effect of active ingredient especially vitamin in gummy candies more towards the textural properties.

According to Bartkiene et al (2018) stated that the higher contents of active ingredient will reduced the hardness and the gumminess of gummy candies. Čižauskaitė et al (2019) also indicated the addition of *acai berry* extract that highly contains antioxidant with Vitamin A and C into gummy candy reduced the textural parameter such as hardness, strength and firmness due to effect of water activity and pH content. In addition of Vitamin D along with calcium ion made a significant changes in texture of gummy candy that result the gels tends to be more brittle and less cohesive and springy (Lau et al., 2000). Lele et al (2018) made a comparison study between gelatin and agar-agar in gummy supplement and found that the gummy supplement using gelatin shown higher acceptability of consumers in compared to agar-agar and observed the used ingredients such as probiotics, prebiotics, and apple pomace could reduced hardness of the gummy supplement texture.

Another studies by Charoen et al (2015) also stated the used of higher content of *Psidium guajava* leaf extract that consist variety of antioxidants such as vitamin C, vitamin E, selenium, beta-carotene, vitamin A, and plant polyphenolic compounds caused changes in texture properties of gummy jelly in decreased of gumminess and chewiness but no effects on their cohesiveness and springiness. Hani, Romli & Ahmad (2015) also observed the increased of *red pitaya fruit puree* incorporated with fish gelatin in gummy confections decreased in hardness, gumminess and Young's moduli. Though overall they provide desirable texture, enhanced antioxidant activity and provided a natural vibrant red colour to the gummy confections.

2.7 Processing Steps Of Gummy Confections

Gummies are traditionally made in a batch process (Scuderi, 2002; Burey et al., 2009) to prevent mechanical damage upon the swollen gelatin granule. Basically, processing steps include mixing the sweeteners together then cooking the syrup at a set temperature to reach the desired product water content, cooling the syrup and adding gelling agent where appropriate, together with colours, flavours and food acids before the end product is formed and finished (Schrieber & Gareis, 2007).

2.7.1 Hydration Of Gelatin

Powdered gelatin must be thoroughly hydrated before adding to sugar solution to ensure proper manufacturing. Usually, to ensure complete hydration, powdered gelatin is dissolved in excess water at 1:2 ratio (Periche et al., 2014; Jiamjariyatam, 2018). Aside from that, temperature control is important to ensure proper solidification that result increase in the viscosity and a decrease in fluidity of the candy mass during processing and ultimately, modifies the appearance, texture and sensory properties of the finished product (Schrieber & Gareis, 2007).

(Schrieber & Gareis, 2007) said it was crucial to allow sufficient time of gelatin hydrated and keep the initial temperature of the gelatin-water solution between 80-90°C to ensure the gelatin fully active and will result maximum outcome. Ziegler & Foegeding (1990) indicated at lower temperatures, the nucleation rate exceeded the growth and annealing rate, but the recrystallization of the poorly ordered structure proceeded more slowly. Thus the formation of gelatin network more numerous but shorter regions of triple helix and, at gelling concentrations, of many weak links between entangled gelatin chains. Pleass (1930) also stated gelatin was slightly hydrated and united in short chains at low hydration temperature. In contrast, as the temperature increased, the greater swelling of gelatin solutions to the osmotic forces which cause the fibrils of gelatin to absorb more water and become swollen will relatively increased the viscosity. Their three-dimensional network also formed more faster than at low hydration temperature (Tosh & Marangoni, 2004).

After all, the gel formation is very much dependent on concentration. At low gelatin concentrations, the melting started earlier than at higher concentrations, and concentration also will relatively affected gelling temperature and gelling time (Somboon et al., 2014). Pleass (1930) also observed the higher concentration of gelatin, the slower the rate of cooling. This may be explained by variations in the specific heat of gelatin solutions of different concentrations by differences of their ability to transmit heat, either by conduction or convection, or by the evolution of heat that occurs as the gel sets. In comparison to melting process, the increase of temperature of the increased concentrations of gelatin is likely due to different amount of heat absorbed that will effect the different physical state of the gel on the convection currents.

2.7.2 Dissolving And Cooking Of Sweeteners

Based on the experimental procedure by Normah & Fahmi (2015), the gummies were prepared with mixing the glucose syrup, fresh juice and gelatin together and slowly heated in the water bath at 90°C to dissolve the gelatin and glucose syrup before then poured into a mould and left to solidify for two days at 7°C. Other experimental procedure by Jiamjariyatam (2018) reported the gelatin was first dissolved in water and subsequently added the glucose syrup. After that, all ingredient were heated in hot plate at 110°C for 5 min prior adding the flavouring and colouring agents. The study by Periche et al (2014) also used the similar method with slight modification of the temperature used which is 60°C.

However, the studies by Pobar (2015), Charoen et al (2015), Porayanee et al (2015) and Kai et al (2017) used the method that been described according to Schrieber & Gareis (2007) to ensure that any crystalline sugars are fully dissolved, to evaporate water, to deaerate the syrup and to ensure the correct viscosity of the forming phase. They indicated the first steps in gummy candies manufacturing involves mixing of sweeteners such as sucrose, glucose syrup and distilled water followed by cooking the slurry at the appropriate temperature to achieve the desired moisture content.

And according to the study by Delgado & Banon (2015), the cooking of the gummy jellies were followed the normal industrial procedures in a local factory. The major ingredient such as sucrose, corn syrup, starch solution and gelatin solution were homogenized in a storage tank and the raw mix was transferred to a continuous cooker before applied the pressure for starch gelatinization. The moisture content of the mixture was adjusted by applying vacuum pressure to increase the solid soluble content of the hot liquor. Prior to molding, the heat-sensitive ingredients (acidifying, flavouring and colouring solutions) were separately mixed in emulsion tanks at room temperature before being transferred into mixing system.

2.7.3 Curing Or Drying Of Gummy Confections

After molding, the gummy confections were kept in the dried at 22–24°C below melting point of gelatin for 24 hours to remove the excess moisture so that its will cools and solidifies (Periche et al., 2014; Lele at al., 2018). Other experimental procedure by Normah & Fahmi (2015) reported the gummies were left solidify for two days at 7°C and Jiamjariyatam (2018) placed the gummies in the chamber at 7°C for 18 hours. Air flow must be sufficient to ensure that each tray has good heat and mass transfer to ensure consistent drying of all tray so that the air flows evenly across each tray. Dead spots, where the air cannot reached, can lead to excessively long curing times and uneven texture for candies in the area (Schrieber & Gareis, 2007).

Delgado & Banon (2015) also indicated the drying times must be higher than 12 hours to ensure the gummies have proper solidification. They observed the increased of drying time could stabilized the textural properties and moisture content of final product at desired conditions. Textural properties such as hardness, gumminess and chewiness increased as longer drying time applied due to effect of gelation and dehydration phenomena. The effect of gelation is described according to Burey et al (2009) due simultaneous action of gelling agents on the colloidal framework containing sugars, water and other minor components that affect texture of the gummy candies.

Another important factor that play important role in texturizing gummies is dehydration because during drying, water transfer from gummies to circulating air slowly reduces the moisture content and increases the solids content with subsequently increased the hardness of gummy candies (Vieira et al., 2008).

2.8 Physical Characteristic Of Gummy Confections

2.8.1 pH Of Gummy Confection Solutions

The pH value of the food is a great indicator of the free hydrogen ions present in the food. The acids found in the food release these hydrogen ions, which give the acid food its distinct sour taste (Vijayakumar & Adedeji, 2017). In confectionery products, pH is important for the stability and gelling capacity of the gelatin gel during cooking and before molding (Lees & Jackson, 1973; Edwards, 2000; Jarret, 2012) since acidity and pH have an effect on the strength of the gelatin set and may degrade it. Too much acid affects the gel strength and reduces the firmness of the gelatin gels (Jarret, 2012). Thus, pH should be kept at a high constant level which is above 4 to keep gummy confection have a firmer texture (Lees & Jackson, 1973).

In order to obtain the desired value of pH, a study by Hani et al (2015) made an adjustment to increased the pH value at desired level with addition of citric acid. Besides, Delgado & Banon (2015) also stated pH of gummy solution is slightly influenced by the drying time. The pH of solution been observed increased as the drying time increased. Other than that, Jiamjariyatam (2018) reported pH of gummy jelly obtained increased when the increasing gelatin concentration. This can be explained by the fact that gelatin was extracted and obtained from collagen, which is a protein in the connective tissue. The subunit gelatin is amino acid, thereby increasing the amino acid content of gelatin, which caused the gummy jelly to have a high pH level.

Furthermore, the taste of the finished gummy confections is highly depends on the balance between sourness, tartness and sweetness that influenced by the addition of acid food in formulation (Burey et al., 2009). Therefore, it is important to maintain pH control and appropriate acidity levels in gummy confections in order to maintain stability, enhanced the flavour and preserved its shelf life.

2.8.2 Total Soluble Solid Of Gummy Confection Solutions

Total soluble solids are measured by a refractometer and expressed as Brix degrees equivalent to the percentage weight of sugar (Widodo et al., 1996; Jayasena & Cameron, 2008). Since the use of a refractometer is a very quick method that only takes less than three minutes to obtain the result, the samples should be homogeneous in order to produce accurate results. Brix also very sensitive to temperature, so that the refractometer should always be used at a constant temperature (Ergun et al., 2015).

In confectionery, Brix is an important parameter for quality control check in order to control of microorganisms growth in food. The higher the Brix, the less water available for microorganisms to expand, as the sugars are bound to the free water. According to Burey et al (2009), gummy confection should have minimum 75% total soluble solid, to exclude mold growth (Delgado & Banon 2015).

Similar to pH, there are several studies have made the adjustment to the Brix value of gummy confection solutions at the desired values prior molding. Based on the study by Charoen et al (2015) claimed the Brix value of the mixture was adjusted to 68-75% by adding a portion of water. However, different adjustment done by Hani et al., (2015) with further heated of mixture until the resultant mixture reached final soluble solid content of about 70–75%. Another study by Delgado & Banon (2015) also vacuum pressured of mixture to increase the solid soluble content of the hot liquor at 78 °Brix.

Thus, it is important to control total solids content since it is sufficient parameter that is used to understand total soluble solid content in confectionery products (Lees & Jackson, E., 1973) that may affect the stability and shelf life of finished product.

2.8.3 Moisture Content Of Gummy Confections

Water content in the food product should be monitored and precisely determined as it affects many chemical and physical properties of food materials, such as the growth of microorganisms (molds, yeasts), stability, texture, organoleptic characteristics and shelf life (Yetim & Kesmen, 2009; Ergun et al., 2015). Since the major function of water in confectionery is to dissolve the ingredients and help with mixing (Burey et al., 2009; Ergun et al., 2015).

There are numerous methods have been used to quantify the amount of water in a substance, from basic drying methods to more complex spectroscopic analyzes. There are three categories of methods are mainly used in the confectionery industry such as drying losses, Karl Fischer titration, distillation and refractometry (Ergun et al., 2015; Mauer & Bradley, 2017). In nowadays technology, moisture analyzer is one the method that provides a fast and accurate analyze of moisture content food constituents. Though, this method has some drawbacks such as carry the risk of the loss of volatile components during heating that results in a further decrease in weight, which is not explained by the release of water. And, samples can only be measured one at a time (Mauer & Bradley, 2017; Determining Moisture Content - Food Quality & Safety, 2020).

The approximate ranges of gummy confections should be around 8-22% (Ergun et al., 2015) with controlled processing method. A study by Delgado & Banon (2015) proved the controlled drying process is important to control the moisture content of the finished product because the water content in gummy confections were circulating into the atmosphere during drying that result moisture content decreased until its stabilized. **Another study from Periche** et al (2014) also reported **the recommended moisture content values of gummy confections should be around 24% and less than that.**

In addition, the moisture content is related to the other characteristics of gummies such as their gelling temperature (Tg), since gummy confections are semi-solid food matrixes. The moisture content has a direct effect on the gelling temperature during the changes of physicochemical substance from glassy to rubbery state (Gustavo et al., 2008) that may affect on the food stability and texture properties (Ergun et al., 2015). In contrast, high moisture content caused a decrease in the gel hardness and in the intensity of the bitter flavour besides increased the chance of microbial growth (Csima et al. 2014).

2.8.4 Textural Properties Of Gummy Confections

Texture is a main quality determinant in gummy confectionery products and their textural changes can be measured through the texture profile analysis,TPA (Shafiur & Al-Mahrouqi, 2009; Chandra & Shamasundar, 2015). TPA analysis commonly carried out at temperature 60°C with gelatin gels of concentration 6.67% (w/v) (Binsi et al., 2009). There are different classification of parameters are evaluated in relation to the deformation of applied force and objectively measured in terms of the force applied, the distance the force is applied and the deformation period (Delgado & Banon, 2015) with two major parameters such as gumminess and chewiness that are main assessment to define gummy confections (Borwankar, 1992). Hardness of gummy confections which are more likely to fracture during mastication is often identified as chewy, while softer texture of gummy sweets which dissolve during mastication is defined as gummy (DeMars & Ziegler, 2001).

Based on the previous research, they found the different type of gelatin used made a significant affect on the texture of gummy confections. Shafiur & Al-Mahrouqi (2009) and Chandra & Shamasundar (2015) made a comparison studies of textural properties between fish, bovine and porcine gelatin gels and found the textural properties of fish gelatin gels were significantly lower compared with the gels prepared from bovine and porcine gelatins. The hardness of bovine gelatin gels was highest, followed by porcine then fish gelatin gels. They reported variations in textural properties of gelatin gels at equal concentrations could be explained by different concentrations of amino acids, molecular weight distributions and less degraded peptides of gelatin. Since compared to bovine gelatin, fish gelatin contained the lowest amount of proline and hydroxyproline, causing their structural differences (Binsi et al., 2009). Besides, gelatin with the lowest chain length could prevent them to form strong gel (Shafiur & Al-Mahrouqi, 2009).

Apart from that, the study from Čižauskaitė et al (2019) indicated when the amount of structuring agent in the formulation increased, the firmness of the product will be increased. Schrieber & Gareis (2007) also stated the increased of gelatine amount in gummy confections, the firmer the final texture will be. Another study by

Piccone et al., (2011) also claimed increasing amount of hydrocolloids in a food matrix has been shown to increase the viscosity and result to be the more rigid and firm candy. They also mentioned the increased thickness of product is associated to a reduction of the perception of flavour that been added in formulations.

The increased of textural properties is also influenced by the addition of sweetener in the formulation (Pizonni et al., 2015) since sweeteners play a major role in faster structuring of gelatin network aside affecting the sensory properties of the product. Čižauskaitė et al (2019) also stated the addition of sweeteners even at low relative concentrations could increased the firmness of the gelled structure as the sweetener played a key role in molecular interaction that can affect the gel toughness (Tau & Gunasekaran, 2016). However, Normah & Fahmi (2015) reported the increases the amount of sucrose or glucose syrup ratio and citric acid content at certain point would resulted in a slight reduction of viscosity, hardness and chewiness of gummy product.

Other than that, the longer drying process also have a major affect to the textural properties of gummy confections. Delgado & Banon (2015) reported the hardness, chewiness and gumminess increased when drying time increased and then be stabilized at certain point. They suggested the increases in these parameters might be mainly due to the capacity of circulating air to stabilize the gel by cooling, since the moisture content hardly decreased. However, other texture parameters such as cohesiveness and springiness show no significant changes over drying time due to high content of gelatin used in formulation. Csima et al (2014) also reported similar behaviour of gummy confections during storage. After all, the increased of drying process up to 6 month had damaged the structure of gummy confections, so the gummies lost its elasticity, became harder and plastic.

CHAPTER 3

METHODOLOGY

3.1 Overview

Generally, multivitamin gummy candies are easy to chew and can usually be taken by people who have difficulty swallowing pills. They are simpler to consume for both kids and adults and convenience to add as their nutrient routines. Multivitamin gummy candies basically are sweet chewable vitamins that have a texture and taste similar to gummy candies and come in a variety of flavours, colours, and shapes. Typical ingredient of production of multivitamin gummy candies consist of gelatin, water, sugar, colouring, flavouring and multivitamin. The multivitamin gummy candies of different gelling agent such as fish and bovine gelatin are prepared with different concentration of gelatin at different hydration temperature, at 70°C, 80°C and 90°C. This chapter explains the detailed preparation of multivitamin gummy candies followed by the analysis done.

3.2 Raw Materials

Both commercial gelatin which are fish and bovine gelatin with 200 Bloom value were obtained from Phywon System Ingredient Sdn Bhd, Shah Alam, Selangor. Other important raw materials involved such as distilled water, glucose syrup, sucrose, citric acid powder and commercial multivitamin solution.

3.3 Method Preparation Of Multivitamin Gummy Candies

The multivitamin gummy solutions at different concentration of gelatins were prepared with 35 ml total of volume samples and this experimental procedures were summarized in Figure 3.1.

3.3.1 Preparation Of Gelatin Solutions

Since one of the objective of the studies are to formulate the production of multivitamin gummy candies at different concentration, thus the choice of gelatin concentration is very crucial. For example, if a product has 5% of gelatin, the product will not have desired texture or elasticity and to avoid too much gelatin yielding a very tough product, gelatin content was limited to 15% (w/v) (Tau & Gunasekaran, 2016). Therefore, two different gelling agent which are fish gelatin and bovine gelatin at different gelatin concentration such as 9, 12 and 15% (w/v) were prepared (Jiamjariyatam, 2018). These gelling agents were hydrated at different temperature such as at 70°C, 80°C and 90°C in order to observed the temperature of gelatin fully active and could have result maximum outcome at ratio 1:2 (w/v) gelatin to water in a waterbath for 15 minutes (Charoen et al, 2015) to ensure complete dissolution of gelatin.

3.3.2 Preparation Of Multivitamin Sugar Solutions

The sugar solutions are prepared according the method studied by Periche., et al (2014) with some modifications. The sugar solutions were prepared with 40% of sucrose and 60% of glucose syrup 40:60 (w/v) of the total sugar content since at these sugar concentrations could help to increase the stability of gelatin gel network (Burey et., 2009). Then, 39.89% (w/v) of distilled water are subsequently added into sugar solution and the solutions were placed on the hot plate until the sugar solutions fully dissolved in order to prevent crystallization of grain sugar in the finished products.

Last but not least, 0.08% (w/v) of citric acids and 0.03% (w/v) of multivitamin solutions were added the end preparation of sugar solutions as to avoid the harsh combination of acid and multivitamin with high temperature that might affecting the other ingredients. Lastly, the hydrated gelatin solutions were slowly poured into the sugar solutions and vigorously stirred for 1 minute in order to ensure all ingredients are homogeneously mixed beside to prevent air entrapment occurs during this stage. Prior to molding, the mixtures were slightly heated further until the resultant mixture reached final soluble solid content. After homogeneous mixture of multivitamin gummy solutions were formed, the mixtures were were poured into the specially made plastic mold trays. Then, the trays were kept in a chiller at 5°C for 24 hours to ensure proper solidification shape of molding before further analysis.

The multivitamin gummy candies were prepared with two different gelling agent such as fish and bovine gelatin in order to make the comparison analysis between these two in term of their physico-chemical, rheological and texture of finished products. The textural properties of best formulation multivitamin confection produced from each gelling agents were compared to the commercial vitamin gummy candy in the market. Then, the products were tasted by the participants.

3.3.3 Formulations For Multivitamin Gummy Candies

Table 3.1: Formulation of multivitamin gummy candies with 35 ml total of volume samples

Formulation	Ratio of gelatin to water, 1:2 (w/v)		Total content of ratio, 4:6 (w/v) glucose and sucrose, (%)	Citric acid, multivitamin, water (40% w/v total)	Total mixture, (%)
	Gelatin (%)	Water (%)			
1	9	18	33	citric acid, (0.08%), multivitamin(0.03%), water (39.89%)	100
2	12	24	24		
3	15	30	18		

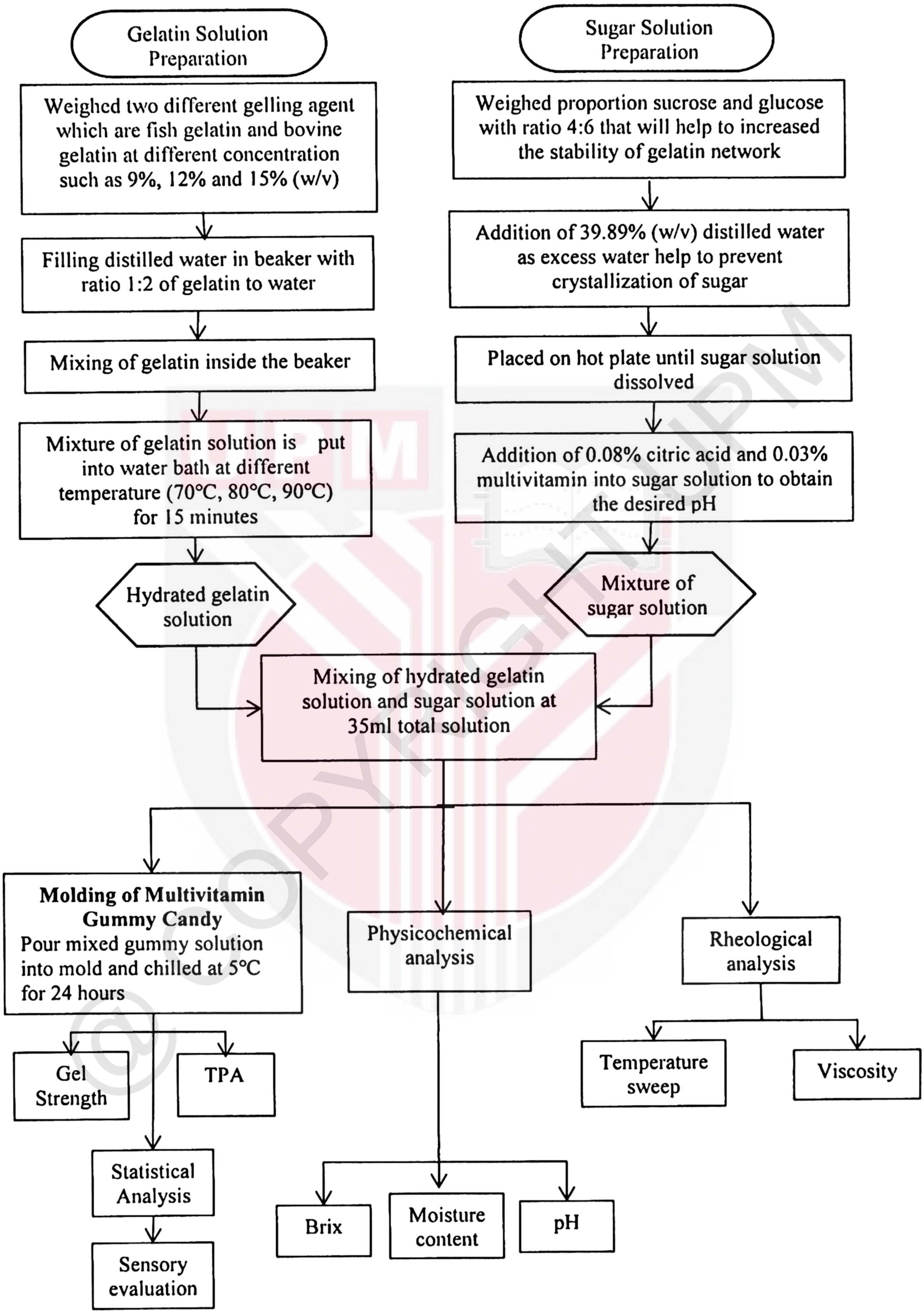

Figure 3.1 : Summary of experimental design

3.4 Physico-chemical Analysis

These physico-chemical properties in gummy candies can be especially affected by the amino acid composition, molecular weight and proportion of α chains in type of gelatin used.

3.4.1 Total Soluble Solid Determination of Multivitamin Gummy Confection Solutions

The total soluble content was measured in °Brix using a digital refractometer (AR200, ABBE Refractometer, Kruss, Germany). The working range was from 58 to 90 °Brix. A small aliquot of warm main solution was poured drop by drop to the instrument reservoir. Then, ° Brix values were recorded. To calibrate the instrument distilled water at room temperature was used. All samples were performed in triplicate.

3.4.2 pH Analysis of Multivitamin Gummy Confection Solutions

The pH is important for the stability of the gel during cooking and before molding (Hartel et al., 2018). According to Lees and Jackson (1973), the pH of the solution should be between 4.4 and 5.0 for gelatin-based products as the pH values lower than 6 can increased reducing sugar which could result in Maillard reaction and consequently flavour change (Ergun et al., 2010). The pH of solution before molding was measured with a pH-meter (s40 SevenMulti, Mettler Toledo, Switzerland). The pH value of all the solutions were kept between 4.3 and 4.5 and adjusted through distilled water. All experiments were conducted as triplicates.

3.4.3 Moisture Content Determination of Multivitamin Gummy Confections

Moisture analyzer is one the method that provides a fast and accurate analyze of moisture content food constituents. In this method, the sample is weighed, heated, dried and weighed again using the automatic function. Moisture content is calculated based on the weight difference before and after the drying procedure.Experiments were conducted as triplicates. The common moisture content for gummies based product should be between 8-22% (Ergun et al., 2010).

3.5 Rheological Analysis

All rheological measurements were done by using a Rheometer (ARG2, TA Instruments, Newcastle, DE, U.S.A.) using parallel plate geometry of 60 mm diameter with 0.8 mm gap. There two main parameters determined in a dynamic rheological test are the storage or elastic modulus (G') describing the amount of energy that is stored elastically in the structure. If it is higher than the loss modulus the material can be regarded as mainly elastic. The viscous or loss modulus (G'') indicating the amount of energy loss or the viscous response and is related to the ability of the material to dissipate heat stress.

3.5.1 Temperature Sweep Of Multivitamin Gummy Confection Solutions

Temperature sweeps where temperatures differ and the frequency of oscillation and strain is kept constant. Viscometric parameters, moduli, and other parameters are defined as a function of temperature. A temperature sweep test was used to determine the gelation and melting temperature of the gelatin samples and was conducted according to Sarbon et al., (2013) with slight modification. The stress and frequency used were 0.1 Pa and 1 rad/s. In the case of gelling, the sample was initially held at a temperature of 50 °C for 10 min to allow for balancing. Gelatin samples were cooled from 50 to 20 °C on a Peltier plate and heated up to 50 °C at a scanning rate of 2 °C/min. The gelation temperature was taken to be the temperature at which the elastic modulus started to increase dramatically. The temperature at which the G'/G'' cross occurred during cooling is near to the sol-gel transition or the gel form.

3.5.2 Shear Rate Of Multivitamin Gummy Confection Solutions

Gelatin is a non-Newtonian fluid with 'shear-thining' behavior so that its viscosity decrease ,increases with shear rate (Chandra et al., 2015). So that, shear viscosity can be find based on stiffening behavior of gelatin and the shear rate that applied to a gelatin gel. Standard shear viscosity at concentration of 6.67% (w/v) at at 60◦C is performed using rheometer (Songchotikunpan et al., 2008).

3.6 Texture Profile Analysis

Texture is defined as the sensory and functional representation of the structural, mechanical, and surface properties of foods that can be interpreted by senses of vision (visual texture), noise (auditory texture), touch (tactile texture), and kinesthetics. Texture profile analysis (TPA) involves applying controlled force to the product and recording its reaction with time. TPA is a method widely used in industry to determine the textured behaviour of foods, as it can provide an indicator of sensory properties. TPA is useful for the study of gel texture due to the texture parameters obtained from the TPA curves being well associated with the sensory assessment of textural parameters (Binsi et al., 2009)

TA-XT Plus texture analyzer (Stable Micro Systems Ltd., Godalming, UK) equipped with a 75mm diameter aluminium cylindrical probe was used to characterise gummy candies gels in terms of hardness, adhesiveness, cohesiveness, springiness, chewiness, gumminess and resilience properties. The samples were tested after the sample was removed from chiller at 5°C. Each gelatin sample was positioned centrally under the probe and the test was started. The test was conducted according to Shafiur & Al-Mahrouqi, (2009) as a platen descending from above was used at a pre-test speed of 1.0 mm/sec, a test speed of 0.1 mm/sec and a post-test speed of 1.0 mm/sec, and 80% compression was used for the one-cycle test. The gels were then compressed twice to 40% of the original height at a compression rate of 0.5 mm/sec at room temperature for the second cycle test pre-and post-compression speeds were 1.5 mm/sec.

3.6.1 Gel Strength Of Multivitamin Gummy Confections

According to the standard method of Gelatin Manufacturers Institute of America (2012), the gel strength of a gelatin sample prepared at 6.67% (w/v) must be measured at 10°C about 16-18 h. For this measurement, a specific container is used, called a "bloom jar," requiring approximately 155mL gelatin solution corresponding to approximately 10g gelatin. The test settings are also calibrated in such a way that the force needed for a 4 mm penetration into the gel of a 12.5 mm diameter sample lowered at a speed of 1 mm/s is given as the gel strength in g.

3.7 Statistical Analysis

Analyses of Variance (ANOVA) in order to discern whether the effect of the gelatin concentration and hydrating temperature on the final product were significant. The interactions between factors were also considered. Furthermore, response surface methodology was applied to describe the relationships between the factors. These analyses were performed using the Design-Expert Trial Educational version 10.0.0 software (State-Ease Inc., Minneapolis, MN, USA).

3.8 Sensory Analysis Of Multivitamin Gummy Confections

The sensory evaluation was conducted with 40 untrained panelists using a 9-point hedonic scale in order to analyze the sensory properties of multivitamin gummy candies from two different gelatin sources compared to commercial multivitamin gummy candies. Sensory attributes consists of the appearance, aroma/smell, taste/flavour, springiness, firmness and overall acceptability. Thus, 6 questions in total were included in the questionnaire.

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

In this chapter, the results of the study are presented and discussed with reference to the aim of the study, which was to study the effect of different concentration to production of multivitamin gummy candies by comparing their rheological, physico-chemical and textural properties. Also to study the effects of different hydration temperature towards multivitamin gummy candies properties. The effect of multivitamin in gummy candies formulation also be further discussed as they may effect the texture and quality of the product.

In section 4.1, will discussed the effect of different type and concentration of gelatin and different hydration temperature applied on rheological and physico-chemical properties of multivitamin gummy candy solutions while section 4.2 discussed the effect of different type and concentration of gelatin and different hydration temperature applied on rheological and physico-chemical properties of multivitamin gummy candies after moulding. After that, the optimization process of multivitamin gummy candies prepared will be explained in section 4.3. Lastly, the sensory evaluation were performed based on the optimized samples and be discussed on section 4.4.

4.1 Effect of different type and concentration of gelatin and different hydration temperature on physico-chemical and rheological properties of multivitamin gummy candy solutions.

The preparation of multivitamin gummy candy solutions according to the formulation described by mixing the sugar solution with citric acid, multivitamin and mixture of gelatin solution at different concentration which are at 9%, 12% and 15% (w/v). The multivitamin gummy candy solutions were then proceed to further analysis.

Table 4.1: The Brix, pH and viscosity values of multivitamin gummy candy by fish gelatin at 70°C hydrating temperature

Concentration of Gelatin, % (w/v)	9	12	15
°Brix	71.29±0.22	70.90±0.12	70.30±0.40
pH	4.03±0.01	4.13±0.03	4.24±0.02
Viscosity (Pa.s)	0.25±0.05	0.33±0.22	0.41±0.28

Table 4.2: The Brix, pH and viscosity values of multivitamin gummy candy by fish gelatin at 80°C hydrating temperature

Concentration of Gelatin, % (w/v)	9	12	15
°Brix	71.23±0.80	70.60±0.21	70.47±0.10
pH	3.93±0.06	4.13±0.02	4.33±0.03
Viscosity (Pa.s)	0.34±0.19	0.73±0.42	0.92±0.17

Table 4.3: The Brix, pH and viscosity values of multivitamin gummy candy by fish gelatin at 90°C hydrating temperature

Concentration of Gelatin, % (w/v)	9	12	15
°Brix	71.19±0.15	70.97.0±0.45	70.32±0.30
pH	4.04±0.01	4.19±0.03	4.32±0.01
Viscosity (Pa.s)	0.31±0.10	0.59±0.02	0.82±0.08

Table 4.4: The Brix, pH and viscosity values of multivitamin gummy candy by bovine gelatin at 70°C hydrating temperature

Concentration of Gelatin, % (w/v)	9	12	15
°Brix	73.53±0.06	73.47±0.10	72.90±0.50
pH	4.23±0.03	4.36±0.02	4.43±0.05
Viscosity (Pa.s)	0.31±0.09	0.40±0.04	0.54±0.18

Table 4.5: The Brix, pH and viscosity values of multivitamin gummy candy by bovine gelatin at 80°C hydrating temperature

Concentration of Gelatin, % (w/v)	9	12	15
°Brix	73.57±0.42	73.50±0.09	72.89±0.30
pH	4.27±0.02	4.45±0.04	4.47±0.01
Viscosity (Pa.s)	0.45±0.15	0.82±0.52	0.99±0.62

Table 4.6: The Brix, pH and viscosity values of multivitamin gummy candy by bovine gelatin at 90°C hydrating temperature

Concentration of Gelatin, % (w/v)	9	12	15
°Brix	73.36±0.11	73.06±0.14	72.73±0.25
pH	4.17±0.02	4.37±0.04	4.48±0.01
Viscosity (Pa.s)	0.41±0.04	0.59±0.01	0.95±0.36

4.1.1 Effect of different type and concentration of gelatin and different hydration temperature on °Brix value of multivitamin gummy candy solutions

°Brix is the indicative value of the total soluble solids in the solution. It is an important parameter used to understand the degree of sugar content in the multivitamin gummy solution before moulding in order to determine the quality of the final product (Xia et al., 2016). The result obtained in Table 4.1 to 4.6 showed that two different types of gelatin gels used in multivitamin gummy candy solutions had almost the same °Brix values. Tau & Gunasekaran (2016) mentioned that the typical gummy product should have approximately of 65 °Brix and that values should not be less than that, otherwise the final product will not have desired texture or elasticity. The high value of °Brix value shows a high amount of sugar in the solution which is correlates to the texture properties such as toughness, gumminess and chewiness of the final gummy candies product (Tau & Gunasekaran, 2016).

Hani et al (2015) also made the adjustment by heating the gummy solution until reached to 70-75 °Brix. They claimed the hardness of gummy candies at constant concentration increases when the °Brix value increased. They also stated the °Brix value highly related to the water activity of final gummy candies as the final product should achieve at least 75% total soluble solids to prevent the increasing of mold growth during storage. The result also showed that there is no major difference in °Brix value at different concentration and hydration temperatures. The findings obtained are therefore somewhat similar from previous research by Hidayanto, et al (2010), and they can be used to improve the quality of the gummy candies product.

4.1.2 Effect of different type and concentration of gelatin and different hydration temperature on pH value of multivitamin gummy candy solutions

The pH of multivitamin gum candy solution is one of the essential criteria in the quality specifications of multivitamin as it required the acidity of vitamin C to be preserved in such a way that it tastes close to the natural taste. So the addition of some multivitamin and citric acid help to contribute to achieve the desired acidity value. In addition, with a present of gelatin gels, pH also affects the stability and gelling capacity of the polymer. Gelatin-based gel strength improves at a pH lower than the isoelectric point of gelatin (Edwards, 2000). Thus, pH measurement is important because it may affect other characteristics, such as the viscosity and texture of the final product, because pH has a major impact on the cross-linking of gel matrices.

According to the results obtained on the Table 4.1 to 4.6, the pH values obtained from two gelatin gels are ranged from 3.93 to 4.48, which is recommended for gummy candies made with 200 Bloom gelatin (Romo-Zamarrón et al., 2019). The results showed the pH of multivitamin gummy candy solution with bovine gelatin are bit higher than fish gelatin due to their nature of isoelectric point are different whereas the isoelectric point of bovine gelatin was ranges 4.8 to 5.0 while fish gelatin ranges 6.0 to 9.0.

Besides, the results also show that the increasing gelatin concentration in formulation will subsequently increased the pH value of the multivitamin gummy candy solution. Since the gelatin has been processed from collagen, which is a protein in the connective tissue. The subunit of gelatin is amino acid, thereby increasing the amino acid content of gelatin, which caused the gummy candies to have high pH values (Jiamjariyatam, 2018) and with the presence of acid, the swelling of the leaf gelatin also become increases (Djabourov et al., 1988). Similar to the °Brix value, there is no major difference in the influence of different hydration temperatures on the pH value.

The varying pH value obtained is therefore dependent on the different type and concentration of gelatin used, because at different hydration temperatures the values are approximately the same. Other than that, the pH of the product is important as it is not suitable at very low pH because the product will not be stable or a gel may not be formed (Romo-Zamarrón et al., 2019). They also plays a crucial role in inhibiting the growth of microorganisms during further storage of gummy candies. Thus, the pH obtained is acceptable for multivitamin gummy candies production.

4.1.3 Effect of different type and concentration of gelatin and different hydration temperature on the viscosity of multivitamin gummy candy solutions.

Viscosity is one of the important commercial property of the gelatin that also plays crucial role in the food applications. From Table 4.1 to 4.6, viscosity of multivitamin gummy candy solutions that prepared with fish gelatin is lower than prepared with bovine gelatin even though both gelatin gels have same gel strength value which is 200 Bloom. Gelatin with lower viscosity may be due to the presence of low molecular weight peptide chains due to overhydrolysis of the collagen during pretreatment process and usually will produces a short and brittle texture gel, whereas high-viscosity gelatin solution produces a strong and extensible gel with higher commercial values (Rafieian et al., 2015).

In general, a higher proportion of gelatin with cross-linked components (β-or Υ-components) have higher gel strength with better viscosity relative to other gelatin because of more random coil and triple helix structures. The intensity and molecular weight β-components of bovine gelatin had considerably higher compared to fish gelatin. High molecular weight of protein molecule leads to high viscosity of gelatin (Mohtar et al., 2010) and will results higher viscosity when blending into the product.

Also the viscosity of multivitamin gummy candy solutions for both gelatin gels are increased as the concentration of gelatin in the formulation increased since the higher cross-linked between protein molecules and hydrogen bonds can contributed to higher viscosity of the solutions. At the lower level concentration of gelatin, the presence of solute is relatively high as to balanced the ingredient in a the formulation that can help to inhibited initial formation of cross-linkings required for gel network due to prevention of gelatin chains from approaching each other kinetically by increased viscosity (Sarbon et al.,, 2013).

Other than that, there are several studies shown definite proved that there is corresponding relationship between the °Brix and viscosity of solution. Hidayanto et al (2010) shown that increasing the sugar content gives rise to increased viscosity. Saravaco & Maroulis (2001) also stated an increase of sugar concentration will relatively increased of viscosity as solution become more viscous probably due to enhancement of sugar content at high concentration of gelatin since the present of protein-protein interactions in more complex behaviors, and the solution exhibits non-ideality. Thus, there is molecular crowding forces between protein molecules and other solutes into limited spaces, that increased the chance of interactions between protein-protein and protein-solvent (He et al., 2011).

The influence of temperature on the intrinsic viscosity is given by the chain flexibility parameter. The gelatin in aqueous solution is a biopolymer with a rod-like conformation with an ability to compact with an increasing temperature. In the gelling system, an increase of hydration temperature results in a increase of the intrinsic viscosity, but when reach a maximum point, viscosity then decreased because a less-extended conformation formed, as the entropy value increases with an increase in temperature and is unfavourable for less-extended conformation (Masuelli et al., 2012).

Thus, the theory described was corresponding to the result obtained that shown viscosity values were increased as hydrating temperature increased. And the viscosity of solutions especially using fish gelatin relatively higher at 80°C of hydrating temperature since the gelatin gels were be able hydrated at the stable state and their cross-link components have bound with water molecules effectively. Other than that, the difference viscosity values as different hydration temperature due to availability of protein polymer to absorbed the water molecule as increasing the hydration temperature. Since the components of a compound are bound to each other in such a way that they have lost the same free translational mobility, the volume of the hydrated molecule is always smaller than the number of the volumes of its components, the hydration is followed by a decrease in the total volume.

Overall, the viscosity increased as both parameters increased. Although the impact changes of the viscosity values are more dependent on concentrations as natural cross-linkers of gelatin can be easily regulated by the formation of sample concentration junction zones (Aydin et al., 2020).

4.1.4 Effect of different type and concentration of gelatin and different hydration temperature on the melting and gelling temperature of multivitamin gummy candy solutions

The melting and gelling temperature of the multivitamin gummy candies are an important rheological properties that need to be observed in order to understand the stability and the quality of the product that will also influenced the condition storage of the final product. The determination of the melting and gelling temperature was obtained from where the storage module (G′) and the loss module (G″) were crossover during the heating and cooling process respectively (Osorio et al., 2007). Osorio et al (2007) also expressed the average for the frequency applied did not influence either gelling or melting temperature therefore melting and gelling temperature of gels showed a consistent loss of tangent value over the frequency range used in this analysis. Generally, the changes of gelling and melting temperatures are accompanied by factors in ion strength and pH of gelatin. They decreased with an increase in ion strength which is likely due to reduction of electrostatic interaction that prevents the attraction of ionic inter-chain bridging and gelation of gelatin gels (Shakila et al., 2012).

4.1.4.1 Effect on melting temperature of multivitamin gummy candy solutions

Based on the experiment conducted, the melting temperature of all samples were plotted in Figure 4.1 to 4.3.

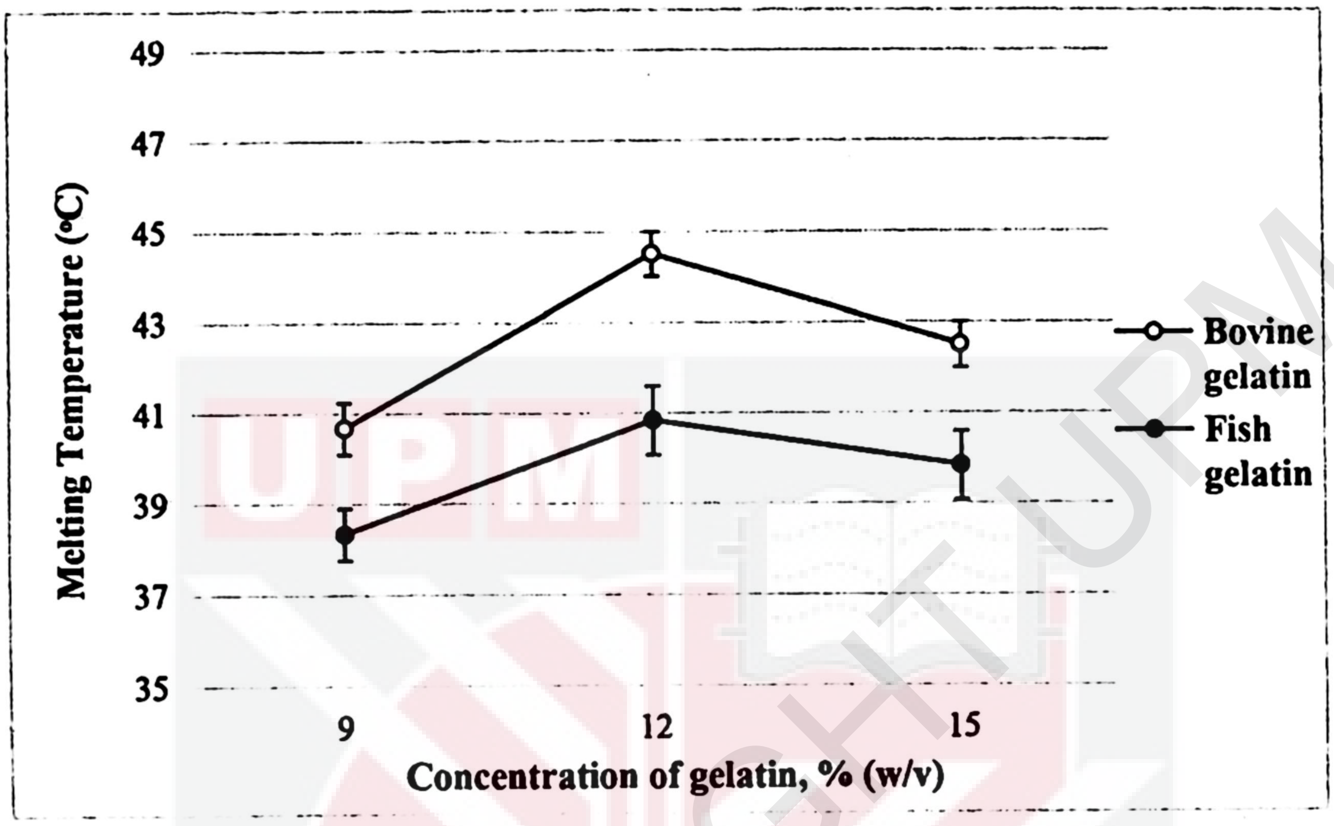

Figure 4.1 : Melting temperature (°C) of multivitamin gummy candy solutions at 70°C

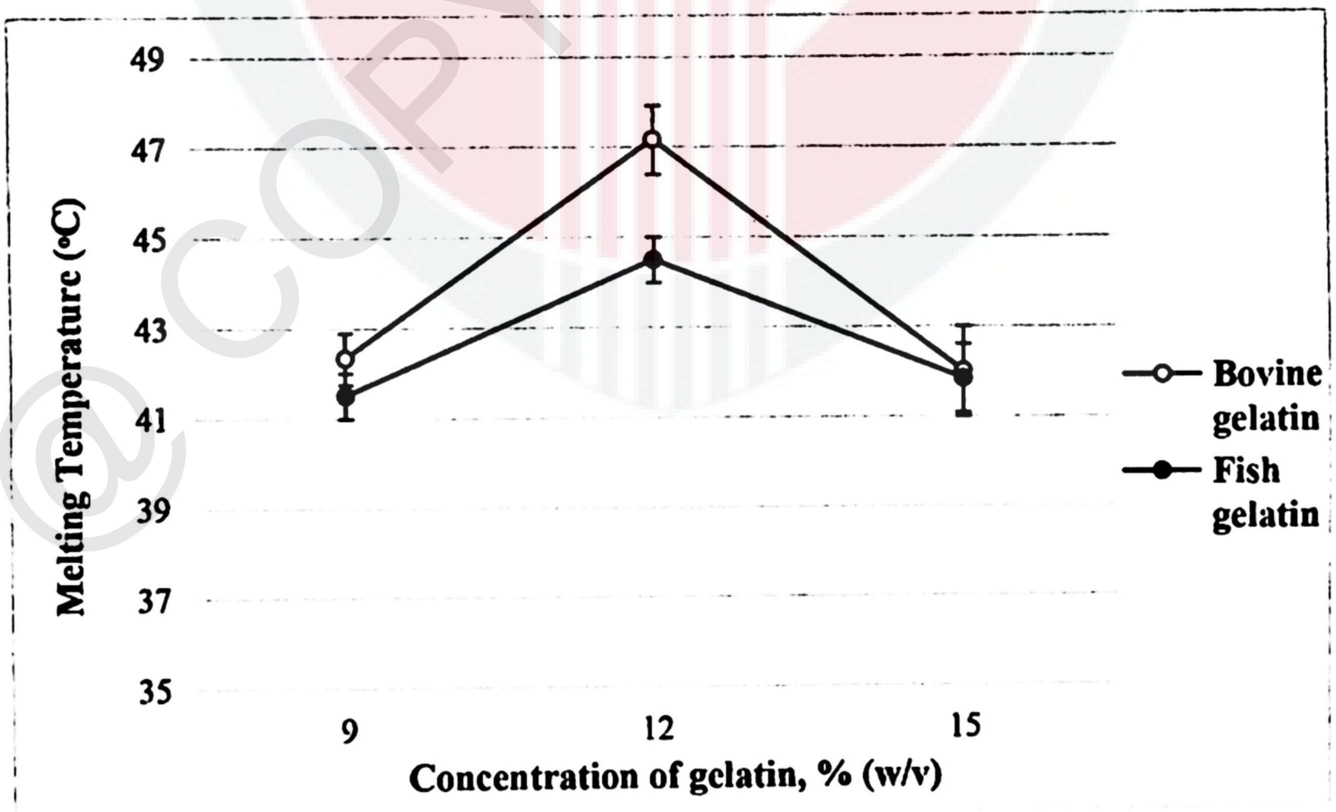

Figure 4.2 : Melting temperature (°C) of multivitamin gummy candy solutions at 80°C

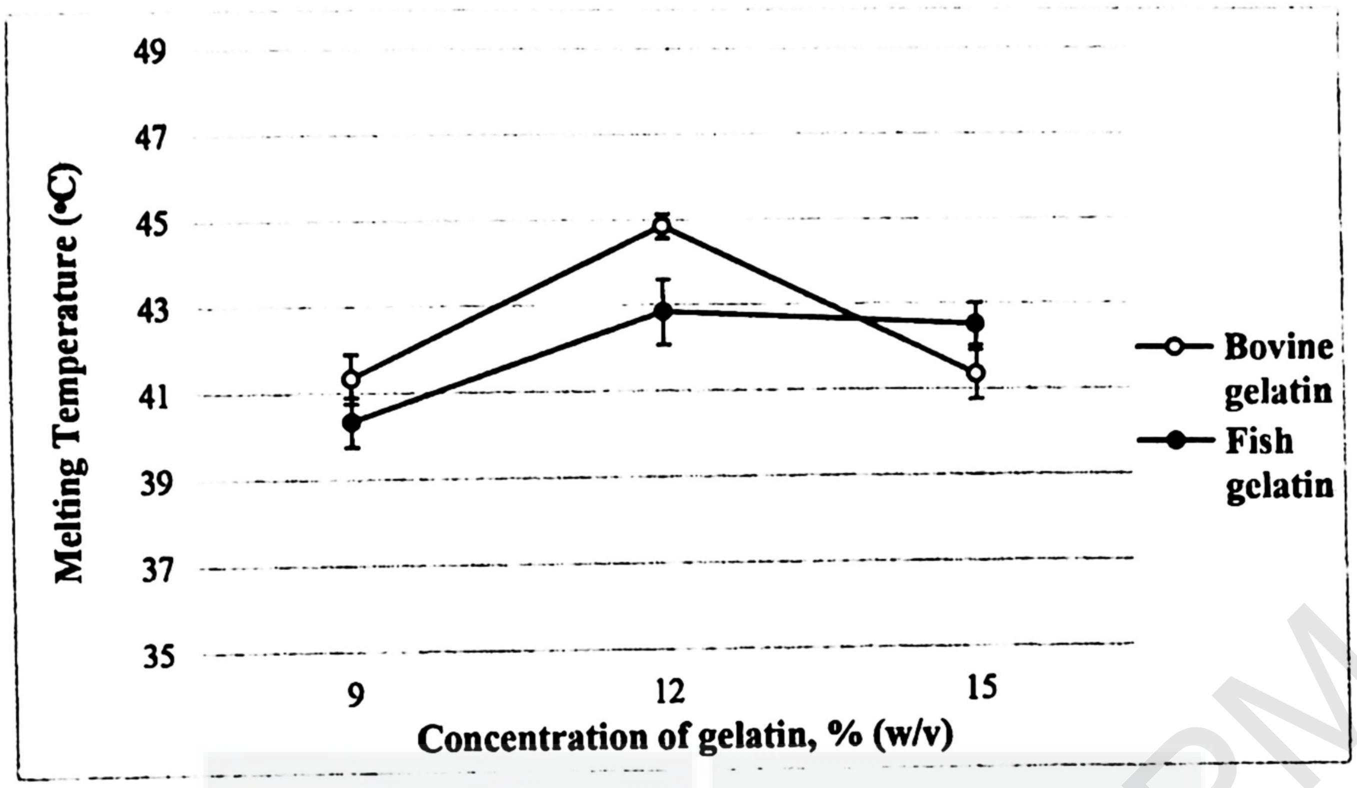

Figure 4.3 : Melting temperature (°C) of multivitamin gummy candy solutions at 90°C

According to the results in Figure 4.1 to 4.3 showed the melting temperature of multivitamin gummy candy solutions that prepared with bovine gelatin at all concentration is higher than prepared with fish gelatin since bovine gelatin generally has a higher melting point compared to fish gelatin (Ghani, 2016). The samples analyzed had a relatively sharp increase in delta due to an increase in temperature during heating, suggesting a rapid transition and phase change for each samples, which implies a relatively homogeneous molecular structure (Sarbon et al., 2013).

In fact, the higher melting temperature of samples that prepared with bovine gelatin because of the imino acid content in bovine gelatin was higher than in fish gelatin. Since, proline and hydroxyproline are responsible for the stability of the collagen structure triple helix by hydrogen bonding between the free water molecules and the gelatin hydroxyproline group (Sarbon et al., 2013). These finding also supported by Gilsenan (2000) that found the higher proportion of the imino acids would contribute higher gelling and melting temperatures.

Besides, the results also showed the melting temperature are slightly increased when increasing the concentration of gelatin from 9% to 12% (w/v) that was due to the greater number of cross-links in higher concentrations of gelatin gels (Rahman & Roos, 2017). This happens because when the increasing concentration of gelatin there are higher interactions between protein-protein and protein-dissolvent with a higher number of bonds formed that requiring higher temperatures to break them and would result in increases in melting temperature (Badii & Howell, 2006). The similar results were obtained by Osorio et al (2007) and Mabbott et al (2016) that stated as the gelatin concentration increased, the melting temperature also increased.

However, when 15% (w/v) concentration of gelatin used especially for the sample that prepared using bovine gelatin, the melting temperature were drastically decreased to the same level when the lowest concentration of gelatin used which is 9% (w/v). Upon the very high proportion of gelatin used, the viscosities will also relatively increased due to formation of macro-molecules which are strongly bound to each other by long peptide chains (Aydin et al., 2020). However, higher concentration of gelatin leads to stronger and more junction zones were formed (Ahmed et al., 2016) thus, the higher temperature is required for the gelatin gels absorbed in order to achieve helix-to-coil transformation by melting the junction zones (Sarbon et al., 2013). In meantime, this phenomenon would lead to the reduction of gelation rate when gelatin concentration is reached to a certain limit that prevented of gelatin chains from approaching each other kinetically during gelation because of the increased viscosity. Also the high concentration of gelatin can affect the stabilization of the junction zones of protein structure and reduce the amount of free water necessary to form junction zones (Somboon et al., 2014).

In contrast, at 15% (w/v) concentration of fish gelatin, the melting temperature of multivitamin gummy candy solutions were slightly increased or remained same as 12% (w/v). This happen due to different thermostability attributed by the lower proline and hydroxyproline content that makes the gelatin gels less viscous even at higher concentration in compared to bovine gelatin gels during gelation (Sarbon et al., 2013).

The obtained results also stated increased of the hydration temperature from 70°C to 80°C subsequently increasing the melting temperature since during hydration, the water molecules bind to the polar side groups of the gelatin polypeptide chains, which affect the hydrogen bonding interactions between them. It thus, can lead to a swelling of the gelatin matrices, accompanied by an increase in the average hole size as the random coil segments of the polypeptide chains are pushed apart. However, at 90°C, the melting temperature were reduced due to limit the degree of the re-arrangement of the random coil segments enforced by the extended physical crosslinks to the ordered triple helical segments (Roussenova et al., 2012).

Overall, the melting temperature of multivitamin gummy candy solutions using fish gelatin generally lower than using bovine gelatin. Thus the preparation of multivitamin gummy candies using fish gelatin under optimum condition such as at optimum hydration temperature and appropriate concentration could help to increase the melting temperature and subsequently improve the quality of the product to the same level as product prepared with bovine gelatin.

4.1.4.2 Effect on gelling temperature of multivitamin gummy candy solutions.

The gelling temperature of all samples were plotted in Figure 4.4 to 4.6.

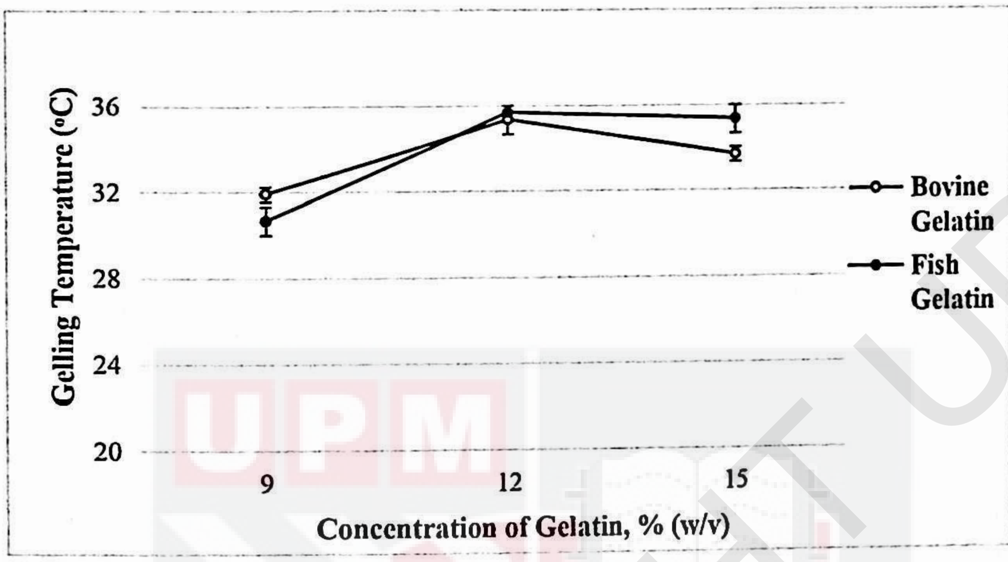

Figure 4.4: Gelling temperature(°C) of multivitamin gummy candy solutions at 70°C

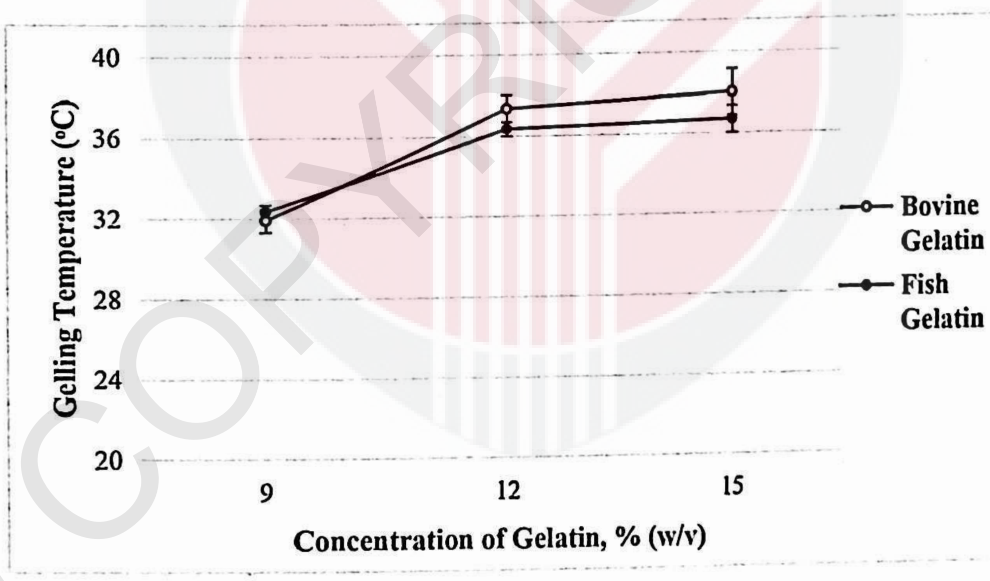

Figure 4.5 : Gelling temperature(°C) of multivitamin gummy candy solutions at 80°C

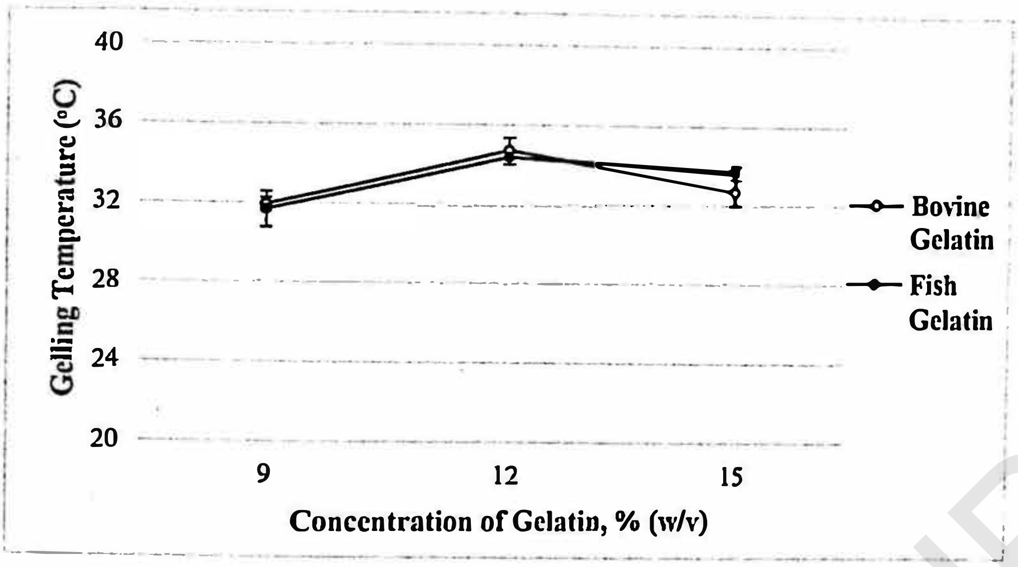

Figure 4.6 : Gelling temperature(°C) of multivitamin gummy candy solutions at 90°C

Based on Figure 4.4 to 4.6, there is slightly significant difference of gelling temperature (≥2) obtained between multivitamin gummy candies that prepared with bovine and fish gelatin. The same principle was discussed in the melting temperature also applied to the gelling temperature (Taberlet et al., 2017), and since the fish gelatin used, which is from the tilapia source, has nearly the same property as bovine gelatin so that their gelling temperature does not show a big significant difference (Gudmundsson, 2002).

Similar to melting temperature, increased concentrations from 9% to 12% (w/v) allow the formation of bonds at higher temperatures thus gelling temperature and G′ values also increases. Because during gelling process, the steadily increased of G′ values analyzed due to the increase in the amount of elastic energy stored, which indicates the rapid development of the junction zones and the rapid stabilization of the gel network (Sarbon et al., 2013). However, the further increased of gelatin concentration did not further increased of G' and G" (Wesolowska-Trojanowsk et al., 2020) as the results show at 15% (w/v) concentrations, the gelling temperature were decreased may due of excessively rapid gel-network formation (Kim, 2013) and variations in the specific heat of gelatin solutions when reach maximum concentrations that reduced their ability to transmit heat. The study by Binsi et al (2009) also stated the reduction in G' values is possibly due to water molecule trapping by high gelatin concentration and making protein gelation unavailable.

As the hydration temperature increased from 70°C to 80°C, the gelling temperature observed also slightly increased because the development gelling transition of the collagen triple helix increasing. During gentle heating at 70°C, the gelatin-water complex tends to lose water and exist as a less hydrated and causing the gelatin molecules to form gelatin-water aggregates of small size until they are sufficiently large to fill the medium and cohere to one another (Masuelli et al., 2012; Brown, 2018). The arrangement of gelatin structure gelatin is less ordered since they were 'frozen' in the form that occurs in the solution state, thus its lead to limited network junctions and is called a 'fine' gel network (Podczeck & Jones, 2004).

However when reach to the temperature of 90°C the same pattern occur as during melting process. Regarding to the structure of gelatin, higher relative temperature would likely decreased the cross-links density between gelatins while increasing its molecular mobility (Pezeshki-Modaress et al., 2018). The higher thermal energy made the gelatin molecules to have randomly move as result in fracturing of intermolecular chains giving gelatin having a weaker gelling ability (Boran & Regenstein, 2010). The studies by Park et al (2020) mentioned that in the case of the polymer network is completely swollen by water, its properties may depend very little on the temperature since the properties of water change little within the temperature window, so that the modulus shows a lower value at a higher temperature. Thus, this could contribute to inconsistent trends in both gelling and melting temperature.

Therefore, different value of the gelling temperature solution is highly effect by the optimum conditions used since both concentration of gelatin and hydration temperature could make high significant impact to increased the gelling temperature. Overall, gelling temperature of fish gelatin did not differ substantially from bovine gelatin, which means that fish gelatin may be a viable alternative to bovine gelatin.

4.2 Effect of different type and concentration of gelatin and different hydration temperature on physico-chemical and textural properties of multivitamin gummy candies.

The multivitamin gummy candy solutions were then poured into specific moulding trays and kept in the chiller for 24 hours in order to form a solid-like candies before proceed to further analysis.

4.2.1 Effect of different type and concentration of gelatin and different hydration temperature on the moisture content of multivitamin gummy candies.

Moisture content is measurement of the total amount of water in the food. Determination of moisture content after moulding is necessary in food product production as it affects many chemical and physical properties of the food materials such as the growth of microorganisms (molds, yeasts), stability, texture, organoleptic characteristics and shelf life of the food product (Yetim & Kesmen, 2009). In case of sugar based confections, moisture content plays a crucial role in determine the quality and the stability of the product after storage for a long time. So addition of water in formulation is important to maintain the moisture content of final product at acceptable level because the water content is also related to the other characteristics of gummies such as their gelling and melting temperature, since gummy candies are semi-solid food matrixes.

Table 4.7: The moisture content of multivitamin gummy candies for both type of gelatin gels

Hydrating Temperature (°C)	Concentration of Gelatin, % (w/v)	Moisture Content,(%) (Fish Gelatin)	Moisture Content,(%) (Bovine Gelatin)
70	9	24.17±0.07	22.01±0.04
	12	24.25±0.10	21.25±0.19
	15	24.03±0.12	21.93±0.05
80	9	25.94±0.13	21.25±0.12
	12	24.03±0.09	20.75±0.14
	15	23.97±0.15	20.09±0.11
90	9	24.35±0.20	21.49±0.08
	12	24.21±0.03	21.57±0.04
	15	24.16±0.10	21.19±0.11

Based on the result obtained in Table 4.7, the percentage moisture content of production multivitamin gummy candies from fish gelatin after 24 hours moulding were higher than from bovine gelatin which is around 24-26% and 20-22% respectively. The different percentage of moisture content between two gelatin gels is due to different nature of gelatin that have different affinity of water. Fish gelatin can be considered to have higher affinity of water compared to bovine gelatin (Stefferud, 1960). Also as increasing the concentration of gelling agent from 9% to 15% (w/v), the percentage of moisture content in multivitamin gummy candies reveals to be a bit decreased because the high concentration of gelatin tend to have physical interaction to each other and bound with water more easily.

The gelatin has the highest affinity for water when mixed with sucrose and therefore allows it to maintain its integrity (Burey et al.,2009). Water content in formulation aids the gel formation (Yap et al., 2019) can influence the gelatin properties, making it glassy, rubbery or viscous by manipulating the temperature of the glass transition. Jiamjariyatam (2018) also stated that the moisture content of gummy candies should be approximately less than 20% as high percentage of moisture content can lead to quality variations of gummy candies such as premature crystallization, stickiness, accelerated rancidity, lack of body structure, inconsistent of hardness and poor handling of forming (Chugunova et al., 2019).

Besides, it is important to understand of boiling point elevation during manufacturing process to control moisture content of gummy candies which is related to the texture of candies (Ergun et al., 2010). This is because even the small amount of water content present in food products could influenced the structure and texture of gummy candies (Ehiem et al., 2019). A moisture content of gummy candies plays the important role as could possibly reduced syneresis and surface stickiness other than help in retaining the shape of product since the moisture value greatly affects the gel strength (Yamabe et al., 2017).

The studies from Delgado & Bañón (2015) and da Silva et al., (2016) also mentioned the moisture content plays crucial role in sugar confections and significantly affects the change in physical and textural characteristic of product. They observed the high moisture content plausibly lead to softer texture and enhance internal mobility of all molecules that present in confections. Therefore, the multivitamin gummy candies product should be stored and dried at high relative humidity until the moisture content of product is stabilized at recommendable values.

Along with that, the moisture content also showed a minor variation impact when hydration temperature increased as the gummy candies become more harder and firmer with more elastic and chewy characteristic. They also less sticky at low moisture content. The water content is highest at the lowest hydration temperatures and the candy solutions have sufficiently low viscosity to be fluid like. As the hydration temperature increases, the moisture content decreases and the viscosity increases, resulting in thicker and thicker syrups of candy (Hartel et al., 2018).

4.2.2 Effect of different type and concentration of gelatin and different hydration temperature on textural properties of multivitamin gummy candies.

Texture Profile Analysis (TPA) is an instrumental method to analyze the textural properties of the food such as hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience that have significant affects the quality while eating. In confectionery, these parameters are important to determine the quality of the products. TPA measurements were performed at room temperature after taking the samples out of the chiller at 5°C and done at two different deformation levels, 25% and 75%.

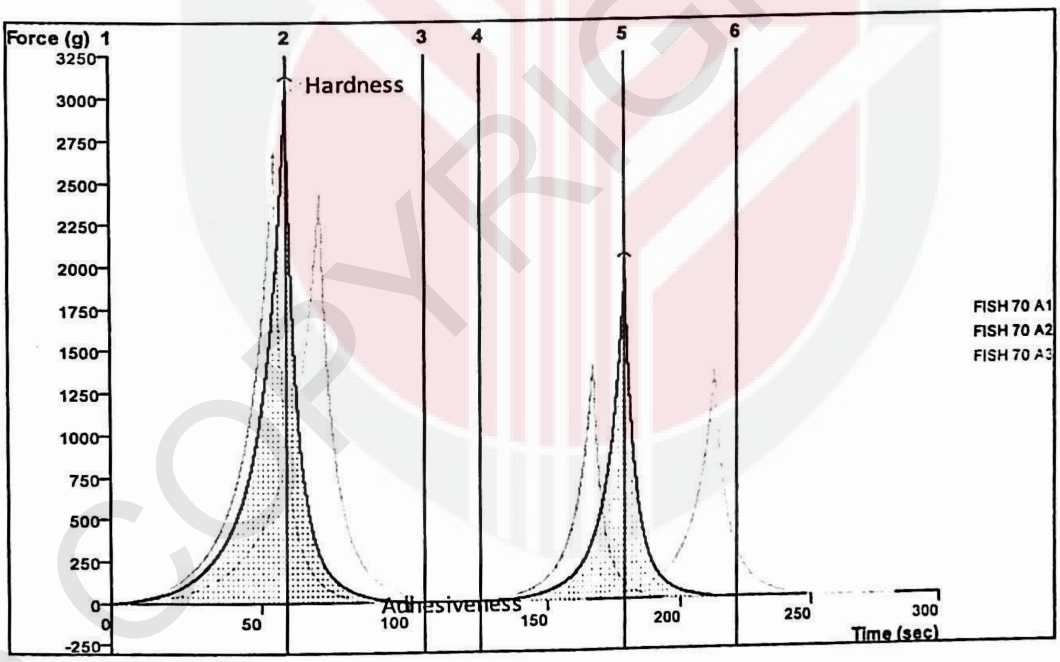

Figure 4.7: TPA profile of multivitamin gummy candies using fish gelatin at 70°C

4.2.2.1 Hardness of Multivitamin Gummy Candies

Hardness, also known as firmness, is the most significant sensory parameter for TPA analysis. It is used to determine the mouth-feel and is defined as the force required to achieve the deformation.

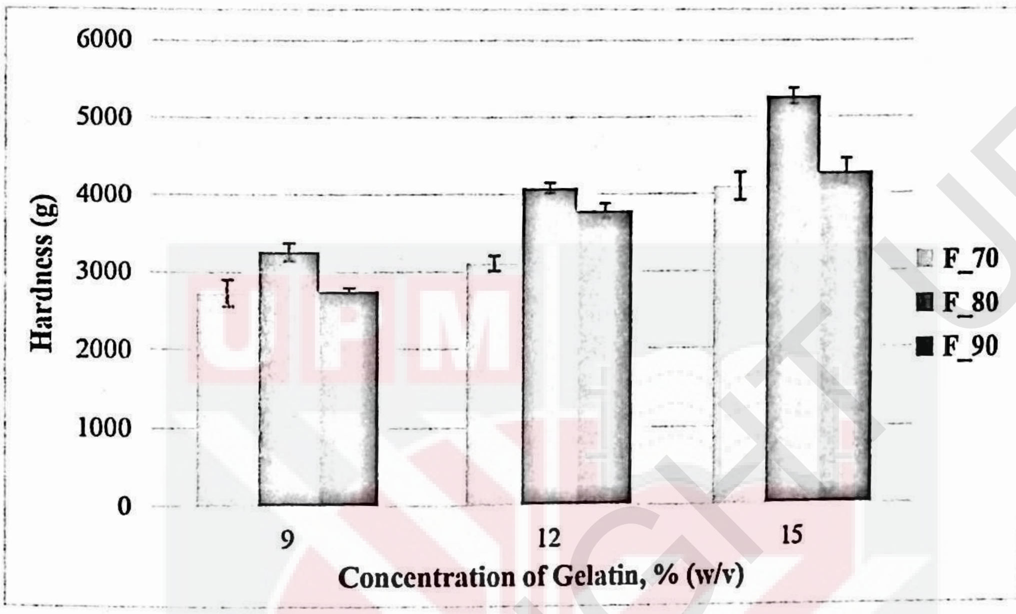

Figure 4.8: Hardness (g) of multivitamin gummy candies using fish gelatin at 70°C, 80°C and 90°C

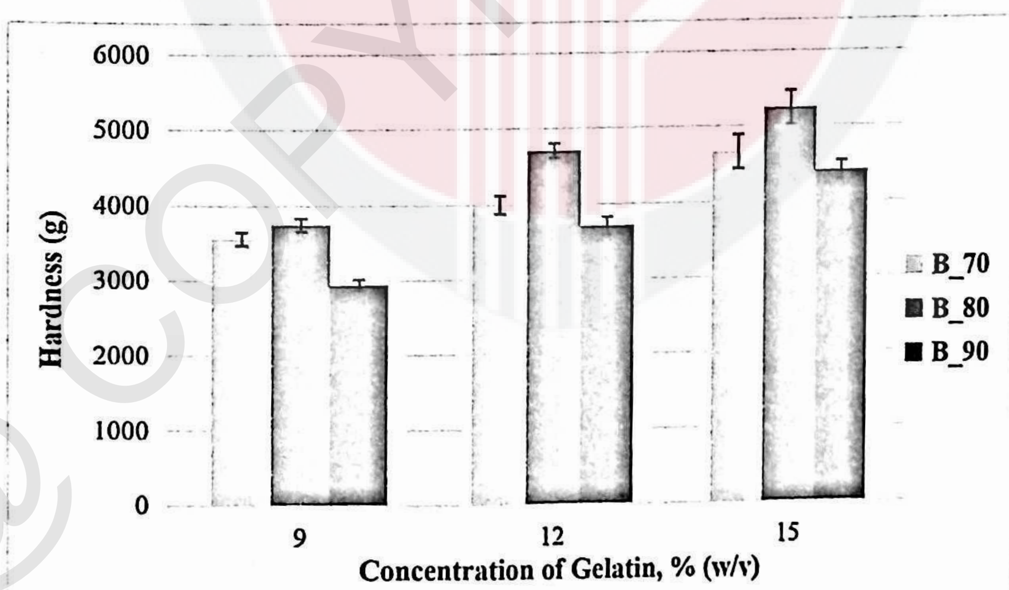

Figure 4.9: Hardness (g) of multivitamin gummy candies using bovine gelatin at 70°C, 80°C and 90°C

At both deformation levels, the highest hardness was observed for the multivitamin gummy candies that prepared with bovine gelatin. There are strong correlations were found between gel strength and hardness at both levels of compression. The strength of the protein structure of bovine gelatin with higher protein content increases the structural bonding of gelatin (Rahman & Al-Mahrouqi, 2009). The hardness of the gummy candies in Figure 4.8 and 4.9 are greatly influenced by the concentration of gelatin from 9% to 15% (w/v). Thus hardness of gummy candies prepared with bovine gelatin is relatively harder and become more harder as increasing the concentration of gelatin gels. Fish gelatin can be a good alternative when soft gels at low concentration are desired. However, in order to produce harder gels at the same degree hardness to gummy candies with bovine gelatin, the concentration of fish gelatin in the gummy candies should be increased.

Other than that, the hardness of the gummy candies is directly related to the moisture content. As the moisture content of gummy candies are reduced, the texture changes from soft to hard (Delgado & Bañón, 2015). The results from Hani et al (2015) also indicated that softening of texture occurred after addition of higher water content in the gummy confections. Since, water is well recognized as a plasticiser and promotes the breakdown of hydrogen bonds as well as the new formation of hydrogen bonds between water molecules and associated gelatin chains. Though the excessive amount of gelling agents more likely resulted to gel strengthening effects due to more reactive groups interacting with gelatin gels.

The difference in hardness between fish and bovine gelatin may be due to differences in the intrinsic characteristics of gelatin, such as the distribution of molecular weights and the composition of gelling agents. Since the moisture content for both kinds of multivitamin gummy candies are relatively same, the hardness of the gelatin gels highly depends on the type of gelatin used (Yusof et al., 2019).

Besides, the hardness also increased as the hydration temperature increased and when reached to 90°C hydration temperature for both gelatin gels started to decreased drastically. At 80°C, the hardness multivitamin gummy candies with fish gelatin surprising higher in compared to all gummy candies tested. In contrast to 70°C hydrating temperature, the hardness of multivitamin gummy candies with fish gelatin show a significantly lower value of hardness at all concentration of gelatin gels applied.

4.2.2.2 Adhesiveness of Multivitamin Gummy Candies

Adhesiveness also known as stickiness implies to the work needed to overcome the attractive forces between the surface of the food and the surface of the substance with which the food comes into contact such as tongue, teeth or palate (Yusof et al., 2019). From the TPA analysis, adhesiveness is the work required to remove the sample from the sample after the first compression (Garrido et al., 2014). The adhesiveness of both gelatin gels decreased significantly as the concentration of gelatin increased even though the bovine gelatin gels have the highest adhesiveness.

Same as hardness, water content in gelatin gels plays a role to create more open conformation for protein molecules, resulting in increased adhesiveness when the protein content is low. Thus, increased moisture content can lead to increased values of adhesiveness and springiness in low-protein products. In addition, high values of total soluble solid from sucrose and glucose in the gelling system also increased the adhesive properties. Because the higher value of adhesiveness implies to soft and sticky texture of product (Rahman & Al-Mahrouqi, 2009).

4.2.2.3 Springiness of Multivitamin Gummy Candies

Springiness also known as elasticity is the rate at which the deformed sample returns to its initial condition following the removal of the deforming force (Yusof et al., 2019). TPA springiness is related to the height that the food recovers during the time it passes at the end of the first bite and at the beginning of the second bite.

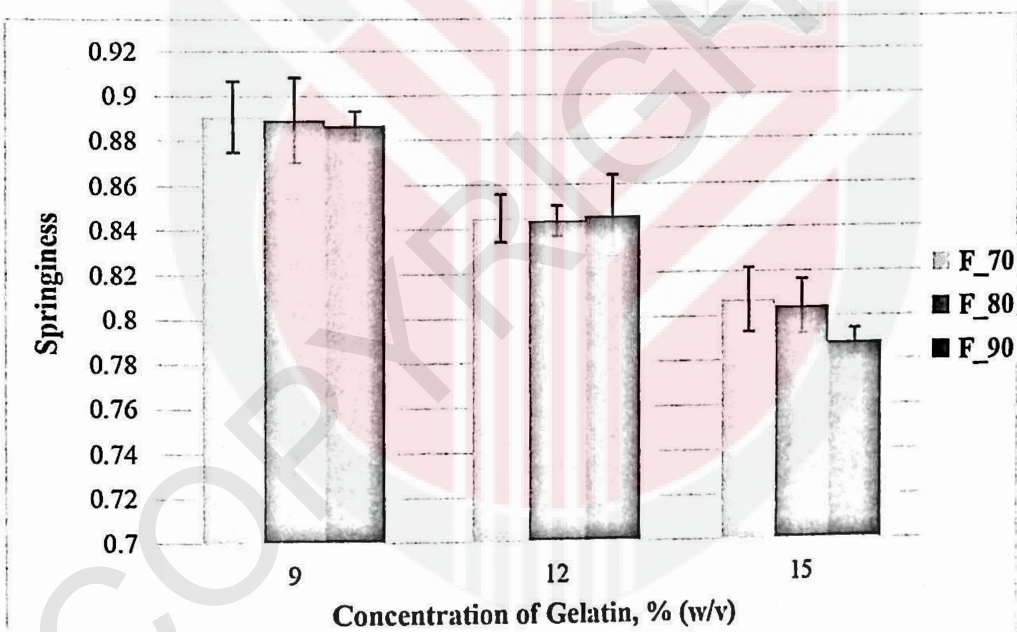

Figure 4.10: Springiness of multivitamin gummy candies using fish gelatin at 70°C, 80°C and 90°C

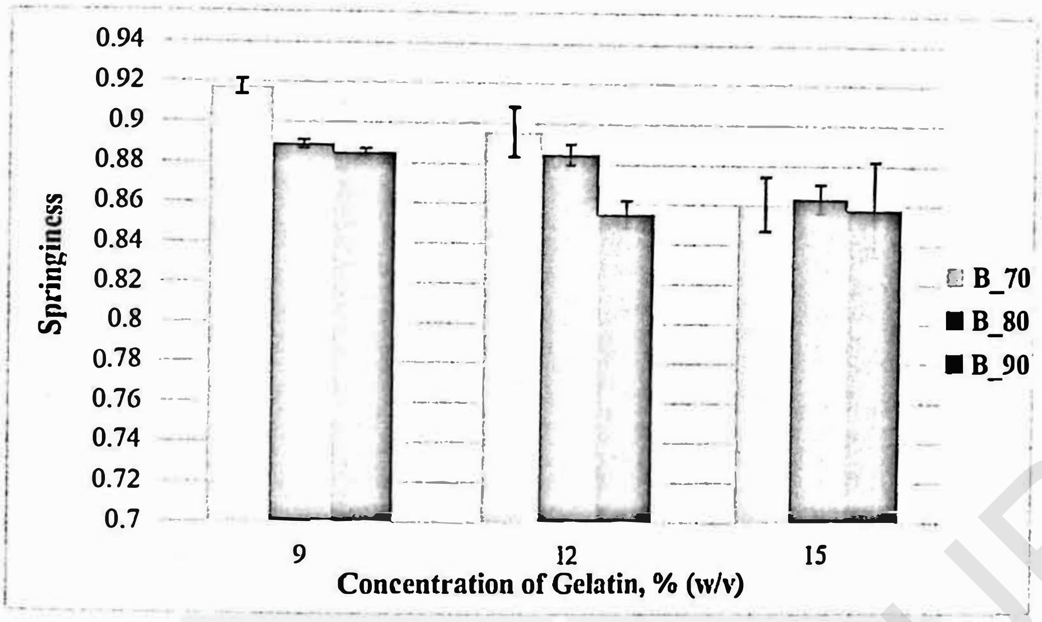

Figure 4.11: Springiness of multivitamin gummy candies using bovine gelatin at 70°C, 80°C and 90°C

The springiness of multivitamin gummy candies for both kind of gelatin gels are close to each other and highly related to the concentration of gelatin. The results in Figure 4.10 and 4.11 show increased the concentration of gelatins would result decreased the springiness of the gummy candies since springiness is inversely to the hardness. The higher springiness values at 9% (w/v) for both gummy candies may requires more mastication energy in the mouth in compared to 15% (w/v) since the gummies obtained to be more elastic (Chandra & Shamasundar, 2014).

Based on result obtained, the springiness values are also considerably related to hydrated temperature since the springiness could marginally reduced as the temperature increased even though they more highly depend on the concentration.

4.2.2.4 Cohesiveness of Multivitamin Gummy Candies

Cohesiveness is defined as the ratio of the positive force area to that of the first compression during the second compression. According to Yusof et al., (2019), cohesiveness is the rate at which the material deforms under mechanical action, which is related to the strength of the internal structure and the intensity of breaking down the internal bonds. Rahman & Al-Mahrouqi (2009) indicated the types of springiness were considered similar to cohesiveness in food product. The cohesiveness indicates the ability of the product to hold together (Chandra & Shamasundar, 2014).

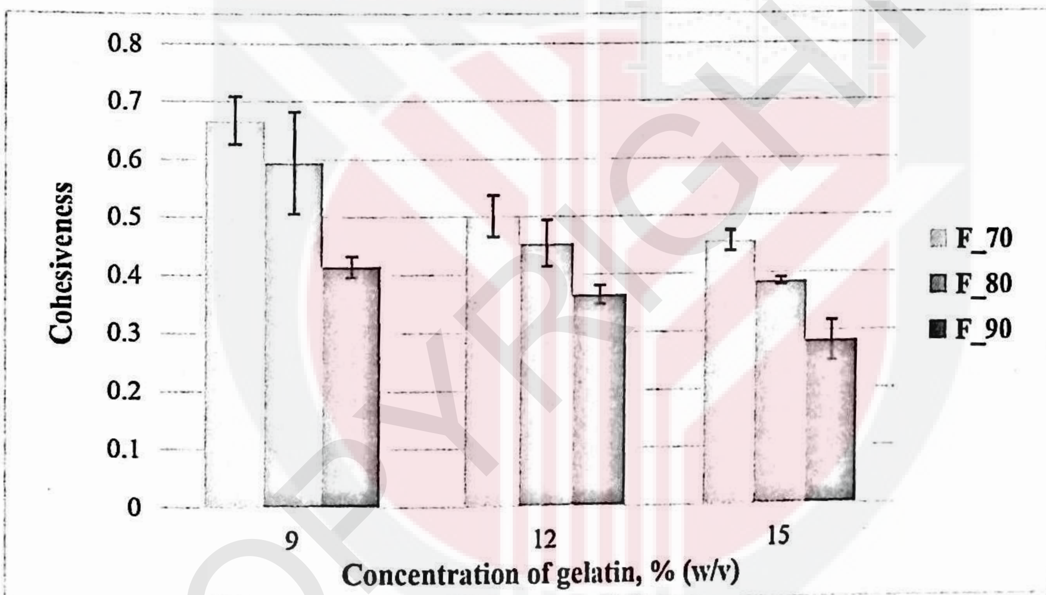

Figure 4.12: Cohesiveness of multivitamin gummy candies using fish gelatin at 70°C, 80°C and 90°C

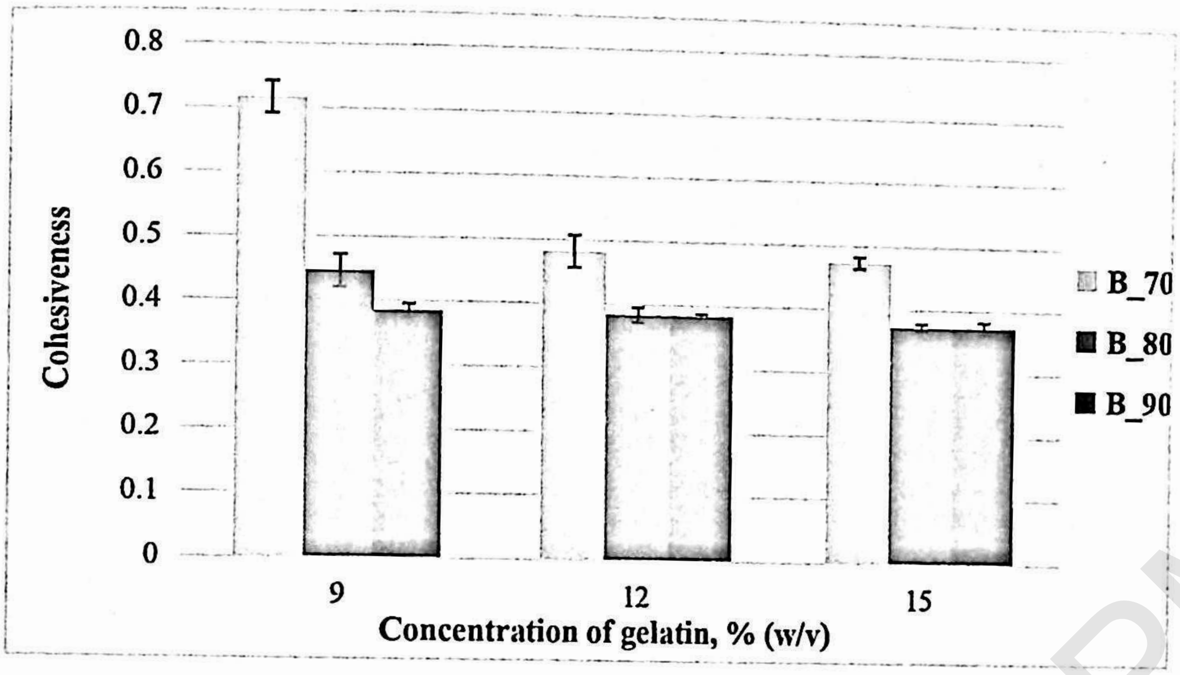

Figure 4.13: Cohesiveness of multivitamin gummy candies using bovine gelatin at 70°C, 80°C and 90°C

In comparison to hardness, cohesiveness decreases with an increase in gelatin concentration. Rahman & Al-Mahrouqi (2009) indicated that the cohesiveness increased with the increase of gelatin concentrations and when reached a maximum value of the concentration; then decreased with the further increase of gelatin concentration. This happen because there a exist a critical concentration exits for maximal cohesive bonding. The result in Figure 4.12 and 4.13 also showed the cohesiveness for both gelatin gels were consistent reduced at small different as the concentration of gelatin increased.

Though, the cohesiveness of the samples were consistently reduced when increased the hydration temperature. For example, the cohesiveness of multivitamin gummy candies with fish gelatin prepared at 12% and 15% (w/v) is lowest during 90°C hydration temperature due to the result of quick melting of fish gelatin at room temperature.

4.2.2.5 Gumminess of Multivitamin Gummy Candies

Gumminess is calculated as the hardness of product multiplied the cohesiveness.

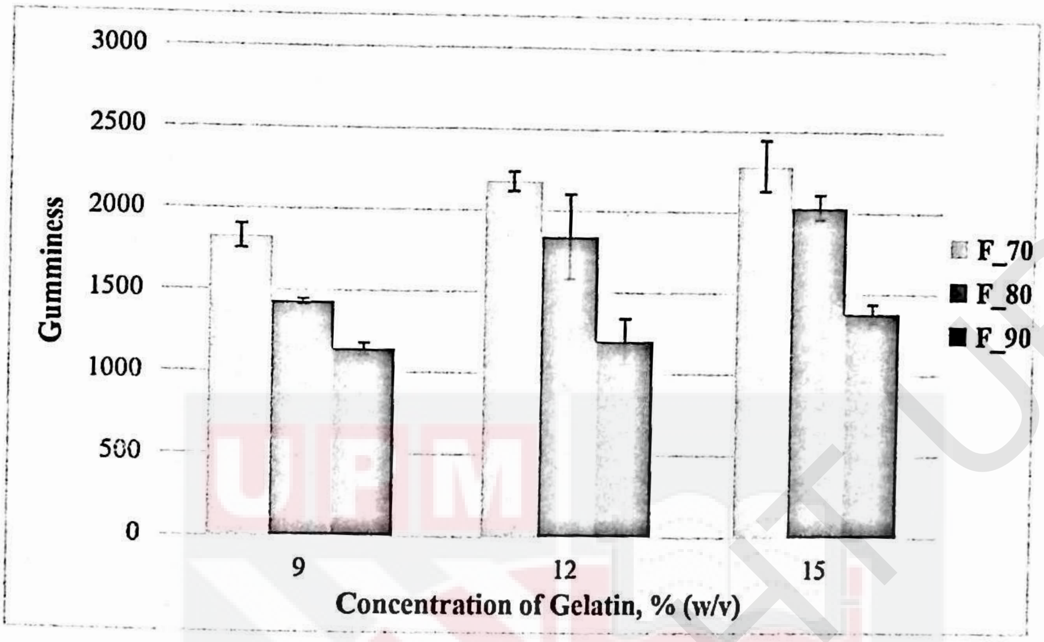

Figure 4.14: Gumminess of multivitamin gummy candies using fish gelatin at 70°C, 80°C and 90°C

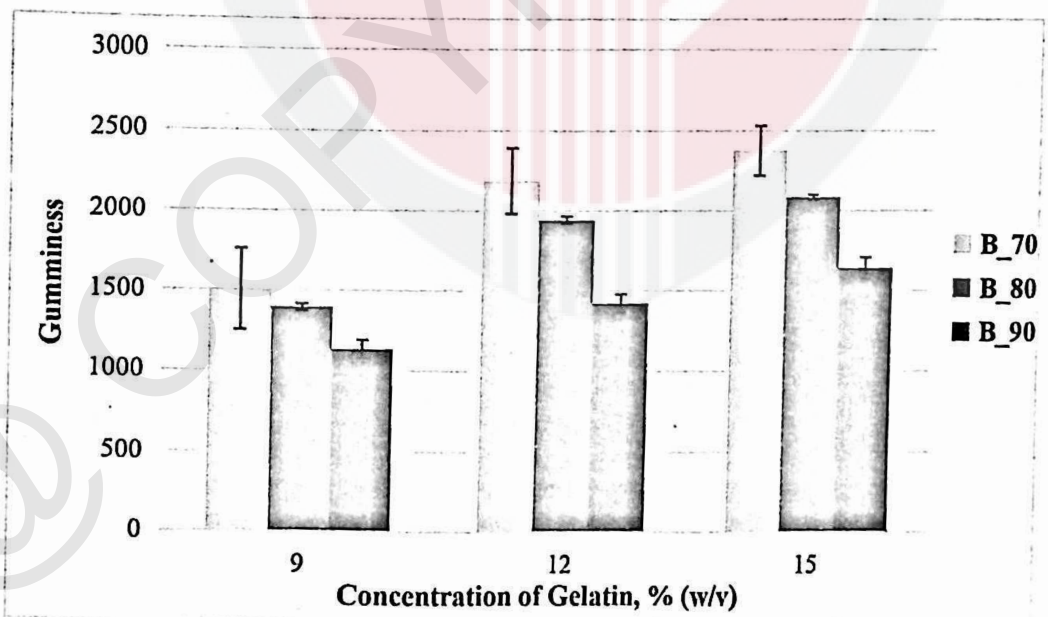

Figure 4.15: Gumminess of multivitamin gummy candies using bovine gelatin at 70°C, 80°C and 90°C

Based on the results on Figure 4.14 and 4.15 show the gumminess for the multivitamin gummy candies prepared with bovine gelatin is kinda higher than fish gelatin. These results are similar with the hardness results since these two parameters are related to each others (Yusof et al., 2019). Thus the higher the hardness caused higher gumminess (Rahman & Al-Mahrouqi, 2009). Mutlu et al., (2018) indicated that the gumminess of a product increases when hardness increases because the energy needed to disintegrate a semi-solid food product to a state ready for swallowing increases when the gummy candies is harder. Also in the case for both gelatin gels, the gumminess increased as the concentration increased. Yet, the consistent reduced of gumminess happen due to increased of hydration temperature.

4.2.2.6 Chewiness of Multivitamin Gummy Candies

Chewiness is defined as the product of gumminess times springiness. Chewiness is most difficult to measure precisely because chewing requires compressing, shearing, piercing grinding, tearing and cutting along with sufficient saliva lubrication at body temperatures (Chandra & Shamasundar, 2014).

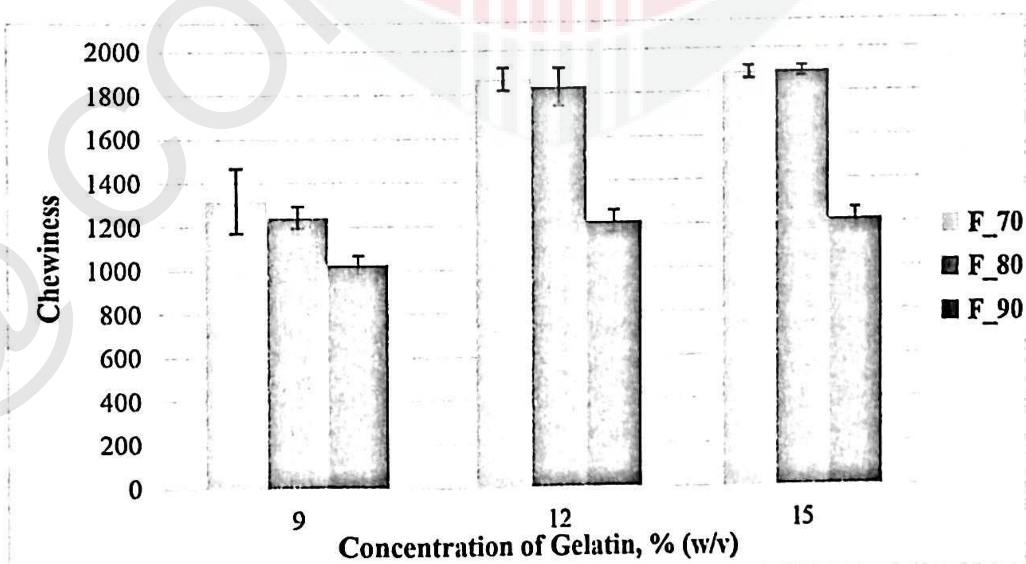

Figure 4.16: Chewiness of multivitamin gummy candies using fish gelatin at 70°C, 80°C and 90°C

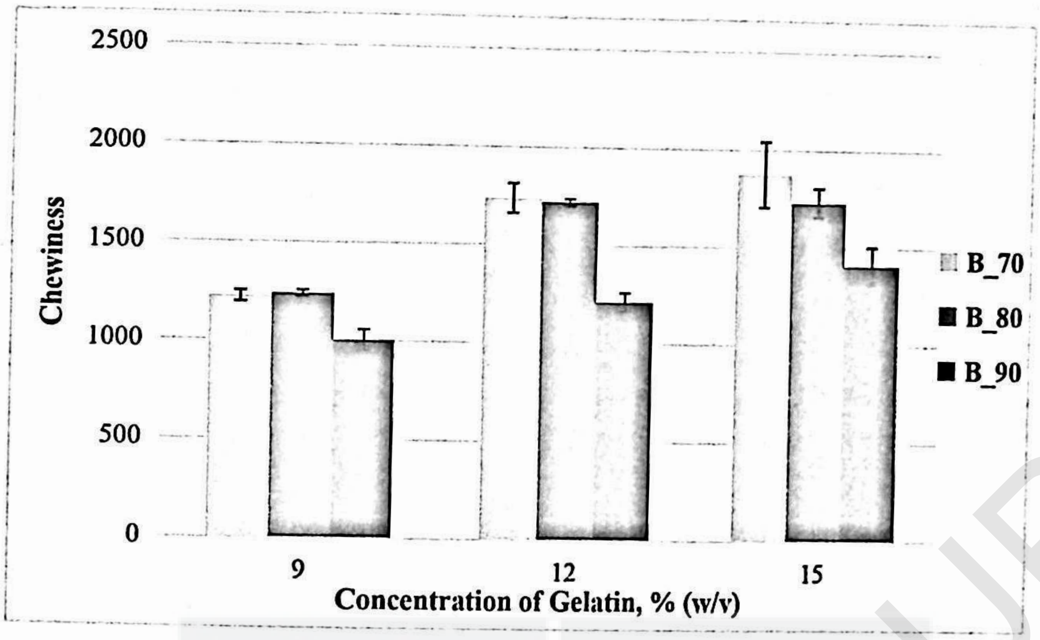

Figure 4.17: Chewiness of multivitamin gummy candies using bovine gelatin at 70°C, 80°C and 90°C

The values for chewiness obtained in Figure 4.16 and 4.17 followed the same trend as gumminess attribute. Chewiness is a measure of energy required to masticate the food and is normally reported for solid foods. The chewiness for both types of gelatin gels follows the same manner as gumminess. The research by Rahman & Al-Mahrouqi (2009) measured the chewiness as a function of water activity and found that chewiness increased with the increase of solids content.

There is a good correlation between bloom strength and chewiness values between gelatin samples. Other than that, chewiness is one of the important texture characteristics for a gummy candies product and it represents the energy required to masticate a solid food to a state ready for swallowing (Yusof et al., 2019). Similar to gumminess, chewiness also increase if the degree of hardness increases (Mutlu et al., 2018). Delgado & Bañón. (2018) has stated that the value of chewiness is more useful than gumminess for discriminating elasticity in gummy candies, a solid matrix food.

4.2.2.7 Resilience of Multivitamin Gummy Candies

Resilience is a measure of how the sample recovers from deformation in both terms of speed and strength. Its related to the ability to recover elastic is related to the nature of the network formed during the gelatin gel, which related to the properties of gelatin and extraction procedure followed (Chandra & Shamasundar, 2014).

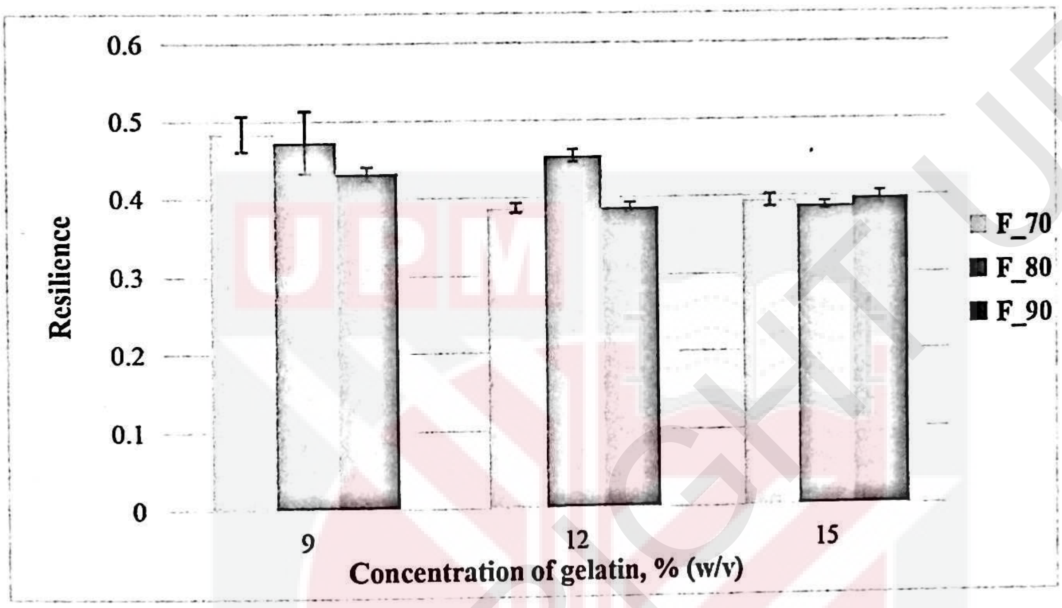

Figure 4.18: Resilience of multivitamin gummy candies using fish gelatin at 70°C, 80°C and 90°C

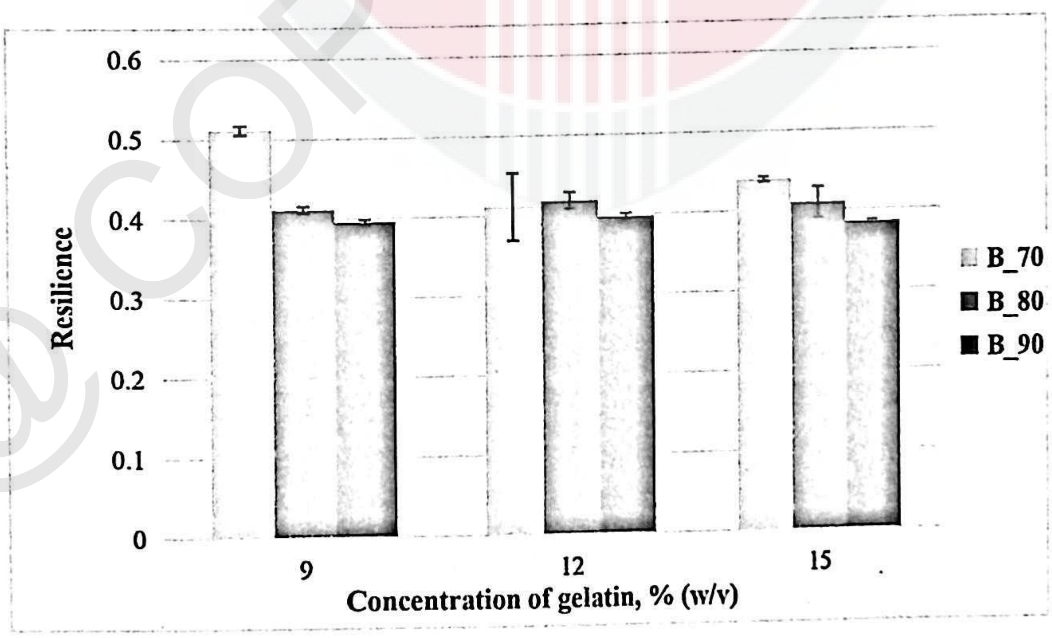

Figure 4.19: Resilience of multivitamin gummy candies using bovine gelatin at 70°C, 80°C and 90°C

Based on Figure 4.18 and 4.19, resilience multivitamin gummy candies of fish gelatin at 9% (w/v) concentration were higher compared with the 12% and 15% (w/v) concentration gels even though the overall resilience values for both gummy candies were same. Resilience decreased as the concentration of both gelatin gels increased (Rahman & Al-Mahrouqi, 2009). The variations in textural properties of multivitamin gum candies for both gelatin gels at similar concentrations could be explained by different concentrations of amino acids, molecular weight distributions and less degraded gelatin peptides (Benjakul et al. 2009).

Overall, the highest textural properties such as hardness, adhesiveness, gumminess and chewiness were observed for multivitamin gummy candies that prepared with bovine gelatins gels. While other properties such as springiness and cohesiveness for multivitamin gummy candies in both gelatin gels were close to each other. Increasing gelatin concentration in formulation caused an apparent increase in the molecular dynamics of the gummy system and hardness parameter will relatively increased due to the lead of the gel junction structure to hold the chain tightly by hydrogen bonding corresponding to a stable density structure and a compact network (Periche et al., 2014). This resulted can contribute to decrease in springiness and cohesiveness due to increase in the viscosity because when percentage of gelatin increased, a larger number of available gel sites were occupied, resulting in a strong gel texture.

The stability of the gummy candies are formulated with a specific ingredient, which is also help to increased viscous behaviour. Other ingredients such as sucrose, glucose syrup, and multivitamin may have formed intersections between gelatin molecules resulting in gels with both covalently cross-linked and microcrystalline regions (Tau and Gunasekaran, 2016). Similar to gel strength and melting temperature results, the addition of solutes significantly increased the hardness and chewiness of gelatin gels. The result was expected since hardness and chewiness values related with the compression strength and chewing energy of the product. Since both sucrose and gelatin gels were observed to contribute in network formation and improved the three-dimensional network (Cai et al., 2017).

However, with the addition of sucrose, the springiness and resilience of multivitamin gummy candies that especially prepared with fish gelatin did not change significantly and remained stable even at a high level. It therefore concluded that fish gelatin may be an effective thickener for gummy candies, as the elasticity of this type of product is needed. Likewise, the cohesiveness and adhesiveness of fish gelatin have not been affected by the addition of sucrose into the gel system which means that fish gelatin is compatible with confectionery ingredients and can be a substitute to bovine gelatin .

The data suggested hardness parameter was increased as the hydration temperature increased from 70°C to 80°C. However, the parameter was reduced at 90°C. Other parameter such as springiness, cohesiveness, gumminess, chewiness and resilience were decreased as the hydration temperature increased from 70°C to 90°C. This could resulted from direct disruption of the protein network as the hydrated gelatin at certain concentration is interfered with gelatin network and thereby lowering the dynamic gelatin stability. Gelation of denatured protein under high temperatures or a higher concentration of gelatin could possibly prevent that gelatin gels may not be able to form a continuous gel because the confectionery system's pH is near the isoelectric point gelling agents as at the isoelectric point, the swelling of gelatin is lowest (Djabourov et al., 1988). This is supported by the lower hardness values at 90°C hydration temperature in .compared to 80°C.

Therefore, the different type and concentration gelatin and different hydration temperature used contribute to the difference on textural properties of multivitamin gummy candies and have major influence to the formation junction network of gelatin gels and influenced to the stability of final product.

4.3 Optimization of Multivitamin Gummy Candies

There are 18 experiments according were carried out to determine the effect of the gelatin concentration and hydrating temperature on the hardness, gumminess and chewiness of multivitamin gummy candies. The detailed statistical data and final equations of responses for each type multivitamin gummy candies are shown in Table 4.8 and 4.9.

Table 4.8: Statistical data and final equations of responses for multivitamin gummy candies using fish gelatin

Responses	Hardness (g)	Gumminess	Chewiness
Lower Limit	2100	1000	900
Upper Limit	4100	1500	1200
Mean	3700±713.45	1200±136.29	1000±119.24
Model	Quadratic	Quadratic	Quadratic
p Value (concentrations)	0.0270	0.0165	0.0222
p Value (temperature)	0.0053	0.0024	0.0139
R^2	0.9591	0.9757	0.9642
R^2 Adjusted	0.8910	0.9351	0.9046
R^2 Predicted	0.6119	0.7126	0.5778
Final Equation	Hardness = +4153.73 +816.04 * A +148.99 * B +39.26 * AB +72.81 * A^2 -743.01 * B^2	Gumminess = +1807.50 +216.36 * A -428.13 * B - 55.99 * AB - 57.67 * A^2 - 98.99 * B^2	Chewiness = +1794.33 +235.23 * A -269.93 * B -94.69 * AB -206.96 * A^2 -233.89 * B^2

*A - concentration ; *B - temperature

Table 4.9: Statistical data and final equations of responses for multivitamin gummy candies using bovine gelatin

Responses	Hardness (g)	Gumminess	Chewiness
Lower Limit	2100	1000	900
Upper Limit	4100	1500	1200
Mean	3700±713.45	1200±136.29	1000±119.24
Model	Quadratic	Quadratic	Quadratic
p Value (concentrations)	0.0351	0.0111	0.0089
p Value (temperature)	0.0039	0.0015	0.0044
R^2	0.9873	0.9900	0.9743
R^2 Adjusted	0.9661	0.9734	0.9315
R^2 Predicted	0.8786	0.8992	0.7380
Final Equation	hardness = +4591.42 +676.40 * A -194.85 * B +89.93 *AB -44.33 * A^2 -686.83 * B^2	gumminess = +1891.81 +310.92 * A -345.38 * B -40.69 * AB -127.76 * A^2 -63.04 * B^2	chewiness = +1658.72 +258.70 * A -201.32 * B -61.48 * AB -143.25 * A^2 -152.37 * B^2

*A - concentration ; *B - temperature

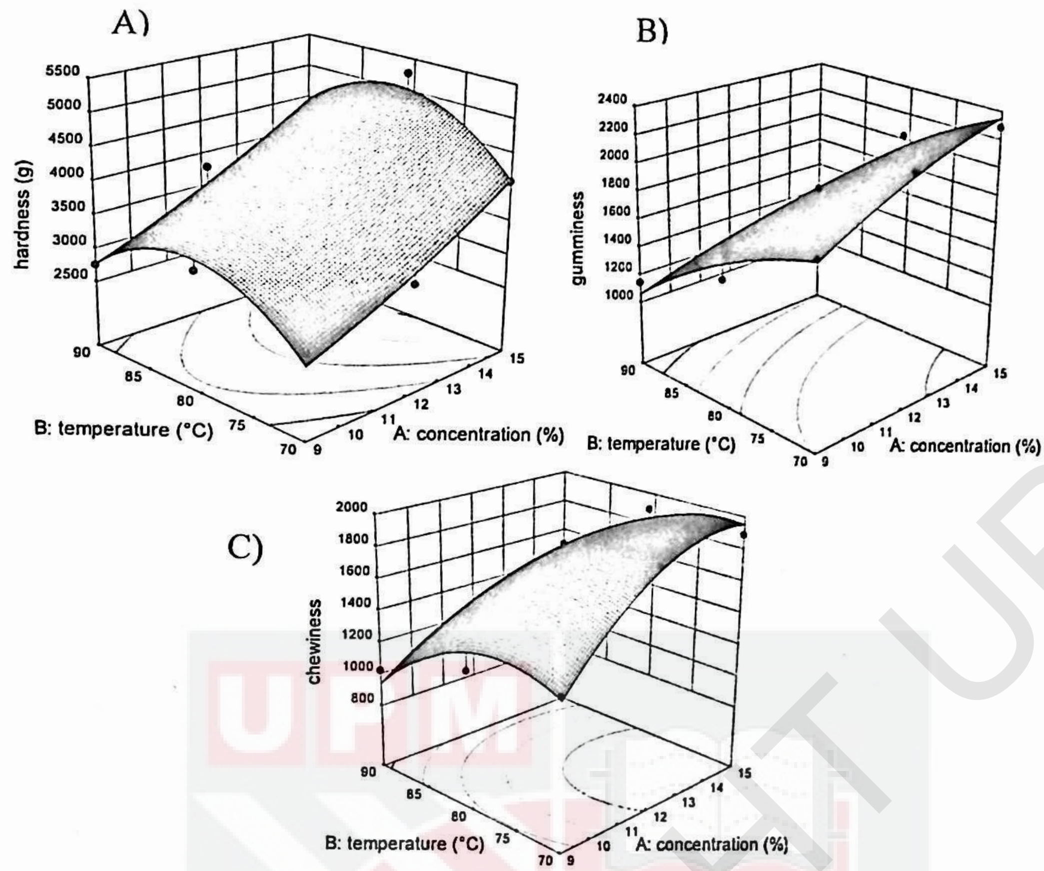

Figure 4. 20 :Influence of variables on the textural properties (hardness (A), gumminess (B) and chewiness(C)) of multivitamin gummy candies with fish gelatin.

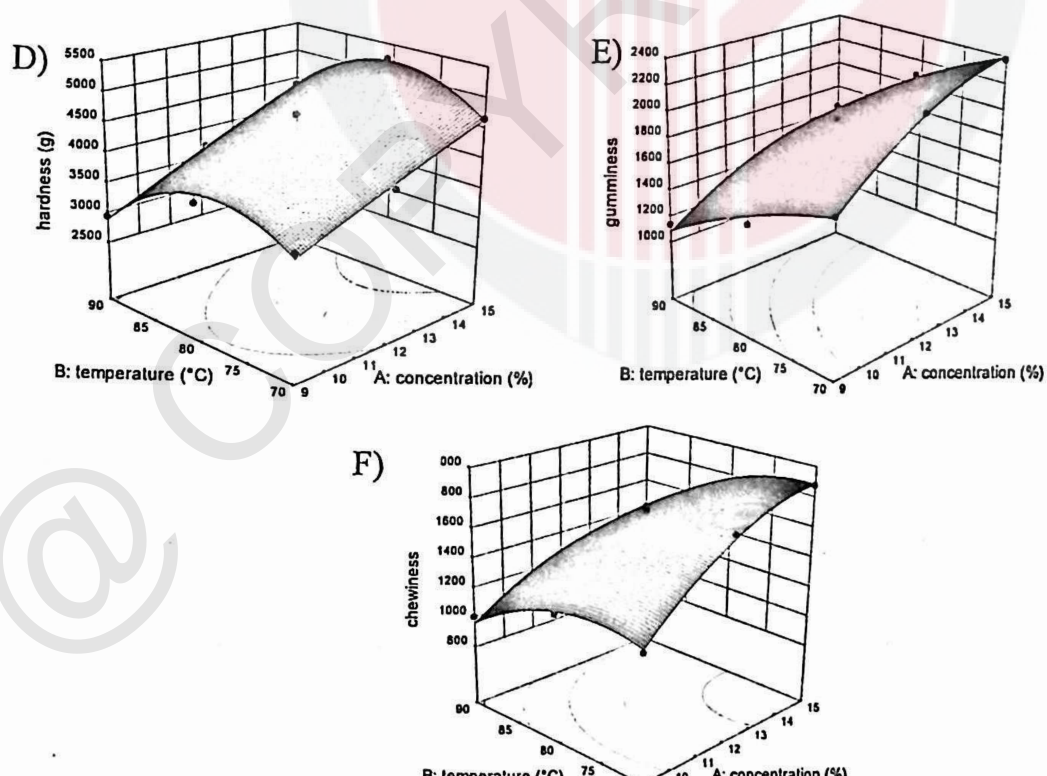

Figure 4.21:Influence of variables on the textural properties (hardness(D), gumminess(E) and chewiness(F) on multivitamin gummy candies with bovine gelatin

Based on the statistical analysis (ANOVA multifactor), it has been shown that the impact of the relationship between concentrations interactions on hardness, gumminess and chewiness for both type gummy candies were significant because p-values observed for concentration in Table 4.8 and 4.9 are less than 0.05 since the set p-value is must less than 0.05 in order to indicate model terms are significant. It also been observed from Figure 4.21 and 4.22 that increased the amount of gelatin concentrations in the formulation would increased the hardness, gumminess and chewiness of gummy candies. There was a direct correlation been observed between gelatin concentration and hardness, gumminess and chewiness. As expected, when the amount of structuring agent increases from 9% to 15% (w/v) in the formulation, the hardness of the product increased. The same trend was observed for gumminess and chewiness. Since hardness and gumminess are similar to textural properties, both can be related to the viscosity index. However the further addition resulted in a decrease in viscosity, probably due to a disruption in the development of the gel network.

On the other hand, the interaction of hydrating temperature on textural properties for both types of gummy candies is higher in compared to the concentration as the p-values obtained is much lower. A lower p-value shows that the effect of temperature is large and that effect on textural properties of gummy candies is much practical importance. From the result obtained, as the hydrating temperature increase from 70°C to 80°C, the textural properties of gummy candies will also increased. However at 90°C in regardless of any concentration, the values of textural properties shown are inconsistent due to hydration of gelatin at high relative temperature.

In general, the model with higher R-squared fits the data better and higher R-squared values represent smaller differences between the observed data and the fitted values. In order to assess the overall regression model fit that supporting the hypotheses, the adjusted R-squared is examined to see the percentage of total variance of the dependent variables explained by the regression model. Whereas R-squared shown how much variation in the dependent variable is accounted for by the regression model, the adjusted value shown how much variance in the dependent variable would be accounted for if the model had been derived from the population from which the sample was taken. Specifically, it reflects the goodness of fit of the model to the population taking into account the sample size and the number of predictors used. The R-squared around 0.9 for all the models revealed that 90% of the data fit the regression model and higher R-squared nearest to 1 is better to explain the changes in the outcome variable. Since most of the models have high R-squared and low p-value means the model explains a lot of variation within the data and is significant which is shown the best scenario of the model.

Subsequently, numerical optimization within the software was used to evaluate the optimum matching conditions. It was carried out using the method of desirability (multiple response). This approach includes target values, maximized or minimized outcome values, and expectations of their importance to evaluate the relationship between the selected variables and the desired responses. The objective of this analysis was to find the most acceptable condition of the base of the multivitamin gummy candies with good textural properties, so that hardness, gumminess and chewiness were specified as responses of major importance. Numerical optimization modulated the solution for multivitamin gummy candies using fish and bovine gelatin according to the results obtained in the experimental design and the ideal conditions with each desirability value of 0.761 and 0.891 respectively. The predicted findings were Table 4.10 and 4.11. After validation of optimized samples, there was some minor difference of textural properties between the actual value and predicted value.

Table 4.10 : The optimization based on surface response design of multivitamin gummy candies using fish gelatin

Variable	Predicted Value	Actual Value
Concentrations, % (w/v)	9	9
Temperature (°C)	79.90	80
Hardness (g)	3409.35	3261.18±0.04
Gumminess	1537.07	1430.47±0.07
Chewiness	1353.82	1243.50±0.08

Table 4.11 : The optimization based on surface response design of multivitamin gummy candies using bovine gelatin

Variable	Predicted Value	Actual Value
Concentrations, % (w/v)	9	9
Temperature (°C)	72.58	73
Hardness (g)	3699.99	3556.81±0.04
Gumminess	1645.61	1595.66±0.03
Chewiness	1276.18	1302.91±0.02

4.3.1 Gel Strength Of Optimized Multivitamin Gummy Candies

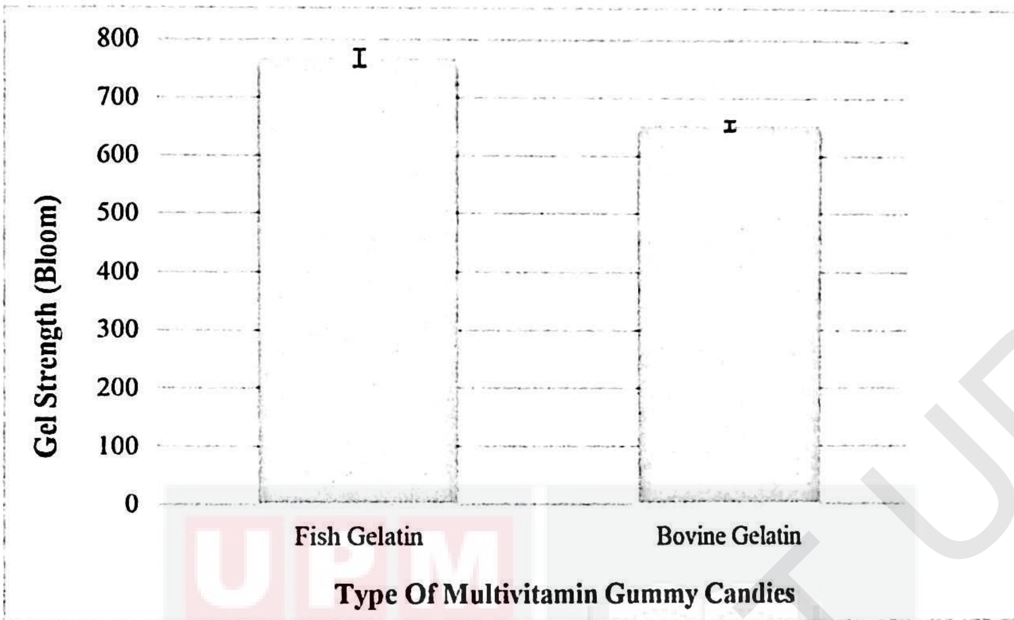

Figure 4.22 : Gel Strength Of Optimized Multivitamin Gummy Candies

Gel strength is the most crucial parameter to describe gelling power of gelatin, which is determined by Bloom test. Bloom test was measures based on the optimized condition of multivitamin gummy candies which is aged for 17h at 10°C (Schrieber & Gareis, 2007). Initial gel strength of both gelatin gels were 200 Blooms and after blending with mixture of ingredient into multivitamin gummy candies product, the obtained gel strength for both type of products increased drastically according to the result obtained in Figure 4.22. This is because the presence of co-solutes such as glucose and sucrose in formulation could increased viscosity and higher viscosity would increased gel strength. The co-solutes also function as inhibitor in the formation of stable cross-linkings gummy candy product (Kamer et al 2019). Besides, the hydrating temperature also plays the important role to increase the viscosity of gelatin during hydration process.

Moreover, the optimization result also showed the multivitamin gummy candy that prepared using with fish gelatin was equally to gummy candy prepared with bovine gelatin. This indicated that the multivitamin gummy candy product required higher gel strength in order to be matched with the characteristic of multivitamin gummy candy the prepared using bovine gelatin. Moreover, high gel strength value of multivitamin with fish gelatin contributed to the gummy and chewy characteristics of gummy (Normah & Fahmi, 2013). Therefore, fish gelatin can be used as gelling agent in multivitamin gummy product and can serve as alternative to mammalian gelatin.

4.3.2 Sensory Evaluation Of Multivitamin Gummy Candies

The optimized condition for each type multivitamin gummy candies were prepared to further analysis based on the sensory perception. According to the evaluated analysis, there was significant different of means sensory scores between multivitamin gummy candies that prepared by fish and bovine gelatin to commercial multivitamin gummy candies in terms of appearance, aroma, flavour, springiness, firmness and overall acceptability.

Table 4.12 : Means sensory scores of multivitamin gummy candies at different group

Attributes	FG	BG	CC
Appearance	6.23±1.14	6.05±1.26	4.54±1.36
Aroma/Smell	6.33±1.07	6.35±1.21	5.70±1.57
Taste/Flavour	7.03±0.95	7.08±1.05	7.75±1.03
Springiness	5.78±1.35	6.65±1.14	8.23±0.73
Firmness	5.93±1.51	6.55±1.20	7.75±1.06
Overall Acceptability	6.60±1.13	6.75±0.90	8.33±0.66

**No. of panelist = 40

*FG - multivitamin gummy candies using fish gelatin

*BG - multivitamin gummy candies using bovine gelatin

*CC - commercial multivitamin gummy candies

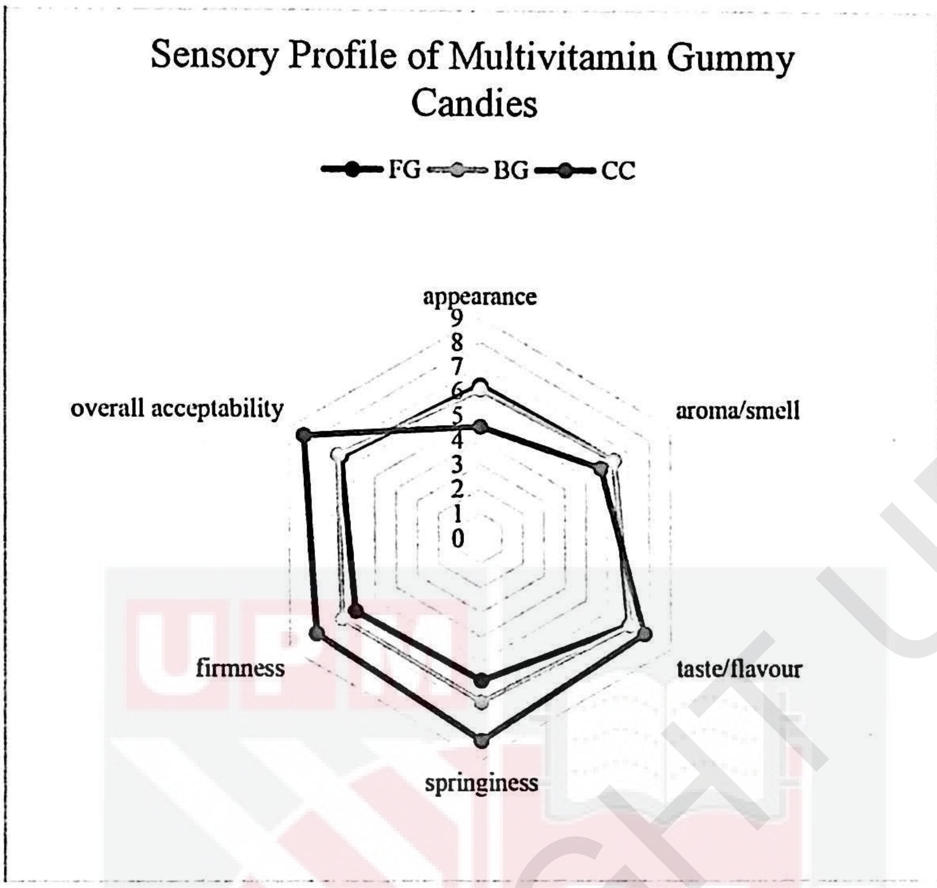

Figure 4.23 : Sensory profile of multivitamin gummy candies at different groups

Based on the analysis carried out, the appearance attributes of the CC group in Table 4.12 obtained the lowest score since the overall appearance, such as the shape and color of the commercial samples, is not very attractive. Other attributes shown in Figure 4.23, such as aroma and taste between these three samples, are slightly identical to each other as the means sensory score of each attribute for all samples is between like slightly and like moderately. From Figure 4.23, the springiness and firmness attribute are maximum in CC group and lowest in FG group samples. The different between CC, BG and FG group revealed by significant differences in mean sensory scores which is because of different source gelatin used in formulation. This is supported by a TPA study that found that the springiness of commercial multivitamin gummy candies is highest among the experimental samples. Opposite to that, the hardness value of the commercial sample is much lowest which is around 1904.97±115.48 g compared to both experimental samples.

In conclusion, the commercial multivitamin gummy candies possessed highest overall acceptability while FG and BG samples had similar overall acceptability due to the difference in attributes discussed above. Most of the panelists preferred the commercial multivitamin gummy candies compared to the experimental samples since the texture of candies is more chewy and softer even though other attribute such as the appearance is slightly unpleasant. They also agreed that as the texture of gummy candies more softer, thus the flavour released in the mouth during chewing are more acceptable. Apart from that, the texture of the candies is not sticky even placed outside the refrigerated area for a long time compared to the experimental samples.

In general, sensory evaluation results showed that commercial multivitamin gummy candies is preferable choice since most of panelist like its chewy and softer texture. However, from this observation, both bovine and fish gelatin were also ideal choice for use in confectionery products because it has similar textural properties to commercial multivitamin gummy candies.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In the scope of this study, the multivitamin gummy candies were formulated by using different concentration of gelatin at different hydrating temperature with the purpose of producing multivitamin gummy candies by using fish gelatin. Different type of gelatin such as bovine gelatin are also studied in order to make a proper comparison between production of the multivitamin gummy candies by using fish gelatin. The effect of different type and concentration of gelatin and different hydration temperature on physico-chemical, rheological and textural properties were studies by conducting several different analyses.

The studies found the physico-chemical, rheological and textural properties of multivitamin gummy candy of bovine gelatin were significantly greater even though their moisture content was approximately 20% lower than with fish gelatin. They also had higher hardness (4656.76g±386.52) and gumminess (2375.16±267.88) compared to hardness (4095.14g±315.58) and gumminess (2287.54±271.26) with fish gelatin, while other properties, such as springiness (0.854±0.05; 0.807±0.03) and chewiness (1875.68±289.01; 1889.0±50.66) for each gummy candies were close to each other since bovine gelatin generally have higher concentrations of amino acids and less degraded gelatin peptides.

There is no significant different in °Brix as concentration of gelatin increased while the moisture content would decreased from 25.34 to 23.97%. The pH increased ranging of 3.93 to 4.47 because the subunit of gelatin is amino acid, thus increasing the amino acid content of gelatin, would increased of pH values. The viscosity in solutions also increased around 0.34 to 0.99 Pa.s due to the higher cross-linked between protein molecules and hydrogen bonds. The melting (38°C to 40.67°C) and gelling (30.67°C to 37.33°C) temperature increased when the concentration of gelatin increased from 9% to 12% (w/v) due to present of the greater number of cross-links. However, further increased of gelatin concentration would decreased the melting (40.67°C to 39.33°C) and gelling (37.33°C to 35.33°C) temperature due of excessively rapid gel-network formation. Also, the increased concentration of gelatin also increased hardness and gumminess parameter. But this also contribute to decreased in springiness (0.89±0.03 to 0.81±0.03) and cohesiveness (0.67±0.07 to 0.46±0.03) as a larger number of available gel sites were occupied, resulting in a strong gel texture.

In addition, there is no major difference in °Brix, pH and moisture content at different hydration temperatures. However, the studies discovered the melting (38°C to 41.5°C) and gelling (30.67°C to 32.67°C) temperature, viscosity (0.25±0.05 to 0.34±0.19Pa.s) and hardness (2723.38g±296.24 to 2925.18g±204.32) parameter increased when hydration temperature increased from 70°C to 80°C. However, at 90°C, these properties was consistently reduced. In contrast, other textural parameter such springiness (0.90±0.03 to 0.89±0.02), cohesiveness (0.67±0.07 to 0.41±0.03), gumminess (1828.16±129.69 to 1143.73±60.89) and chewiness (1319.54±256.69 to 1025.57±73.25) also consistently decreased when hydration temperature increased from 70°C to 90°C. This could resulted from direct disruption of the protein network thereby lowering the dynamic gelatin stability.

The optimization study proposed the ratio of gelatin concentration(%) and hydrating temperature(°C) as 9:79.9 and 9:72.5 respectively for each production of multivitamin gummy candies by fish and bovine gelatin to give a better textural characteristic near to targeted values. The hydrating temperature is the most significant factor affecting the quality of gelatin although gelatin concentration is also important thus they are included as independent variables to determine their optimum levels to obtain high quality of multivitamin gummy candies. Since the present of multivitamin in formulation increased the value of candies, sensory analysis was conducted. Based on the sensory analyses conducted, it showed that commercial multivitamin gummy candies is preferable choice since most of panelist like its chewy and softer texture. However, from this observation, both bovine and fish gelatin were also ideal choice for use in confectionery products because it has similar textural properties to commercial multivitamin gummy candies.

5.2 Recommendation For Future Work

For the improvement of future work, further analyses on how refrigeration, coating, different packaging other ingredients might help preserve vitamins in gummy candies are needed. This is because the color in all the multivitamin gummy candies faded away over time, which was also noticed among the sensory evaluation panelists. Since refrigeration is being known to help preserve the quality of food product, thus it can be argued whether refrigeration might also preserve multivitamins in gummy candies rather than when stored at ambient temperature. Also, what is different between the gummy candies in this study and commercial multivitamin gummy candies in a store, is that they do not contain any coating. It would be interesting to see if coating (for example carnauba wax or beeswax) affects vitamin activity in gummy confections.

Other that that, multivitamin gummy candies should be formulated by using different type of sweeteners (isomalt, maltitol and stevia) at different concentration with the purpose of decreasing the caloric value of the gummy candies product. Then the low calorie of gummy candies were characterized in terms of physical and textural properties by using different sweetener in order to evaluate in terms of different superiorities.

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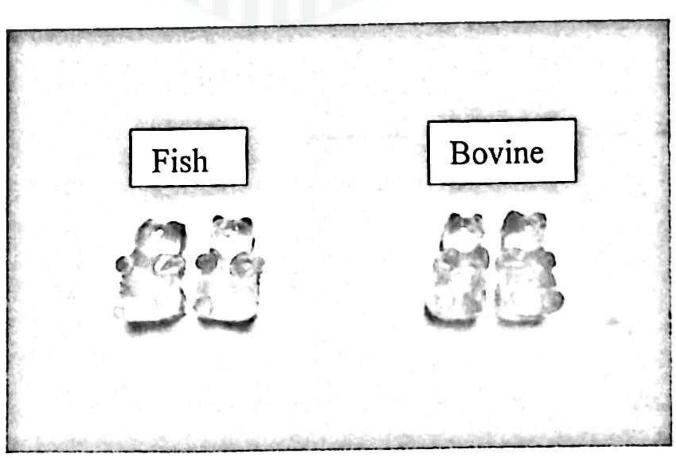
APPENDICES

Appendix 1: Bovine Gelatin

Appendix 2: Fish Gelatin

Appendix 3:Glucose Syrup

Appendix 4: Multivitamin Liquid



Appendix 5: Multivitamin Gummy Candies

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
40	7.49E-03	0.0802	0.02159	0.2051	713.4	361.5
38	8.38E-03	0.09212	0.03616	0.2765	1663	654.7
36	0.01084	0.1181	0.08934	0.4229	1803	441.6
34	0.01859	0.1766	0.2697	0.73	1866	876
32	0.08034	0.3732	1.045	1.574	2079	915.6
30	1.077	1.185	6.202	3.956	2320	979.2
28	10.87	2.518	36.19	6.863	2354	1057
26	40.87	3.885	104.4	9.714	2725	840.9
24	86.79	5.117	205.3	11.31	2530	699.9
22	150.3	5.856	335.6	16.87	2474	699.8
20	238.2	7.438	519.4	12.84	2082	1293
18	345	16.54	635.7	40.44	2269	1210
16	433.8	4.516	771.7	7.985	1895	988.8
14	538	27.28	1050	-46.36	667.5	630.4
12	607.6	52.51	933.6	63.52	130.6	126.6
10	598.1	126.4	285.4	874.1	58	56.93

Appendix 6: G'/G'' Fish 9% at 70°C during gelling

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
10	969.4	-983.3	6.807	5.107	874.2	-3.365
12	1558	1799	10.56	6.134	1028	-21.01
14	1109	-60.56	9.452	5.925	828	-99.6
16	2419	98.47	10.74	9.022	873.8	160.5
18	1327	36.22	43.55	37.16	773.6	123.1
20	1351	206.5	123.9	91.88	697.5	-44.45
22	1100	251.2	156.4	121.5	595	35.58
24	1110	55.84	212.8	134	523.9	15.98
26	819.4	-197.1	368.4	199.9	440.9	26.79
28	651	-43.7	453.1	144.8	335.8	15.5
30	509	58.57	291	188	221.1	15.51
32	270.4	26.7	293	190.7	123	6.415
34	108.6	9.424	455.4	219.5	46.9	4.063
36	18.22	4.751	460.9	264.5	6.016	2.163
38	1.388	1.5	516.8	299.7	0.1769	0.4283

Appendix 7: G'/G'' Fish 9% at 70°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
40	0.01207	0.1219	0.03362	0.03362	0.08954	0.4683
38	0.02232	0.1701	0.03998	0.03998	0.4282	0.9517
36	0.09058	0.3292	0.05101	0.05101	1.713	2.145
34	0.2467	0.5869	0.0681	0.0681	8.886	5.607
32	0.4543	0.8657	0.09367	0.09367	43.39	10.98
30	0.7678	1.195	0.128	0.128	139.8	14.1
28	1.411	1.707	0.1864	0.1864	331.2	2.508
26	2.761	2.481	0.2959	0.2959	605.6	104.1
24	6.332	4.147	0.5065	0.5065	881.9	64.61
22	20.89	7.813	1.002	1.002	1309	153.7
20	70.37	11.77	2.488	2.488	1760	223.7
18	175.9	16	4.444	4.444	2922	753.2
16	344.7	12.99	6.472	6.472	2097	-93.09
14	537.2	24.29	8.717	8.717	2350	521.4
12	841.1	-2.03	11.37	11.37	2325	-3109
10	1154	58.94	-2.377	-2.377	5434	1955

Appendix 8: G'/G'' Fish 12% at 70°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
20	1427	-4926	2289	-7729	1291	-11.59
22	4686	-452.4	3211	2973	1294	58.53
24	1146	-3129	2004	733.2	1132	270.7
26	1008	-10900	4295	1426	1037	-108
28	1771	777	3935	-3427	926.6	-0.394
30	3958	-444.4	3309	957.5	734.1	0.9289
32	2151	1061	2753	-84.41	442.8	70.99
34	2273	-336.2	2830	-529.4	212	22.85
36	1824	-556.7	2348	203	74.88	11.73
38	1642	385.9	2564	133.2	26.2	7.581
40	881.3	91.93	789	-495.6	16.3	6.955
42	853.9	88.11	918.9	-6.26	29.04	20.49
44	351.4	73.01	579.3	-11.83	69.23	51.97
46	130.2	15.06	235.8	28.21	135.3	97.81
48	21.28	7.181	65.77	15.69	262	173.6

Appendix 9: G'/G'' Fish 12% at 70°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
40	311.7	180.6	0.6861	1.424	0.07458	0.4899
38	567.9	210.8	13.55	16.96	0.4006	0.9451
36	733.5	367.7	39.08	39.73	1.907	2.147
34	915.2	436	86.46	80.85	9.79	5.919
32	988	380.3	140.3	122.8	48.03	12.7
30	761.3	451.6	192.9	146	160.5	18.42
28	519.6	415.1	147.6	122	393.5	32.89
26	546.8	421.4	82.2	78.61	761.3	-0.9835
24	316.2	320.4	73.17	63.91	1243	85.84
22	134.2	93.43	105.6	50.3	1594	249.9
20	257.2	51.89	252.2	46.72	1725	-36.43
18	572.8	31.66	530.4	-0.5094	1404	437
16	928.9	-339.1	871.6	65.37	2319	528
14	1506	75.44	1269	177.5	858.4	-856.9
12	1739	198.2	2069	-68.73	1203	2019
10	2434	-555.7	2542	408.3	-1247	-800.5

Appendix 10: G'/G'' Fish 15% at 70°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
20	1617	-107.8	1829	-156.9	1956	1342
22	636.3	1816	2043	203.4	3399	43.78
24	2439	241.4	2257	185.7	2013	-268
26	2269	155.8	1875	32.57	1677	-598.8
28	1695	411.9	1717	57.11	1433	118
30	1051	94.41	1439	-106.6	1106	58.87
32	692.3	25.63	1064	-50.62	639.1	67.95
34	274.6	26.5	621.1	38.16	254.5	22.52
36	55.99	15.05	315.4	32.36	70.4	12.7
38	7.898	5.876	108.7	24.57	12.8	5.746
40	3.204	2.416	29.88	15.77	2.42	2.119
42	3.756	2.694	17.81	13.34	0.5592	1.066
44	10.49	8.085	64.83	53.09	0.2273	0.6945
46	36.96	24.66	208.7	146	0.1871	0.6005
48	85.39	46.66	372.9	233.2	0.2678	0.689
50	129.8	65.21	569.5	313.6	0.5591	1.038

Appendix 11: G'/G'' Fish 15% at 70°C during melting

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
50	0.3027	0.7731	7.18E-03	0.08972	1937	-220.4
48	13.25	17.49	0.08038	0.251	1248	770.4
46	23.5	28.65	0.2772	0.658	2842	-1962
44	46.31	50.01	0.3757	0.8446	1219	-392.5
42	57.82	57.65	0.504	1.051	1732	143
40	76.49	75.94	0.4506	0.88	1766	1225
38	42.11	47.64	0.5451	0.944	1424	84.32
36	13.18	16.74	0.657	0.9724	1558	-1741
34	3.267	4.197	1.15	1.231	2824	2933
32	4.699	3.596	2.596	1.889	968.2	1744
30	15.67	6.762	8.375	4.089	4464	-3384
28	59.3	10.37	42.41	7.306	5246	-1515
26	154	15.33	116.5	11.87	4525	-1554
24	299.4	18.37	235.3	15.33	6162	1324
22	519.5	20.19	406.6	20.39	6167	-2512
20	730.3	51.47	616.9	8.912	1566	-6495

Appendix 12: G'/G'' Fish 9% at 80°C during gelling

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
20	843.2	-51.02	8793	-1314	830.1	36.15
22	895.9	-58.07	1082	1280	818.4	20.97
24	783.9	168.3	-2079	9195	863.6	3.928
26	656.8	-14.82	10180	-5609	740.3	97.03
28	571.7	55.52	9416	2390	559.7	-9.031
30	444.7	47.3	60.4	-8195	376.8	11.45
32	271.7	14.82	1734	957.7	197.9	12.44
34	118.6	12.02	1695	740.6	73.7	7.805
36	31.85	7.998	1063	318.2	19.01	4.42
38	17.42	8.379	845.6	419.9	8.957	2.508
40	43.55	32.75	610.4	593.2	7.55	4.062
42	131.2	95.34	1206	160.7	19.29	17.35
44	204.6	135.6	1132	413.3	59.9	49.68
46	284.2	190.8	1851	585.6	160.8	114.3
48	437.6	249	604.6	572.9	284.4	191.1
50	613.5	263.6	1686	685.9	314.9	200.7

Appendix 13: G'/G'' Fish 9% at 80°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
50	1.68E-03	0.06616	8.96E-03	0.1123	2.98E-03	0.05893
48	2.05E-03	0.0794	0.01036	0.1256	4.20E-03	0.07346
46	4.72E-03	0.1038	0.01481	0.1537	8.48E-03	0.0989
44	0.0147	0.148	0.02839	0.212	0.02344	0.1473
42	0.04562	0.2258	0.07182	0.3167	0.06923	0.235
40	0.1467	0.3836	0.21	0.5194	0.1594	0.3565
38	0.3438	0.5983	0.6936	0.9429	0.3483	0.5346
36	0.8117	0.9592	1.874	1.698	0.767	0.8116
34	2.112	1.747	5.925	3.847	1.856	1.367
32	7.574	3.961	25.61	8.215	6.799	3.248
30	35.43	7.323	91.08	13.39	28.49	5.966
28	95.93	10.53	227.2	16.15	79.35	8.473
26	210	11.41	465.3	31.74	181.4	11.97
24	349	17.46	755.5	-22.73	315.1	21.42
22	528.7	79.11	1017	67.22	480.6	19.22
20	710.8	14.91	1350	-15.24	719.7	168.4

Appendix 14: G'/G'' Fish 12% at 80°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
19.9	929.4	-26.78	173.7	15.06	343	23.67
22	884	23.34	154.3	19.16	435	24.18
24	960.4	95.01	113.1	10.54	448.7	11.85
26	718.7	38.21	60.55	7.538	397.6	18.5
28	574.1	18.37	27.03	7.862	334.2	36.83
30	434.5	6.816	13.01	5.314	239.4	12.97
32	267.6	17.55	8.89	4.742	135.4	6.704
34	114.7	11.24	9.954	7.766	47.68	5.71
36	34.25	6.586	16.97	14.74	10.89	3.025
38	10.16	3.358	33.97	28.67	3.234	1.029
40	4.862	2.003	65.21	53.51	1.672	0.5786
42	3.295	1.839	109.9	83.19	1.022	0.6663
44	3.712	3.057	130.6	94.97	0.9137	0.7151
46	11.67	10.68	156.7	115.8	1.952	1.458
48	36.43	29.05	184.3	128.7	7.477	6.188
50	79.32	58.09	199.9	142.9	20.97	16.64

Appendix 15: G'/G'' Fish 12% at 80°C during melting

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
50	315.6	181.1	0.02744	0.2355	0.01012	0.1805
48	418.8	227.4	0.2306	0.5585	0.03107	0.2793
46	595	110.8	1.43	2.279	0.1456	0.5131
44	518.9	266.4	7.024	8.838	0.3972	0.8533
42	671.5	325.8	9.522	10.99	0.8175	1.263
40	856.8	286.2	11.09	11.97	1.638	1.837
38	471.8	469.7	13.16	14.46	3.208	2.633
36	793.1	436.3	14.04	12.92	6.405	3.925
34	915.7	496.3	17.71	10	15.12	7.379
32	739.8	-79.12	53.46	16.15	57.03	15.08
30	1688	239.3	174.6	25.41	170.2	24.4
28	1982	1300	412.4	46.88	417.5	36.48
26	2906	-47.94	711.5	27.81	746.7	37.07
24	283	-2516	1280	525.9	1264	103.9
22	4791	1227	1655	-201.6	1699	165.4
20	5612	5970	2123	508.4	2650	-428.8

Appendix 16: G'/G'' Fish 15% at 80°C during gelling

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
19.9	1457	63.49	92.67	10.24	3389	-808.5
22	1251	252.9	82.02	10.51	8383	-1419
24	1364	406.7	47.71	8.172	4742	-6920
26	1132	174.5	17.61	5.559	1998	-8283
28	963.5	102.4	6.408	2.611	2824	5578
30	675	3.664	3.395	1.596	14770	-8627
32	414.2	21.65	2.158	1.308	4350	334.4
34	197.8	17.64	1.753	1.371	3219	-483.7
36	62.31	10.42	2.323	2.199	782.9	204.6
38	16.28	5.363	6.318	5.977	708.4	402.3
40	7.068	2.773	23.43	20.05	775.1	272.5
42	4.869	2.352	69.86	54.33	547.2	286.7
44	5.04	3.177	114.7	86.78	1067	202.6
46	14.61	10.98	150.1	114.2	600.4	631.5
48	36.51	27.27	201.6	147.2	1711	327.6
50	72.5	51.71	225.6	155	2164	677

Appendix 17: G'/G'' Fish 15% at 80°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
50	5.26E-03	0.07629	43.86	33.77	3.30E-03	0.03639
48	0.03423	0.1548	153.6	105.9	3.74E-03	0.0418
46	0.5866	0.994	260.2	170.8	4.59E-03	0.04999
44	2.66	3.686	399.8	241.2	6.60E-03	0.06432
42	3.083	4.255	485.9	279.8	0.01091	0.08539
40	4.67	6.18	460.9	254.2	0.02168	0.1189
38	5.606	7.252	619.8	307.8	0.0493	0.1724
36	4.567	5.87	603.9	347.7	0.1275	0.2661
34	1.999	2.375	610.8	347.4	0.3765	0.4486
32	3.679	3.002	485.1	324.9	1.168	0.8435
30	14.27	5.931	349.2	265.7	4.473	2.03
28	61.08	8.784	303.8	249.7	23.28	3.705
26	140.1	13.5	268.1	234.3	67.42	5.5
24	261.6	18.45	128	135.8	129.9	7.969
22	427.4	14.06	34.2	44.76	225.5	13.04
20	627.8	37.35	21.99	16.88	334.6	12.71

Appendix 18: G'/G'' Fish 9% at 90°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
30	873.1	75.43	418.1	-9.31	155.7	17.91
32	1002	10.07	437.7	15.15	139.9	13.02
34	960.8	-89.84	377	-13.4	101.2	14.08
36	767	108	347.9	-8.562	71.27	17.47
38	619.2	16.7	264.4	2.882	31.72	10.04
40	439.9	-5.225	202.2	7.39	15.28	7.54
42	291.4	17.39	104.9	6.646	9.275	5.845
44	107.9	11.78	40.34	3.907	12.41	10.93
46	25.97	7.899	10.06	2.326	29.5	25.07
48	3.679	3.143	3.336	0.9585	55.51	44.76
50	1.831	1.401	1.596	0.6357	77.06	63.01
52	2.162	1.727	1.058	0.5748	113.9	85.96
54	16.98	15.62	1.101	0.8411	149	107.7
56	77.79	59.42	3.169	3.192	163	120.6
58	170.4	132.1	12.31	11.5	157.9	125.8
60	299.4	197.1	33.34	27.66	175.7	131.1

Appendix 19: G'/G'' Fish 9% at 90°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
50	8.23E-03	0.06524	0.1202	0.2904	3.09E-03	0.04192
48	0.01069	0.07207	0.08067	0.219	3.78E-03	0.04592
46	0.01328	0.08375	0.07103	0.2238	4.97E-03	0.05348
44	0.01682	0.1027	0.08723	0.2795	6.82E-03	0.06482
42	0.0215	0.1319	0.1149	0.3742	9.82E-03	0.08257
40	0.03102	0.1869	0.1806	0.5651	0.01717	0.1174
38	0.07263	0.3316	0.3587	0.9205	0.04406	0.1885
36	0.3017	0.7023	0.9989	1.752	0.1753	0.3683
34	1.626	1.678	3.69	3.563	0.8829	0.9471
32	8.007	3.338	13.12	6.104	5.321	2.418
30	28.9	5.23	39.88	8.981	22.92	4.119
28	67.22	7.163	78.8	11.99	63	6.156
25.9	124.5	9.013	132.5	15.6	136	8.63
24	185.6	12.55	200.1	20.42	219.2	12.52
22	260.1	16.42	272.2	24.68	319.4	18.01
20	339	24.16	368.4	28.09	441	27.85

Appendix 20: G'/G'' Fish 12% at 90°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
20	425.1	-13.76	420.5	29.14	621	42.59
22	427.2	16.79	459.4	32.02	609.6	20.35
24	402.1	38.22	405	35.92	594.6	24
26	364.1	21.78	375.8	32.26	547.8	4.738
28	298.6	21.4	313.8	20.3	449.2	17.96
30	216.8	14.77	245.2	10.7	310.1	9.74
32	141.9	10.48	188.7	15.3	185.1	9.906
34	84.04	6.967	113.8	12.2	88.47	6.869
36	36.81	5.182	55.26	8.654	28.34	3.987
38	9.977	3.327	19.86	5.94	5.225	2.018
40	2.027	1.448	5.486	3.429	0.8579	0.7072
42	0.4403	0.6308	1.596	1.721	0.1843	0.3326
44	0.1185	0.3302	0.6523	1.016	0.05925	0.1932
46	0.06172	0.2276	0.3962	0.7244	0.03407	0.1428
48	0.05225	0.1937	0.3414	0.6208	0.02949	0.1271
50	0.06442	0.2005	0.3951	0.6437	0.03476	0.132

Appendix 21: G'/G'' Fish 12% at 90°C during melting

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
50	1579	1015	0.2323	0.7991	0.02666	0.1533
48	2255	995.2	0.4321	1.104	0.0426	0.187
46	2977	481.3	0.8101	1.614	0.06519	0.2334
44	1214	974.9	1.55	2.428	0.09849	0.2964
42	1845	543.5	2.696	3.509	0.1598	0.3994
40	1861	1253	3.845	4.638	0.2409	0.5314
38	3834	585.2	4.796	5.8	0.3822	0.7497
36	1470	1015	5.571	7.056	0.5627	1.046
34	857.9	637.4	7.121	9.126	0.9243	1.6
32	406.8	515.1	11.18	12.95	1.993	2.832
30	308	284.9	23.53	19.36	6.474	5.606
28	533.5	275.2	61.91	27.87	26.59	10.02
26	1067	305.3	138.8	36.52	71.13	13.29
24	2397	580.3	243.6	42.92	148.5	16.51
22	2750	-604.5	394.8	51.91	266.7	22.92
20	2781	1169	545.1	51.82	391.7	35.79

Appendix 22: G'/G'' Fish 15% at 90°C during gelling

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
20	5219	62.79	699	172.1	713.7	-6.716
22	2078	-4554	676.8	58.86	757.1	91.91
24	-8.299	-7222	639.7	11.48	663.5	94.26
26	3974	-1680	536.1	32.45	588.7	10.52
28	2522	177.3	451.1	19.65	413.4	8.66
30	1400	-462.4	290.1	34.41	234.9	17.59
32	978.6	164.8	150.9	27.29	91.53	12.8
34	365.3	213	59.5	21.01	22.05	8.191
36	445.3	387.5	20.83	13.99	4.696	4.019
38	972.4	553.6	8.866	8.919	1.436	2.048
40	834.3	1114	5.174	6.449	0.7667	1.297
42	1836	-242	4.043	5.388	0.6247	1.003
44	1883	1634	4.154	5.14	0.6903	0.9314
46	1671	1028	5.94	5.94	1.027	1.056
48	2447	1201	11.08	9.704	1.724	1.354
50	2141	1608	19.69	17.23	3.537	2.345

Appendix 23: G'/G'' Fish 15% at 90°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
50	36.83	33.26	9.43E-04	0.03362	2.02E-03	0.03362
48	83.81	70.74	2.01E-03	0.03998	2.78E-03	0.03998
46	125.1	94.47	2.82E-03	0.05101	5.96E-03	0.05101
44	202.9	136.4	5.05E-03	0.0681	0.01379	0.0681
42	225.3	158.4	0.01045	0.09367	0.02657	0.09367
40	177.3	129	0.01996	0.128	0.0521	0.128
38	73.62	69.15	0.04452	0.1864	0.1075	0.1864
36	14.54	17.49	0.1192	0.2959	0.2379	0.2959
34	3.421	4.281	0.3477	0.5065	0.6	0.5065
32	4.109	3.508	1.122	1.002	1.783	1.002
30	11.5	5.862	4.972	2.488	8.791	2.488
28	60.55	10.38	25.65	4.444	43.88	4.444
26	161.9	12.52	69.33	6.472	106.4	6.472
24	338	24.97	127.9	8.717	197.2	8.717
22	541.7	35.77	210.2	11.37	321.5	11.37
20	802	64.54	299.2	-2.377	463.6	-2.377

Appendix 24: G'/G'' Bovine 9% at 70°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
20	142.1	11.85	1954	41.9	569.5	41.38
22	87.18	7.702	2104	-23.26	578.9	-5.48
24	40.17	5.076	1739	235.7	548.9	-24.81
26	10.68	2.964	1805	-348.1	466.8	8.87
28	3.067	1.183	1647	126.6	387.2	24.1
30	1.162	0.6497	974.9	19.76	283.7	18.41
32	0.5969	0.475	605.9	31.25	173.7	12.26
34	0.4884	0.4975	307	33.81	78.71	8.136
36	0.7936	0.9026	102.2	17.65	19.67	5.006
38	2.387	2.365	41.81	11.94	5.009	1.933
40	12.02	9.674	28.48	12.17	2.102	1.106
42	30.59	22.93	44.64	30.03	1.321	0.9658
44	43.75	32.92	117	77.53	1.489	1.432
46	54.68	41.09	208	136.8	4.938	4.71
48	74.93	55.5	313.5	204	21.98	17.83
50	101.2	69.62	488.6	290.8	56.93	42.94

Appendix 25: G'/G'' Bovine 9% at 70°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
50	0.01412	0.1008	0.02241	0.1046	0.01571	0.1068
48	0.01693	0.1162	0.02716	0.1199	0.01875	0.1213
46	0.02225	0.1432	0.0336	0.149	0.02253	0.148
44	0.03499	0.1894	0.04857	0.2074	0.03089	0.2006
42	0.06707	0.2687	0.08643	0.306	0.0574	0.2991
40	0.1487	0.4072	0.1895	0.484	0.1334	0.4669
38	0.3587	0.6401	0.4719	0.8049	0.3594	0.787
36	0.9357	1.086	1.29	1.431	1.282	1.692
34	2.874	2.275	4.042	3.07	4.866	3.86
32	13.2	5.675	17.86	7.064	21.31	7.491
30	57.01	10.29	67.47	11.84	68.06	11.9
28	169.8	16.87	167.4	20.29	161.2	16.47
26	342	26.81	342.3	21.91	296.7	22.15
24	527.3	47.95	547.2	15.12	450.7	7.304
22	783.1	21.49	810.1	-28.63	618.8	54.37
20	1083	110.2	1009	-46.75	844.3	94.95

Appendix 26: G'/G'' Bovine 12% at 70°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
20	990.8	22.41	960.3	80.15	1266	115.8
22	1181	132.3	980.2	30.29	1231	159.7
24	1048	253.6	952	163.1	1147	-93.42
26	919.7	56.04	817	27.6	970.5	100.8
28	733.9	-8.403	683.7	23.57	789.5	77.63
30	572.6	60.34	504.6	48.28	605.6	6.725
32	375.8	23.12	338.4	27.44	361.8	40.17
34	189.3	15.66	196	20.53	169.6	15.51
36	65.19	10.68	80.45	12.2	50.06	8.865
38	17.05	5.509	22.33	6.846	10.89	3.972
40	6.443	2.587	7.081	3.233	4.243	1.913
42	3.465	1.847	3.509	2.021	2.658	1.528
44	2.669	1.905	2.408	1.736	2.609	2
46	4.876	4.104	2.397	2.109	10.12	9.245
48	13.72	11.29	7.288	7.086	36.8	28.32
50	36.89	27.78	25.72	22.98	68.8	50.42

Appendix 27: G'/G'' Bovine 12% at 70°C during melting

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
60	0.01548	0.1475	5.33E-03	0.1291	6.23E-03	0.09039
58	0.2479	0.6024	6.42E-03	0.1575	0.02089	0.1426
56	2.673	3.895	9.58E-03	0.2052	0.09167	0.2912
54	6.447	8.835	0.02198	0.2909	0.4958	0.996
52	12.24	15.6	0.0642	0.4448	2.104	3.239
50	23.5	27.94	0.1742	0.6861	3.483	4.966
48	36.19	40.21	0.4088	1.07	5.817	7.665
46	29.7	34.52	1.065	1.885	8.102	10.02
44	23.28	28.17	3.619	4.085	9.057	11.15
42	22.81	27.18	16.96	8.883	6.345	8.349
40	18.79	22.53	64	14.78	5.412	7.444
38	6.668	8.809	165.7	20.32	4.786	6.666
36	4.513	5.274	351.9	35	4.3	5.62
34	7.632	7.257	546.5	118.9	6.465	6.572
32	21.48	12.99	835.3	68.36	17.93	11
30	76.19	21.22	1096	79.99	58.6	17.18

Appendix 28: G'/G'' Bovine 15% at 70°C during gelling

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
30	234.8	34.4	202.2	28.36	61.96	10.17
32	200.4	29.28	160.9	24.59	56.65	9.327
34	120.7	18.59	100.5	13.38	28.31	6.744
36	45.98	12.59	52.41	13.09	6.123	3.659
38	15.51	7.219	16.96	7.281	0.9943	1.139
40	7.583	4.218	6.626	3.874	0.3414	0.5175
42	5.345	3.522	2.862	2.148	0.1755	0.3535
44	4.674	3.677	1.541	1.478	0.1412	0.3149
46	11.48	9.524	1.182	1.415	0.1872	0.3733
48	39.76	29.16	0.7465	1.122	0.3482	0.5817
50	71.93	49.29	0.9627	1.46	1.399	1.802
52	119.5	76.91	2.514	3.199	16.45	14.87
54	181.8	111.7	8.023	8.658	59.65	50.06
56	227.1	142.8	23.06	22.79	115.6	89.29
58	258	155.7	51.31	47.15	195.8	139.6
60	239.4	152	74.75	67.1	288.3	187.6

Appendix 29: G'/G'' Bovine 15% at 70°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
60	2.706	4.005	21.76	22.46	0.2976	0.7117
58	40.1	38.07	85.04	67.77	14.78	20.17
56	93.12	74.33	123	97.92	33.3	40.09
54	125.1	104.5	147.6	112.9	52.48	59.89
52	161.1	126.9	189.3	130.8	82.39	88.03
50	211.8	157.8	237.9	158.5	103.1	103.4
48	240.4	187.4	221.5	165.4	86.68	98.2
46	233	190.4	177.6	146.8	83.74	96.03
44	174.6	155.2	177.8	149.5	93.6	103.8
42	148.7	137.4	176.3	147.1	88.09	101.1
40	121.4	125	151.5	132.6	51.26	63.13
38	108.1	112.6	74.79	81.39	23.76	31.49
36	56.09	65.36	31.1	39.83	10.06	14.56
34	12.8	18.48	16.34	21.6	4.367	6.233
32	5.775	7.099	11.01	12.45	3.916	3.965
30	14.2	8.231	13.88	8.773	14.72	6.942

Appendix 30: G'/G'' Bovine 9% at 80°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
30	69.09	9.877	14.88	14.71	58.6	7.586
32	55.6	8.879	31.79	35.16	46.04	6.539
34	29.55	6.852	78.32	70.71	25.74	5.218
36	10.24	4.566	184.8	145.1	10.43	3.533
38	3.81	2.321	232.5	170.7	4.354	2.001
40	2.787	2.188	272.5	204.7	2.609	1.496
42	4.396	3.928	320.1	237.6	3.334	2.812
44	10.49	8.963	411.4	260.5	12.23	9.685
46	34.59	26.45	395.7	272.4	27.4	20.75
48	93.79	64.11	463.6	306.1	47.73	35.3
50	155.5	95.86	530.4	299.8	90.94	60.16
52	213.6	129.8	511.4	301.3	146.9	89.9
54	293.3	171.3	487.2	298.9	173.8	116.2
56	290.8	175.9	490.4	331.9	196.5	120.9
58	249.7	159.4	495.04	351.7	210.3	129.7
60	246.7	165.2	513.64	428.7	241.2	132.4

Appendix 31: G'/G'' Bovine 9% at 80°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
60	4.54	6.596	9.95E-03	0.2168	0.6666	1.376
58	65.39	58.35	0.0657	0.4048	32.34	32.15
56	159.4	118.4	0.3458	0.8396	71.38	63.93
54	250.5	169.5	0.9453	1.625	139.1	101.9
52	340.7	222.9	1.357	2.013	135.7	104.4
50	358	250.3	1.751	2.236	132	100.7
48	403.7	275.2	3.083	3.005	145.4	141
46	463.9	297.5	5.989	4.325	213.7	138.2
44	487.8	312.3	15.32	8.109	152.3	135.9
42	368.2	278.8	64.4	15.14	104.8	105
40	226.2	217.1	183.6	22.13	91.8	93.55
38	205.6	198	413.2	18.59	92.29	90.52
36	186	179.1	725.4	18.83	56.86	57.79
34	76.32	80.44	1178	-82.1	9.184	10.56
32	27.92	21.02	1618	-22.16	13.24	6.296
30	78.34	18.78	2053	398.4	47.12	10.92

Appendix 32: G'/G'' Bovine 12% at 80°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
30	42.16	7.528	68.91	11.82	62.62	10.78
32	40.09	6.809	67.04	12.32	56.95	9.223
34	20.21	4.997	58.91	9.19	27.26	6.736
36	3.705	2.653	35.86	9.08	4.681	3.374
38	0.2733	0.8014	19.5	6.977	0.4808	0.996
40	0.03626	0.3024	6.234	4.387	0.1182	0.4179
42	0.01717	0.1853	2.141	2.317	0.06024	0.2782
44	0.0148	0.1442	1.405	1.8	0.05553	0.2452
46	0.01862	0.1331	2.132	2.591	0.0934	0.2908
48	0.03333	0.1496	5.377	5.35	0.2418	0.4933
50	0.07889	0.2162	10.37	9.248	1.362	1.651
52	0.4635	0.6407	20.42	16.05	13.54	12.17
54	4.091	3.834	40.41	27.73	56.18	47.45
56	11.55	10.11	57.81	38.53	104.1	82.48
58	27.48	23.4	72.22	48.12	166.1	124.1
60	59.5	48.49	89.24	63.54	253.1	165.5

Appendix 33: G'/G'' Bovine 12% at 80°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
60	9.28E-03	0.08361	8.36E-03	0.07749	6.60E-03	0.05537
58	0.05894	0.2084	0.03932	0.1728	0.01576	0.09598
56	0.408	0.8281	0.3076	0.6391	0.07234	0.2111
54	4.777	6.868	2.873	3.963	0.2201	0.4863
52	11.69	15.15	11.27	13.3	1.359	2.52
50	17.9	21.89	20.36	22.79	2.88	4.665
48	26.01	31.31	24.26	27.24	2.991	4.878
46	37.34	41.3	29.72	33.29	4.02	6.209
44	37.18	41.69	38.6	41.86	5.246	7.433
42	27.49	32.33	37.13	40.72	5.13	7.172
40	21.87	25.92	24.09	27.48	2.613	3.789
38	18.82	21.72	16.46	19.27	2.031	2.268
36	13.47	14.86	12.54	14.01	3.284	2.702
34	10.6	8.807	14.23	12.43	6.713	4.125
32	24.78	9.591	28.19	12.35	19.34	7.272
29.9	66.86	13.18	68.04	14.51	59.38	11.05

Appendix 34: G'/G'' Bovine 15% at 80°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
30	43.4	14.78	24.17	16.67	24.6	14.74
32	45.7	14.48	33.77	17.48	32	15.57
34	44.43	12.45	34.42	16.44	32.06	14.53
36	32.63	10.68	29.15	14.54	26.18	12.15
38	21.65	9.16	20.47	12.26	17.55	9.635
40	11.91	7.34	12.37	10.08	11.05	8.103
42	4.564	4.995	7.065	8.087	4.767	5.456
44	1.606	3.218	5.195	7.227	2.069	3.935
46	0.5963	1.914	5.826	7.956	0.8974	2.634
48	0.3376	1.379	8.029	9.924	0.5138	1.945
50	0.2625	1.123	9.899	11.69	0.3901	1.584
52	0.2918	1.032	14.3	15.48	0.446	1.529
54	0.4858	1.209	25.93	23.98	0.6946	1.61
56	1.079	1.912	36.25	33.2	1.427	2.248
58	3.442	4.609	39.39	34.72	3.562	4.394
60	11.18	11.73	50.36	41.17	6.799	7.741

Appendix 35: G'/G'' Bovine 15% at 80°C during melting

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
60	0.02418	0.1311	0.5759	0.9858	1.303	2.305
58	2.988	3.918	13.66	12.28	37.07	33.09
56	29.37	26.32	38.79	29.52	114.2	76.54
54	86.73	62.88	79.37	51.54	185.9	128.7
52	142.5	97.61	125.8	74.17	237.9	142.5
50	174.8	115.3	183.4	108	286.7	164.4
48	211.7	140.5	193.1	122.6	362.3	201.5
46	270.1	171.9	176.7	123.9	407.7	230.3
44	334.1	197.6	242.7	140.6	397.7	214.6
42	299.2	188.3	282.5	168.9	335.1	220.3
40	219.1	158.1	266.1	176.3	320.6	201.4
38	179.2	149.7	188.6	141.7	308.4	231.7
36	158.8	141.6	110.6	102.2	279.7	223.2
34	144.6	132.2	79.12	84.31	144.4	140.7
32	98.56	104.5	58.62	66	55.61	69.28
30	55.44	54.33	51.54	51.64	47.57	45.22

Appendix 36: G'/G'' Bovine 9% at 90°C during melting

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
30	60.53	10.03	69.09	9.877	52.9	15.26
32	65.34	10.69	55.6	8.879	71.09	37.19
34	49.47	8.885	29.55	6.852	70.11	6.059
36	33.53	8.093	10.24	4.566	37.79	8.898
38	13.69	5.505	3.81	2.321	25.73	11.93
40	4.972	3.842	2.787	2.188	11.73	9.129
42	2.228	2.261	4.396	3.928	8.34	9.904
44	1.62	1.829	10.49	8.963	12.15	14.15
46	2.213	2.468	34.59	26.45	30.37	28.95
48	5.938	5.536	93.79	64.11	61.33	50.84
50	19.84	15.39	155.5	95.86	71.57	59.22
52	41.49	30.57	213.6	129.8	70.85	60.03
54	67.98	47.98	293.3	171.3	77.89	66.58
56	107.9	72.41	290.8	175.9	89.32	74.97
58	130.7	85.75	249.7	159.4	92.31	78.28
60	131.4	90.33	246.7	165.2	95.4	79.97

Appendix 37: G'/G'' Bovine 9% at 90°C during melting

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
60	0.06758	0.3747	8.56E-03	0.07923	14	13.45
58	2.152	2.581	0.1152	0.2916	70.06	53.21
56	1.61E+01	14.39	1.06	1.848	119.7	81.62
54	41.5	31.73	5.628	7.68	148.7	104.4
52	73.3	48.94	13.55	16.58	185.4	133.3
50	91.11	60.27	17.71	21.45	252.7	148
48	104.9	73.32	18.5	22.7	282.9	176.6
46	149.7	96.41	22.32	26.9	255.5	178.5
44	180.7	117.8	27.69	32.41	265.6	181.1
42	155.9	105.9	24.06	28.97	278.7	196.4
40	115.3	91.52	13.94	18.01	296.8	210.5
38	108.5	99.3	8.107	11.03	205.2	171.2
36	104.6	106	5.467	7.408	120.5	119.5
34	102.6	103.1	5.14	6.087	87.52	93.16
32	71.91	76.84	8.758	6.424	72.92	75.97
30	66.87	54.98	27.34	8.26	72.65	58.05

Appendix 38: G'/G'' Bovine 12% at 90°C during gelling

temperature	G'	G"	G'	G"	G'	G"
°C	Pa	Pa	Pa	Pa	Pa	Pa
30	26.98	14.59	114.7	10.51	23.29	14.13
32	30.73	13.82	102.7	15.53	23.55	11.73
34	24.7	11.94	78.22	10.14	16.39	8.515
36	13.97	9.297	47.64	8.94	9.573	6.147
38	5.511	6.421	20.44	6.166	5.821	6.137
40	1.838	3.883	6.562	3.176	2.091	3.991
42	1.196	2.756	2.82	1.766	0.6919	1.783
44	2.935	3.738	1.621	1.263	0.6089	1.523
46	9.008	8.212	1.252	1.136	2.372	3.391
48	21.09	17.27	1.265	1.226	10.21	9.89
50	56.25	39.44	2.366	2.222	26.76	22.22
52	109.3	67.24	8.618	6.957	64.51	45.52
54	171.8	92.67	23.96	18.04	116.6	70.08
56	226.6	110.7	44.45	31.8	178.1	97.04
58	234.2	116.4	76.23	50.19	207.1	103.9
60	241	127.7	114.3	70.74	216.7	111.4

Appendix 39: G'/G'' Bovine 12% at 90°C during melting

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
60	14.44	17.71	0.2981	0.7372	0.02085	0.1265
58	52.98	49.97	25.89	29.97	0.1467	0.3778
56	108.5	82.76	97.84	85.06	2.171	3.338
54	166.8	117.5	163.3	121.9	10.79	12.55
52	229	156.9	184.6	144.9	22.57	23.15
50	222.1	153.3	268.2	179.9	43.6	40.37
48	233.2	170.8	341.5	224.1	64.35	57.15
46	264.4	194	335.7	231.8	65.87	60.28
44	317.7	214.6	285.2	219.8	61.91	60.84
42	311.2	215	250.8	205.9	70.98	68.86
40	202.7	197.6	238.6	202.2	77.52	77.45
38	46.91	46.15	211.3	207	64.54	65.03
36	58.05	35.88	108.4	124.9	38.04	42.4
34	-9.285	43.23	38.11	53.04	24.6	27.08
32	60.87	64.4	20.39	26.47	32.98	23.17
30	118.3	71.5	27.8	19.06	66.58	24.39

Appendix 40: G'/G'' Bovine 15% at 90°C during gelling

temperature	G'	G''	G'	G''	G'	G''
°C	Pa	Pa	Pa	Pa	Pa	Pa
30	97.33	19.92	52.48	11.97	129	33.71
32	102.8	19.7	62.2	13.11	130.9	32.86
34	83.85	15.81	49.63	11.48	100.2	34.21
36	61.8	13.73	27.7	8.926	66.12	26.38
38	36.82	10.95	11.79	6.248	41.18	27.96
40	14.5	7.453	5.911	4.001	35.11	33.82
42	5.219	4.548	3.494	2.867	59.42	56.04
44	3.228	3.262	2.935	2.822	71.71	68.79
46	3.922	3.772	3.896	4.217	77.17	68.11
48	7.942	6.804	10.99	11.35	95.63	80.87
50	16.97	13.3	37.35	33.46	118.7	96
52	38.38	27.45	84.4	66.47	123.3	101.9
54	70.83	47.36	123.5	90.23	124.2	102.6
56	92.02	60.38	151.4	107.9	142.7	116
58	83.41	59.68	162.5	111.5	168.1	134.2
60	86.13	63.57	191.9	126.7	189.5	143.9

Appendix 41: G'/G'' Bovine 15% at 90°C during melting

Test ID	Batch		Force 1	Area-FT 1:2	Time-diff. 1:2	Area-FT 1:3	Area-FT 2:3	Area-FT 4:6	Time-diff. 4:5	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
			g	g.sec	sec	g.sec	g.sec	g.sec	sec	g					
			Force 1	Area F-T 1:2	Time Difference 1:2	Area F-T 1:3	Area F-T 2:3	Area F-T 4:6	Time Difference 4:5	Force 2	J#/F#	I#/G#	K#*O#	P#*N#	H#/E#
Start Batch TPA FISH 70 A	TPA FISH 70 A														
FISH 70 A1	TPA FISH 70 A		1961.241	27940.752	58.745	41983.871	14043.119	23355.885	53.435	3037.617	0.91	0.666	1689.845	1537.099	0.503
FISH 70 A2	TPA FISH 70 A		1400.417	25969.924	54.755	37353.341	11383.418	15888.562	49.45	2698.01	0.903	0.621	1847.621	1036.433	0.438
FISH 70 A3	TPA FISH 70 A		1353.718	27774.78	70.165	41972.939	14198.159	19678.67	60.26	2446.517	0.859	0.741	1947.03	1385.107	0.511
End Batch TPA FISH 70 A	TPA FISH 70 A														
Average:	TPA FISH 70 A (F)	AVERAGE("BATCH")	1571.792	27228.485	61.222	40436.717	13208.232	19641.039	54.382	2727.381	0.891	0.667	1828.165333	1319.546333	0.484
S.D.	TPA FISH 70 A (F)	STDEV("BATCH")	338.08	1093.101	7.998	2670.287	1582.235	3733.804	5.467	296.643	0.028	0.071	129.6916469	256.6909847	0.04
Start Batch TPA FISH 70 B	TPA FISH 70 B														
FISH 70 B1	TPA FISH 70 B		829.525	41716.785	68.965	57496.965	15780.18	11832.832	55.18	2809.189	0.8	0.566	2178.129	1962.57	0.378
FISH 70 B2	TPA FISH 70 B		754.049	41654.832	71.835	58242.275	16587.443	11804.09	59.4	2732.213	0.827	0.495	2283.744	1857.888	0.398
FISH 70 B3	TPA FISH 70 B		813.173	39976.9	67.665	55292.33	15315.43	11539.152	57.17	2753.278	0.845	0.445	2074.591	1785.471	0.383
End Batch TPA FISH 70 B	TPA FISH 70 B														
Average:	TPA FISH 70 B (F)	AVERAGE("BATCH")	798.916	41116.172	69.488	57010.523	15894.351	11725.358	57.25	2764.893	0.824	0.502	2178.821333	1868.643	0.387
S.D.	TPA FISH 70 B (F)	STDEV("BATCH")	39.707	987.125	2.134	1533.953	643.646	161.899	2.111	39.781	0.023	0.061	104.5782188	89.03800576	0.01
Start Batch TPA FISH 70 C	TPA FISH 70 C														
FISH 70 C1	TPA FISH 70 C		1185.828	58454.689	66.835	80764.513	22309.823	15054.148	55.82	4203.308	0.835	0.458	2183.478	1854.354	0.382
FISH 70 C2	TPA FISH 70 C		1481.677	62801.315	69.155	88504.13	25702.815	22087.45	55.23	4342.421	0.799	0.425	2083.712	1865.497	0.409
FISH 70 C3	TPA FISH 70 C		994.759	59796.364	77.595	83100.776	23304.412	15453.243	61.05	3739.701	0.787	0.486	2595.427	1947.146	0.39
End Batch TPA FISH 70 C	TPA FISH 70 C														
Average:	TPA FISH 70 C (F)	AVERAGE("BATCH")	1220.755	60350.789	71.195	84123.139	23772.35	17531.614	57.367	4095.143	0.807	0.456	2287.539	1888.999	0.394
S.D.	TPA FISH 70 C (F)	STDEV("BATCH")	245.331	2225.72	5.663	3969.803	1744.225	3950.513	3.203	315.583	0.025	0.031	271.2647767	50.66405845	0.014

Appendix 42: TPA Fish at 70°C

Test ID	Batch		Force 1	Area-FT 1:2	Time-diff. 1:2	Area-FT 1:3	Area-FT 2:3	Area-FT 4:6	Time-diff. 4:5	Hardness	Springines s	Cohesiveness	Gumminess	Chewiness	Resilience
			g	g.sec	sec	g.sec	g.sec	g.sec	sec	g					
			Force 1	Area F-T 1:2	Time Difference 1:2	Area F-T 1:3	Area F-T 2:3	Area F-T 4:6	Time Differenc e 4:5	Force 2	J#/F#	I#/G#	K#*O#	P#*N#	H#/E#
Start Batch TPA FISH 80 A	TPA FISH 80 A														
FISH 80 A1	TPA FISH 80 A		1879.347	36570.039	62.895	50933.816	14363.777	23466.857	53.63	3159.424	0.853	0.461	1455.649	1241.219	0.393
FISH 80 A2	TPA FISH 80 A		2655.904	24350.068	60.935	36663.408	12313.34	31507.16	55.88	2831.622	0.917	0.759	1433.39	1331.523	0.506
FISH 80 A3	TPA FISH 80 A		2625.987	21949.058	57.895	33353.334	11404.276	28776.067	52	2784.498	0.898	0.563	1402.365	1157.751	0.52
End Batch TPA FISH 80 A	TPA FISH 80 A														
Average:	TPA FISH 80 A (F)	AVERAGE("BATCH")	2387.079	27623.055	60.575	40316.853	12693.798	27916.695	53.837	2925.181	0 889	0.594333333	1430.468	1243.497667	0.473
S.D.	TPA FISH 80 A (F)	STDEV("BATCH")	439.964	7840.765	2.519	9342.327	1515.989	4088.46	1.948	204.224	0.033	0.151450762	26.76190813	86.90840717	0.07
Start Batch TPA FISH 80 B	TPA FISH 80 B														
FISH 80 B1	TPA FISH 80 B		2541.487	54504.881	66.945	79270.136	24765.254	39687.465	59.75	4113.89	0.893	0.501	2109.731	1882.985	0.454
FISH 80 B2	TPA FISH 80 B		1659.122	50088.836	72.315	72145.377	22056.541	27155.997	63.61	4015.681	0.88	0.376	1323.326	1664.029	0.44
FISH 80 B3	TPA FISH 80 B		2553.269	58302.893	68.115	85537.833	27234.94	41566.53	63.23	4112.574	0.882	0.486	2095.666	1945.371	0.467
End Batch TPA FISH 80 B	TPA FISH 80 B														
Average:	TPA FISH 80 B (F)	AVERAGE("BATCH")	2251.293	54298.87	69.125	78984.449	24685.579	36136.664	62.197	4080.715	0.885	0.454	1842.907	1830.795	0 454
S.D.	TPA FISH 80 B (F)	STDEV("BATCH")	512.869	4110.902	2.824	6700.797	2590.119	7834.029	2.127	56.32493969	0.007	0.068	450.026	147.7537726	0.013
Start Batch TPA FISH 80 C	TPA FISH 80 C														
FISH 80 C1	TPA FISH 80 C		2926.015	76692.418	66.975	107103.225	30410.806	42527.142	57.08	5495.381	0.852	0.397	2182.034	1859.656	0.397
FISH 80 C2	TPA FISH 80 C		2723.236	73649.157	66.715	101880.738	28231.581	38500.675	58.52	5246.191	0.877	0.378	1982.533	1939.006	0.383
FISH 80 C3	TPA FISH 80 C		2694.318	66876.81	63.075	92324.917	25448.107	35384.63	54.9	5053.123	0.87	0.383	1936.67	1885.663	0.381
End Batch TPA FISH 80 C	TPA FISH 80 C														
Average:	TPA FISH 80 C (F)	AVERAGE("BATCH")	2781.189	72406.128	65.588	100436.293	28030.165	38804.149	56.833	5264.898	0.867	0.386	2033.745	1894.775	0.387
S.D.	TPA FISH 80 C (F)	STDEV("BATCH")	126.253	5024.478	2.18	7494.292	2487.473	3580.914	1.823	221.722	0.013	0.01	130.453	40.45215733	0.009

Appendix 43: TPA Fish at 80°C

Test ID	Batch		Force 1	Area-FT 1:2	Time-diff. 1:2	Area-FT 1:3	Area-FT 2:3	Area-FT 4:6	Time-diff. 4:5	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
			g	g.sec	sec	g.sec	g.sec	g.sec	sec	g					
			Force 1	Area F-T 1:2	Time Difference 1:2	Area F-T 1:3	Area F-T 2:3	Area F-T 4:6	Time Difference 4:5	Force 2	J#/F#	I#/G#	K#*O#	P#*N#	H#/E#
Start Batch FISH 90 A	FISH 90 A														
FISH 90 A1	FISH 90 A		1404.059	35360.598	67.305	50188.658	14828.06	20501.04	60.98	2778.056	0.906	0.408	1134.779	1028.138	0.419
FISH 90 A2	FISH 90 A		1310.374	38264.779	72.115	55429.974	17165.195	21475.933	63.05	2807.689	0.874	0.387	1087.818	951.077	0.449
FISH 90 A3	FISH 90 A		1486.89	29588.773	59.775	42263.694	12674.921	19024.836	54.28	2684.942	0.908	0.45	1208.616	1097.51	0.428
End Batch FISH 90 A	FISH 90 A														
Average:	FISH 90 A (F)	AVERAGE("BATCH")	1400.441	34404.717	66.398	49294.109	14889.392	20333.936	59.437	2756.896	0.896	0.415	1143.738	1025.575	0.432
S.D.	FISH 90 A (F)	STDEV("BATCH")	88.314	4416.283	6.22	6628.566	2245.765	1234.063	4.584	64.051	0.019	0.032	60.895	73.25	0.015
Start Batch TPA FISH 90 B	TPA FISH 90 B														
FISH 90 B1	TPA FISH 90 B		1869.922	54502.648	66.775	74620.475	20117.827	26111.854	59.11	3976.824	0.885	0.35	1235.85	1231.865	0.369
FISH 90 B3	TPA FISH 90 B		1935.968	47717.359	65.535	66024.209	18306.85	26218.27	57.51	3708.213	0.878	0.397	949.024	1292.217	0.384
FISH 90 B2	TPA FISH 90 B		1652.791	53605.152	72.945	74315.531	20710.38	25765.264	64.335	3673.441	0.882	0.347	1423.473	1123.259	0.386
End Batch TPA FISH 90 B	TPA FISH 90 B														
Average:	TPA FISH 90 B (F)	AVERAGE("BATCH")	1819.56	51941.719	68.418	71653.405	19711.686	26031.796	60.318	3786.159	0.882	0.365	1202.782	1215.78	0.38
S.D.	TPA FISH 90 B (F)	STDEV("BATCH")	148.153	3685.823	3.969	4877.41	1252.179	236.877	3.569	166.033	0.004	0.028	238.947	85.62	0.009
Start Batch TPA FISH 90 C	TPA FISH 90 C														
FISH 90 C1	TPA FISH 90 C		1717.552	51326.875	66.015	72611.03	21284.155	22762.229	54.82	3942.337	0.83	0.313	1391.605	1126.272	0.415
FISH 90 C2	TPA FISH 90 C		1290.36	63527.271	71.255	89708.981	26181.71	19113.589	60.23	4454.211	0.845	0.213	1472.535	1302.185	0.412
FISH 90 C3	TPA FISH 90 C		1869.422	57126.448	66.455	82505.234	25378.786	26400.812	56.97	4448.499	0.857	0.32	1273.585	1220.303	0.444
End Batch TPA FISH 90 C	TPA FISH 90 C														
Average:	TPA FISH 90 C (F)	AVERAGE("BATCH")	1625.778	57326.865	67.908	81608.415	24281.55	22758.877	57.34	4281.682	0.844	0.282	1379.242	1216.253333	0.424
S.D.	TPA FISH 90 C (F)	STDEV("BATCH")	300.242	6102.666	2.907	8584.183	2626.682	3643.613	2.724	293.696	0.013	0.06	100.049	88.02639231	0.018

Appendix 44: TPA Fish at 90°C

Test ID	Batch		Force 1	Area-FT 1:2	Time-diff. 1:2	Area-FT 1:3	Area-FT 2:3	Area-FT 4:6	Time-diff. 4:5	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
			g	g.sec	sec	g.sec	g.sec	g.sec	sec	g					
			Force 1	Area F-T 1:2	Time Difference 1:2	Area F-T 1:3	Area F-T 2:3	Area F-T 4:6	Time Difference 4:5	Force 2	J#/F#	I#/G#	K#*O#	P#*N#	H#/E#
Start Batch BOVINE 70 A	BOVINE 70 A														
BOVINE 70 A1	BOVINE 70 A		3491.689	22037.245	43.915	33049.27	11012.025	29608.003	42.6	3712.119	0.91	0.696	1146.951	1226.011	0.5
BOVINE 70 A2	BOVINE 70 A		3267.545	22191.523	45.925	33594.846	11403.323	29801.732	44.98	3534.604	0.923	0.687	1373.462	1171	0.514
BOVINE 70 A3	BOVINE 70 A		3144.869	23308.282	48.475	35437.183	12128.901	30682.659	46.96	3423.71	0.92	0.766	2596.566	1271.713	0.52
End Batch BOVINE 70 A	BOVINE 70 A														
Average:	BOVINE 70 A (F)	Average:	3301.368	22512.35	46.105	34027.1	11514.75	30030.798	44.847	3556.811	0.917666667	0.716333333	1705.66	1222.908	0.511
S.D.	BOVINE 70 A (F)	STDEV("BATCH")	175.866	693.6	2.285	1251.265	566.714	572.778	2.183	145.482	0.006806859	0.043247351	779.816	50.42815235	0.011
Start Batch TPA BOVINE70 B	TPA BOVINE70 B														
BOVINE 70 B1	TPA BOVINE70 B		1575.107	51862.997	71.935	70548.199	18685.202	23353.485	62.87	3464.807	0.874	0.531	2437.691	1702.416	0.36
BOVINE 70 B2	TPA BOVINE70 B		1790.866	52711.175	67.965	72694.679	19983.505	26513.075	60.88	3765.817	0.896	0.465	1934.557	1630.286	0.379
BOVINE 70 B3	TPA BOVINE70 B		2937.077	30038.121	55.725	44925.627	14887.506	32788.992	51.1	3557.668	0.917	0.45	2186.124	1881.059	0.496
End Batch TPA BOVINE70 B	TPA BOVINE70 B														
Average:	TPA BOVINE70 B (F)	AVERAGE("BATCH")	2101.017	44870.764	65.208	62722.835	17852.071	27551.85	58.283	3596.097	0.896	0.482	2186.124	1737.920333	0.412
S.D.	TPA BOVINE70 B (F)	STDEV("BATCH")	732.042	12852.444	8.449	15450.155	2648.184	4802.759	6.3	154.141	0.022	0.043092923	355.769	129.101482	0.073
Start Batch BOVINE 70 C	BOVINE 70 C														
BOVINE 70 C1	BOVINE 70 C		3054.041	54772.893	58.615	79016.71	24243.817	38757.793	52.035	4969.796	0.888	0.491	2325.594	2164.041	0.443
BOVINE 70 C2	BOVINE 70 C		2450.159	49578.131	62.915	71193.211	21615.08	32600.162	51.58	4224.744	0.82	0.458	2135.52	1586.02	0.436
BOVINE 70 C3	BOVINE 70 C		2750.14	46558.362	62.562	71213.23	22313.66	35670.45	50.54	4775.765	0.87	0.455	2664.359	1876.98	0.433
End Batch BOVINE 70 C	BOVINE 70 C														
Average:	BOVINE 70 C (F)	AVERAGE("BATCH")	2752.1	52175.512	60.765	75104.96	22929.448	35678.977	51.807	4656.768333	0.854	0.474	2375.157667	1875.680333	0.439
S.D.	BOVINE 70 C (F)	STDEV("BATCH")	427.009	3673.251	3.041	5532.049	1858.798	4354.103	0.322	386.5174973	0.048	0.023	267.880738	289.0126917	0.005

Appendix 45: TPA Bovine at 70°C

Test ID	Batch		Force 1	Area-FT 1:2	Time-diff. 1:2	Area-FT 1:3	Area-FT 2:3	Area-FT 4:6	Time-diff. 4:5	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
			g	g.sec	sec	g.sec	g.sec	g.sec	sec	g					
			Force 1	Area F-T 1:2	Time Difference 1:2	Area F-T 1:3	Area F-T 2:3	Area F-T 4:6	Time Difference 4:5	Force 2	J#/F#	I#/G#	K#*O#	P#*N#	H#/E#
Start Batch BOVINE 80 A	BOVINE 80 A														
BOVINE 80 A1	BOVINE 80 A		1706.821	57042.366	75.175	80005.988	22963.621	28165.793	67.14	3849.576	0.893	0.452	1355.228	1210.376	0.403
BOVINE 80 A2	BOVINE 80 A		1763.803	51620.363	72.885	73124.313	21503.949	27688.425	64.64	3701.837	0.887	0.399	1401.696	1243.131	0.417
BOVINE 80 A3	BOVINE 80 A		1770.301	49102.064	70.715	69407.912	20305.848	26913.586	62.7	3674.131	0.887	0.488	1424.68	1263.203	0.414
End Batch BOVINE 80 A	BOVINE 80 A														
Average:	BOVINE 80 A (F)	AVERAGE("BATCH")	1746.975	52588.265	72.925	74179.404	21591.14	27589.268	64.827	3741.848	0.889	0.446333333	1393.868	1238.903	0.411
S.D.	BOVINE 80 A (F)	STDEV("BATCH")	34.926	4057.675	2.23	5377.24	1331.03	631.965	2.226	94.318	0.004	0.044769781	35.381	26.666	0.007
Start Batch BOVINE 80 B	BOVINE 80 B														
BOVINE 80 B1	BOVINE 80 B		2447.445	80175.917	77.055	112228.514	32052.598	41501.293	68.38	5142.027	0.887	0.37	1901.485	1687.412	0.4
BOVINE 80 B2	BOVINE 80 B		2508.141	82494.197	78.885	117178.249	34684.052	44017.448	70.4	5208.221	0.892	0.376	1956.443	1746.005	0.42
BOVINE 80 B3	BOVINE 80 B		2424.952	74926.531	81.445	107506.277	32579.745	43728.953	71.26	4845.192	0.875	0.407	1970.817	1724.359	0.435
End Batch BOVINE 80 B	BOVINE 80 B														
Average:	BOVINE 80 B (F)	AVERAGE("BATCH")	2460.179	79198.882	79.128	112304.347	33105.465	43082.564	70.013	5065.147	0.885	0.384	1942.915	1719.259	0.418
S.D.	BOVINE 80 B (F)	STDEV("BATCH")	43.031	3877.285	2.205	4836.432	1392.273	1376.998	1.478	193.34	0.009	0.02	36.592	29.628	0.018
Start Batch BOVINE 80 C	BOVINE 80 C														
BOVINE 80 C1	BOVINE 80 C		2685.299	94756.977	83.355	132627.755	37870.778	50358.901	73.585	5438.006	0.883	0.38	2064.817	1822.8	0.4
BOVINE 80 C2	BOVINE 80 C		2425.738	70631.52	70.445	97580.657	26949.137	36898.323	61.74	4789.781	0.876	0.378	2111.167	1587.358	0.382
BOVINE 80 C3	BOVINE 80 C		2533.561	64493.573	75.705	93325.814	28832.241	43057.572	65.15	5494.017	0.861	0.361	2073.397	1784.318	0.447
End Batch BOVINE 80 C	BOVINE 80 C														
Average:	BOVINE 80 C (F)	AVERAGE("BATCH")	2548.199	76627.357	76.502	107844.742	31217.385	43438.265	66.825	5240.601333	0.873	0.373	2083.127	1731.492	0.409
S.D.	BOVINE 80 C (F)	STDEV("BATCH")	130.398	15997.842	6.492	21567.898	5838.428	6738.359	6.098	391.4250091	0.011	0.010440307	24.65938564	126.298	0.034

Appendix 46: TPA Bovine at 80°C

Test ID	Batch		Force 1	Area-FT 1:2	Time-diff. 1:2	Area-FT 1:3	Area-FT 2:3	Area-FT 4:6	Time-diff. 4:5	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
			g	g.sec	sec	g.sec	g.sec	g.sec	sec	g					
			Force 1	Area F-T 1:2	Time Difference 1:2	Area F-T 1:3	Area F-T 2:3	Area F-T 4:6	Time Difference 4:5	Force 2	J#/F#	I#/G#	K#*O#	P#*N#	H#/E#
Start Batch BOVINE 90 A	BOVINE 90 A														
BOVINE 90 A1	BOVINE 90 A		1313.659	36309.64	66.675	50435.649	14126.009	18452.094	58.72	2793.694	0.881	0.366	1022.085	900.14	0.389
BOVINE 90 A2	BOVINE 90 A		1515.024	39553.155	67.125	55436.479	15883.324	22170.586	59.56	3034.618	0.887	0.4	1213.628	1076.852	0.402
BOVINE 90 A3	BOVINE 90 A		1545.943	36022.95	58.935	49533.528	13510.578	19304.801	52.29	2990.989	0.887	0.39	1165.684	1034.252	0.395
End Batch BOVINE 90 A	BOVINE 90 A														
Average:	BOVINE 90 A (F)	AVERAGE("BATCH")	1458.209	37295.248	64.245	51801.885	14506.637	19975.827	56.857	2939.767	0.885	0.385	1133.799	1003.748	0.395333333
S.D.	BOVINE 90 A (F)	STDEV("BATCH")	126.135	1960.652	4.604	3179.805	1231.316	1947.948	3.977	128.37	0.004	0.017	99.673	92.221	0.006506407
Start Batch BOVINE 90 B	BOVINE 90 B														
BOVINE 90 B1	BOVINE 90 B		1916.184	48230.383	65.245	67528.131	19297.749	25773.343	54.87	3805.162	0.841	0.382	1452.309	1221.369	0.4
BOVINE 90 B2	BOVINE 90 B		2041.93	49573.382	63.885	68820.449	19247.067	26901.184	55.14	3837.009	0.863	0.391	1499.846	1294.537	0.388
BOVINE 90 B3	BOVINE 90 B		1721.745	43281.998	63.975	60723.037	17441.038	22956.336	55.08	3461.912	0.861	0.378	1308.776	1126.805	0.403
End Batch BOVINE 90 B	BOVINE 90 B														
Average:	BOVINE 90 B (F)	AVERAGE("BATCH")	1893.286	47028.588	64.368	65690.539	18661.951	25210.288	55.03	3701.361	0.855	0.384	1420.31	1214.237	0.397
S.D.	BOVINE 90 B (F)	STDEV("BATCH")	161.316	3313.399	0.761	4350.239	1057.645	2031.804	0.142	207.979	0.012	0.007	99.473	84.093	0.008
Start Batch BOVINE 90 C	BOVINE 90 C														
BOVINE 90 C1	BOVINE 90 C		2072.563	59673.43	68.885	82392.002	22718.572	29845.102	55.89	4171.689	0.811	0.362	1511.124	1226.053	0.381
BOVINE 90 C2	BOVINE 90 C		2266.931	68851.724	71.865	95539.84	26688.116	34848.097	62.93	4582.417	0.876	0.365	1671.434	1463.624	0.388
BOVINE 90 C3	BOVINE 90 C		2381.966	57947.613	62.115	80205.244	22257.631	31385.11	55.08	4444.175	0.887	0.391	1739.05	1542.089	0.384
End Batch BOVINE 90 C	BOVINE 90 C														
Average:	BOVINE 90 C (F)	AVERAGE("BATCH")	2240.487	62157.589	67.622	86045.696	23888.106	32026.103	57.967	4399.427	0.858	0.373	1640.536	1410.589	0.384
S.D.	BOVINE 90 C (F)	STDEV("BATCH")	156.387	5861.16	4.996	8294.55	2435.807	2562.352	4.317	208.988	0.041	0.016	117.063	164.558	0.003

Appendix 47: TPA Bovine at 90°C

Sensory Evaluation Form

The purposes of the study are to evaluate and compare between the multivitamin product produced by fish (A) and bovine gelatin (B) with the commercialized gummy vitamin (C). Evaluate each samples and rate them based on the following preference test of 9-point hedonic scale.

The 9-point hedonic score of preference test

9 = Like extremely
8 = Like very much
7 = Like moderately
6 = Like moderately
5 = Neither like nor dislike
4 = Dislike slightly
3 = Dislike moderately
2 = Dislike very much
1 = Dislike extremely

Attributes	A	**Sample No.** B	C
Appearance			
Aroma/Smell			
Taste/Flavour			
Springiness			
Firmness			
Overall Acceptability			

Appendix 48: Sensory Evaluation Form

Panelist No.	Appearance	Aroma/Smell	Taste/Flavour	Springiness	Firmness	Overall Acepptability
1	5	7	8	8	6	7
2	4	8	7	7	7	7
3	5	6	6	6	8	6
4	6	5	8	7	6	7
5	7	6	7	6	7	7
6	6	7	6	7	6	6
7	4	8	7	8	7	7
8	5	6	8	8	8	6
9	6	5	6	7	6	5
10	5	7	5	8	5	7
11	4	7	7	5	7	6
12	5	6	7	5	8	8
13	7	7	8	6	6	6
14	5	6	6	8	7	7
15	6	5	9	8	5	6
16	8	6	8	7	8	7
17	5	8	6	8	7	8
18	8	7	7	7	7	7
19	8	8	6	8	8	7
20	7	8	6	5	7	6
21	8	7	8	6	5	8
22	8	7	6	7	5	8
23	7	6	8	5	6	7
24	6	5	7	7	7	8
25	7	8	6	7	8	8
26	5	5	6	6	4	7
27	6	6	8	5	6	5
28	6	5	7	5	5	7
29	5	6	8	6	8	8
30	5	7	8	5	6	8
31	6	6	6	6	7	6
32	6	3	8	6	4	8
33	7	6	9	7	5	6
34	5	5	8	5	6	6
35	4	4	6	8	8	7
36	6	8	8	7	6	6
37	8	6	7	8	8	6
38	8	6	8	5	6	6
39	6	7	5	8	8	5
40	7	8	8	8	8	7
Mean	6.05	6.35	7.075	6.65	6.55	6.75
SD	1.259833119	1.21000106	1.047279749	1.144664322	1.197219	0.898717034

Appendix 49: Means sensory scores of multivitamin gummy candies by fish gelatin

Panelist No.	Appearance	Aroma/Smell	Taste/Flavour	Springiness	Firmness	Overall Aceptability
1	5	7	8	9	8	9
2	4	8	7	9	9	9
3	5	4	6	9	7	8
4	6	5	8	8	6	9
5	7	6	7	9	7	9
6	3	7	9	7	6	8
7	4	8	7	8	7	9
8	5	5	8	8	8	8
9	6	4	6	7	6	9
10	2	3	5	8	5	8
11	4	7	7	9	7	9
12	5	6	7	9	8	8
13	3	7	8	9	6	9
14	5	6	8	8	7	7
15	6	5	9	8	9	9
16	3	6	8	7	8	7
17	5	8	9	8	7	8
18	3	7	7	9	7	9
19	4	8	9	8	8	8
20	3	8	6	9	7	8
21	5	7	8	9	8	8
22	3	7	9	7	9	8
23	3	6	8	9	8	7
24	6	5	7	7	7	8
25	7	4	9	9	8	8
26	4	5	9	8	9	9
27	3	6	8	8	9	9
28	2	5	9	8	9	9
29	4	6	8	8	8	8
30	5	7	8	9	9	8
31	6	6	6	9	7	9
32	6	3	8	8	9	8
33	7	4	9	9	9	9
34	5	5	8	7	8	9
35	4	4	7	8	8	8
36	3	3	8	7	9	8
37	5	2	7	8	8	9
38	5	6	8	9	9	8
39	6	7	9	8	8	8
40	4	5	8	8	8	7
Mean	4.525	5.7	7.75	8.225	7.75	8.325
SD	1.358496529	1.572194286	1.031553471	0.73336247	1.056117709	0.655841601

Appendix 50: Means sensory scores of multivitamin gummy candies by bovine gelatin

Panelist No.	Appearance	Aroma/Smell	Taste/Flavour	Springiness	Firmness	Overall Acceptability
1	8	7	8	3	8	7
2	7	8	7	5	6	6
3	6	7	6	5	7	6
4	6	6	8	4	6	7
5	7	6	7	4	7	5
6	6	7	5	5	5	6
7	4	8	7	6	4	5
8	5	5	8	6	5	4
9	6	6	6	5	6	5
10	8	8	5	4	5	6
11	4	7	7	5	7	7
12	5	6	7	6	8	6
13	8	7	8	4	6	5
14	5	6	6	6	5	6
15	6	5	7	5	6	6
16	6	6	8	5	8	7
17	8	8	8	5	5	8
18	8	7	7	4	7	6
19	4	8	6	4	8	7
20	6	8	6	6	7	8
21	5	6	8	6	5	5
22	6	7	6	6	4	8
23	6	6	8	6	4	7
24	6	5	7	5	4	6
25	7	8	6	7	8	6
26	6	5	6	8	8	8
27	7	6	8	8	4	8
28	7	5	7	7	6	7
29	6	6	8	7	8	8
30	5	7	8	6	6	8
31	6	6	6	5	7	6
32	6	6	8	5	7	8
33	7	6	6	7	6	7
34	5	5	8	6	8	6
35	6	4	6	6	5	5
36	8	5	8	7	5	8
37	6	6	7	8	4	7
38	7	6	8	8	6	8
39	6	7	7	8	3	8
40	8	5	8	8	3	7
Mean	6.225	6.325	7.025	5.775	5.925	6.6
SD	1.14326335	1.071483515	0.946992541	1.34902624	1.50873249	1.127738831

Appendix 51: Means sensory scores of commercial multivitamin gummy candies