

A Review: Sugar-Based Confectionery and the Importance of Ingredients

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ABSTRACT

Sugar-based confectionery products have a historical basis for many cultures and sugar-based confectionery, especially soft candies, has increased in popularity in recent years. Optimizing a well-designed candy is important to meet consumer expectations, which includes ingredient information about water, sucrose, corn syrup and various kinds of sugar substitutes, and gelling agent alternatives. For instance, water content, temperature, pH, glass transition temperature, molecular weight, and natural gelling properties of the gelling agents have impacts on the quality parameters of the final product. The objective of this review is to examine the production of sugar-based candies focusing on hard candies, soft candies, and Turkish delight. The review also reports on new trends in the formulations and how ingredients affect the final product in a very simple way.

Keywords: Corn Syrup, Gelatin, Soft Candy, Sugar Alcohol.

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I. INTRODUCTION

Confectionery products are primarily composed of sugar, water, coloring, and flavoring and include chocolates, marshmallows, nougats, hard boiled candies, soft candies, Turkish delights etc. [1]. These products can be distinguished into two types: chocolate-based products such as chocolate bars, and chocolate-covered confections and sugar-based candies such as hard candies, jellies, and nougats [2]. Sugar-based candies vary according in their cooking method, gelling agents, and moisture contents [3]. For instance, hard candies have a 2% moisture content whereas, gelatin-based jellies contain 22%, grained marshmallows contain 12% and Turkish delights contain 20% moisture, respectively [1]. The general ingredients of sugar based confectionery products are corn syrup, gelling agent, sugar, and water.

The candy industry is one of the largest food industry categories in the USA [3]. According to What We Eat in America (WWEIA) and National Health and Nutrition Examination Survey (NHANES) 2007-2008 and 2009-2010 data, 21% and 31% of Americans between 2 and 18 years old consume non-chocolate and total candy (chocolate included) per day, respectively [4]. By comparison, adults consume 9.8% non-chocolate candy per day and total candy consumption decreases from 31% to 23.8%. Additionally, American candy consumers eat almost 40 g of candy per day, which is around 176 kcal [4].

Although functional candy production is significant, main ingredients of sugar-based confectionery should be discussed because understanding of the ingredients will help obtain optimum end products. Therefore, in this review, the

functionality and ingredients in sugar based soft candies are examined with plain expression in order to encourage colleagues to study sugar-based confectionery.

II. SUGAR BASED CANDY TYPES

A. High-Boiled Candies

High-boiled candies (also known as hard candies) have very low moisture content (1-2%), resulting in a total solid content of the hard candies up to 97% [1], [3]. Hard candies can be grained or non-grained, graining is a physical change due to the recrystallization of the sugar crystals during storage [1]. Grained high-boiled candies are opaque; on the other hand, non-grained hard candies appear clear [3].

A high-boiled candy contains cane or beet sugar (the major component) with glucose syrup as a secondary ingredient. Glucose syrup varies according to dextrose equivalent (DE) which affects not only the sweetness value but also other functional properties such as viscosity and nutritive value [5]. The DE value is related to the amount of reducing sugars present with a high DE having greater sweetness. The most common types of glucose syrups used in the candy industry are 42 DE and 63 DE. During hard candy production, 42 DE glucose syrup is added to the recipe in order to prevent graining [1]. A recent study focused on utilization of syrup by discoloration with the active carbon, which is the most common adsorbent because of its efficiency in various areas. The reprocessed syrup is added to lollipop type of hard candies for the quality testing and consumer acceptance, and they have found that up to 15% reprocessed syrup can be added to the production of the candies [6].

Another important property of hard candies is the glassy state. When a liquid is cooled, two possible structural properties are the crystal or glassy state [7]. The glassy state forms when a liquid is supercooled preventing formation of a crystalline structure [1]. Glass transition temperature (T_g) can be measured in order to track this phenomenon using a differential scanning calorimeter (DSC) [8].

There are numerous recipes for hard candies, but the general procedure is shown in Fig. 1 [1].

B. Soft Candies

Soft candies have a high demand in Europe and the consumption of these candies is also becoming more popular in the US [1]. Soft candies can be produced using different gelling agents separately or in combination with different gelling agents with the most common being starch, gelatin, and pectin [1]. The cooking and settling temperatures, time in molds and final desired textural properties vary according to the type of gelling agent. For example, the temperature of the solution to create soft candies is between 93-100 °C, 71-82 °C, and 60-65 °C for soft candies based on pectin, starch, and gelatin, respectively [1]. The moisture content of the soft candies is between 8-22% and this is the main distinct property compared to high boiled or hard candies [1], [9].

Moreover, addition of natural colorants (red beet extract, betacyanins, betaxanthins), decreasing the sugar content or enhancing the nutritional value of the soft candies such as fiber content (inulin) or antioxidant content (grape skin powders), fruit powders (pineapple and papaya peel) and marine derived nutrients are becoming popular [10]-[15]. However, these natural food colorants or flavorings are heat, oxygen, light sensitive therefore, have low shelf life. This problem can be eliminated by using carriers to encapsulate the natural nutrients for the product fortification [11], [16].

Furthermore, quality parameters are significant for soft candies such as moisture content, textural parameters or T_g .

T_g mentioned in reference to hard candies is also a critical factor for soft candies as well but in a different way. Glass transition temperature is a physicochemical property where a substance changes from a glassy to rubbery state [7]. This is critical since soft candies remain in the rubbery state whereas hard candies stay in the glassy state as stated earlier. If not processed correctly, the candy can crystallize which results in the lower quality soft candy products. The relationship between T_g and some ingredients will be mentioned in the Table I.

Lastly, the general soft candy production steps are shown in Fig. 2 [1].

C. Turkish Delight

Turkish delight, also known as lokum, is one of the oldest and most delicate candy types for more than three centuries originating from the Eastern Mediterranean [1], [17], [18]. Lokum was originally produced with honey or grape molasses and flour, then sucrose and starch were discovered as options, and Turkish delight is now more commonly produced by using those ingredients [18]. Moreover, the most accepted flavor is rosewater, but various flavors can be added to the product such as lemon, geranium or other fruit extracts [18], [19]. Besides adding the fruit extracts for flavorings, different concentrations of fruit pulps (cornelian cherry pulp) can be added to the Turkish delight owing to its health improving effects and natural pigmentation [20].

Furthermore, there are many types of starch in the market including wheat, maize (corn), tapioca but the best starch option for Turkish delight is acid modified maize starch [18]. Starch gelatinization is a term that decreases the crystallinity, which is irreversible [21]. Complete gelatinization of starch is critical since if the gelatinization fails, it causes the cheesy or spongy texture to the product [1].

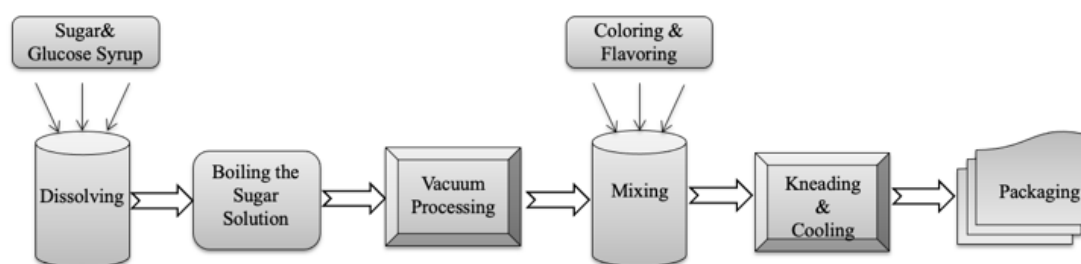


Fig. 1. Hard candy production process flow.

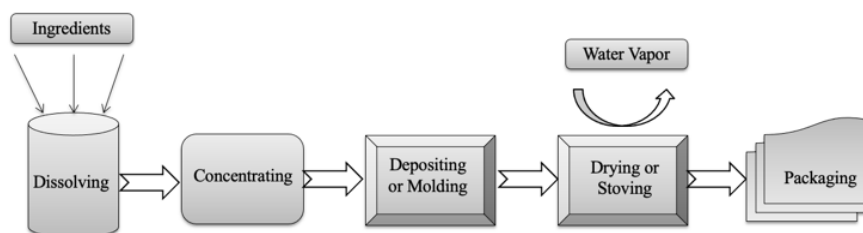


Fig. 2. The production flow of soft candies.

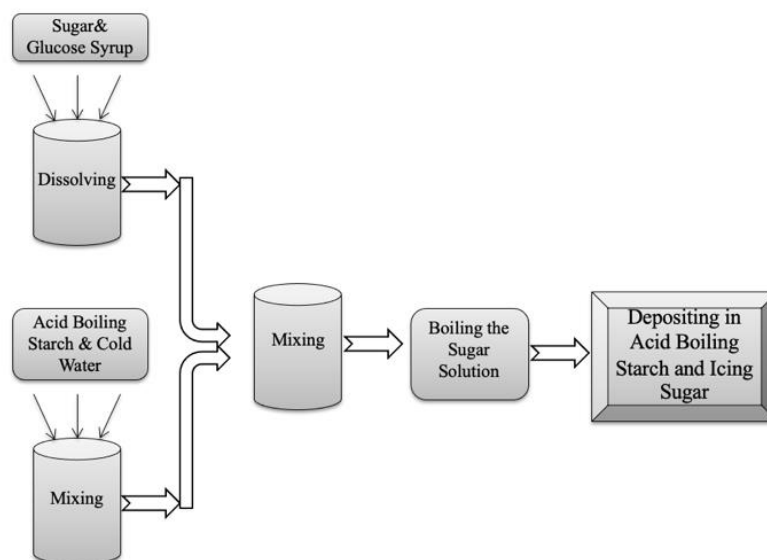


Fig 3. General production scheme for Turkish delights.

Even though the most common and accepted gelling agent is modified starch for Turkish delight, nowadays pectin and gelatin are also suitable gelling agents according to the final product textural parameters and shelf life [19]. The major problem could be syneresis during storage, if the product is made from starch [19]. In order to eliminate this, low methoxyl pectin (LMP) could be used instead as explained in section F.

Control of pH is needed for gelatinization and to prevent crystallization thus the pH of the candy mixture should be 5.5 ± 0.5 for Turkish delights [1]. Tartaric acid and citric acid are the two most common acid types used to adjust pH in the production of Turkish delight [22].

The general production scheme of the Turkish delight is shown in the Fig. 3 [1]. After pouring the mixture into a tray, the solution is allowed to set, then cut and dusted with sugar to prevent sticking and absorb the traces of water during storage [1], [18].

III. INGREDIENTS OF SOFT CANDIES

As stated earlier, the main ingredients in confectionery products are sugar, gelling agents, and water. The other ingredients vary according to the types of the product, desired texture, economic conditions, consumer acceptance, and culture.

A. Water

Water plays a significant role in food systems, thus understanding the chemistry of confectionery gel systems and final product storage is important [23].

To begin with, water has macroscopic interactions with the solute in aqueous systems, which leads to the important property of water holding capacity. Water holding capacity is a term, which describes the similar characteristics as water binding, and hydration [24]. Thus, water-holding capacity is the ability of physically entrapping water with the macromolecules present in low concentrations in the water when an external force is applied such as gravitational force [24]. Thus, in the confectionery gel systems, the food matrix

which entraps water, might be gelatin, starch, or pectin and sugar based confectionery products can be classified according to their water content [1].

Besides water holding capacity, there are other concepts that are important to better understand the interactions of water in confectionery products such as water activity, and moisture content. Moisture content or water content cannot predict the microbial stability, but water activity (a_w) is used to predict food shelf life [24]. The a_w of pure water is 1.0 and a_w relates to the microbial growth in a food matrix [1], [25]. Shelf stable foods have a water activity of 0.85 or less. The water activity of hard candies should be less than 0.60 and soft candies should be between 0.50 and 0.75. Additionally, moisture content of hard candies should be between 2-5% and soft candies should be between 8% and 22% [25]. Therefore, water activity and water content should be analyzed accordingly because these concepts affect the shelf life of the product [25]. Additionally, nuclear magnetic resonance (NMR) relaxometry or spectroscopy can be used to correlate the results for soft candies since NMR is a promising technique in order to understand the proton mobilization in confectionery gel systems, water distributions and structural changes as a non-destructive method [9], [26], [28].

Lastly, it is also significant to know the inverse relationship between T_g and water content therefore, the choice of the right ingredients and the concentration affect the desired end product. The more water present in the final product, the lower the T_g [29]. Quantitatively, T_g of the water, $-134\text{ }^\circ\text{C}$, and other some ingredients can be seen in the Table I.

TABLE I: T_g OF CONFECTIONERY INGREDIENTS		
Material	T_g ($^\circ\text{C}$)	References
Sucrose	65 to 70	(30)
Corn Syrup (42 DE)	79	(25)
Dry Citric Acid	11	(31)
Water	-134	(32)
Isomalt	63.6	(33)
Maltitol	39	(25)
Erythritol	42.5	(30)
Sorbitol	-9	(25)
Isomaltulose	60.56	(34)

B. Sweeteners

1) Sucrose

Sucrose, also known as saccharose or most commonly the table sugar, is a main ingredient in confectionery products due to its sweetness and textural enhancing properties [35]. Sucrose is a disaccharide composed of two different monosaccharides, glucose, and fructose with alpha 1-2 glycosidic linkage [36], [37].

Reducing sugars have a free reducing group in the structure whereas non-reducing sugars do not have this group exposed. Reducing sugars have the ability to oxidize or contribute to Maillard reaction while non-reducing sugars such as sucrose will not participate in the Maillard reaction [36]. Moreover, sweetness is another important attribute of sucrose since it is considered as a reference compound to which other sweetening agents are compared in a relative sweetness (RS) scale [9], [36]. In addition to its RS, sucrose has a caloric value of 4 cal/gram and molecular weight of 342.297 g/mol [38], [39].

The sources of sucrose are usually sugar beet or sugar cane and the features of these two sucrose types are different according to their purity, moisture content, reducing sugar content, ash and impurities [1]. On the other hand, another difference is the consumer acceptance since beet sugar is acceptable when it is completely white whereas, cane sugar is acceptable when it is light brown or dark brown [40]. During confectionery production, the sugar forms can differ according to the variety of the product [40]. While white granulated sugar is used in the production of boiled sweets, toffees/fudges, gums/pastilles, and liquorice; brown sugar is a component only in toffees/fudges and liquorice [40].

Sucrose has many effects on the final confectionery product. For instance, it is a hygroscopic substance, called as humectant, which means that it can entrap water from the environment in two ways, absorption, or adsorption [25]. Owing to the fact that sucrose may be called as a_w depressor and decrease the microbial spoilage by decreasing the a_w . Therefore, there is an inverse relationship between a_w and sucrose concentration [41]. Corn syrup, invert sugar and other polyols are also called as humectant [41], [42]. Furthermore, sucrose increases T_g values more than other sugars [43]. Low calorie sugar substitutes will be discussed in the section 4.

2) Invert Sugar

Invert sugar is made by acid hydrolysis or enzymatic reduction of disaccharides and is mostly used in syrup form. Tartaric acid or citric acid can be used for the acid hydrolysis and invertase enzyme is the enzyme that break downs the bonds in disaccharides that are mostly sucrose [19]. Monosaccharides glucose and fructose are the two components of invert sugar [2].

Invert sugar is used in confectionery products by buying ready to use invert sugar from the market or heating sucrose with acid and generate invert sugar. The second way is generally used for old-fashioned confectionery products [40].

There are some advantages of using invert sugar in confectionery products for example, invert sugar will not form crystals compared to sucrose and it has a positive effect on stability by reducing water activity and limiting microbial growth [2], [19]. Yet, the final products will be prone to absorb water from the environment which makes the

hygroscopic nature of invert sugar a disadvantage [40]. So even if there are some advantages of using invert sugar, glucose syrup is more popular than invert sugar because of the lower cost [40].

3) Corn Syrup

Corn syrup, also known as glucose syrup, is a replacement of invert sugar and table sugar because it's relative low cost [40]. There are two common ways to produce corn syrup. First is by enzymatic hydrolysis and the second one is by acid hydrolysis of starch. The main raw ingredients used to produce glucose syrup are corn, potato, or wheat starch [5]. The most commonly used one is corn starch and after treatments the resulted product, corn syrup, is differentiated by its 'dextrose equivalent (DE)' [44]. Dextrose equivalent is the proportion of% reducing sugar according to dextrose values and% dry substances, which is multiplied by 100.

Corn syrup, independent of DE, affects the sweetness values, viscosity, and nutritional values of the final products. It also has other functions for instance, it acts as humectant, thickening agent and foam stabilizer [1]. However, these functions differ according to DE values. Therefore, market has different types of corn syrups including 42 DE, 50 DE and 63 DE [35]. The most common type of corn syrup is 42 DE in confectionery products because it prevents sucrose crystallization, yet higher DE can also be used [21], [35], [40], [45]. Moreover, molecular weight and moisture content are inversely related to DE values. For 42 DE and 68 DE, molecular weights are 460 g/mol and 353 g/mol and, moisture contents are 18.7% and 18.0%, respectively [1], [24], [25].

In candy industry, during hard candy and soft candy productions, glucose syrup is being used due to its high production yield, good sweetness value and is more affordable than sucrose [1], [35]. Glucose syrup also lowers the water activity reducing microbial growth improving shelf stability of the final product [21].

4) Low Calorie Sugar Substitutes

Low calorie sugar substitutes have increased in popularity in confectionery products to reduce the sugar content [10]. The most popular type of soft candy product is gelatin based soft candies among children and adolescents due to the desirable texture [10]. There are many different types of artificial sweeteners such as acesulfame-K, sucralose, and aspartame. However, the most popular replacements for table sugar in candy production are stevia, natural non-nutritive sweetener, and sugar alcohols, which are called as polyols, such as isomalt, maltitol, erythritol, and xylitol [9], [37], [46]. These polyols can be found in nature yet in a trace amount thus, they do not show functional properties [24]. Polyols are water soluble and hygroscopic, can increase viscosity, and contribute lower caloric values to the diet [45], [47]. Furthermore, they have various RS values compared to sucrose for instance, isomalt has 0.4-0.6, maltitol has 0.75, erythritol has 0.7 and xylitol has 1.0 RS values [9], [24], [36], [45]. These polyols can be used solo or in combination with other sugars/sweeteners in order to obtain the desired sweetness in the final product. A disadvantage of using polyols in confectionery is their higher cost than sugar yet they are still an alternative for people who has diabetics since they have low glycemic index [45].

Furthermore, stevia is also becoming popular in sugar-based confectionery because it is a natural extract from the leaves of *Stevia rebaudiana* plant, having natural bioactive compounds such as beta-carotene and caffeic acid [48]. It was shown that stevia had more opaque appearance and decreased the springiness value more than isomalt and maltitol. T_g values decreased in all the formulations except sucrose because sucrose displayed greater humectant properties than polyols and stevia. Besides polyols and stevia, d-psicose, which is low-calorie rare hexose, has also recently gained interest [48]. Different concentrations of d-psicose, which has 0.7 RS values and 0.39 kcal/g, were used to produce gelatin based low calorie soft candies [28], [49]. Results showed that, d-psicose acted as humectant in the system by reducing the water activity and prevented the sugar crystallization, which may be a quality problem during the storage [25], [28].

Lastly, isomaltulose, which is an isomer of sucrose, has 4 kcal/g, but increases blood sugar levels slower than sucrose and is non-hygroscopic, can replace sucrose in order to produce Turkish delight [50], [51].

C. Gelling Agents in Confectionery Gel Systems

Gelling agents are selected according to the product type and the desired final product characteristics such as firmness or opacity. Gelatin, starch, pectin, and gums are potential gelling agents that are widely used in confectionery.

D. Gelatin

Gelatin is used for various applications including food products (especially confectionery products), pharmaceutical products, and paper production. Gelatin is made from collagen tissues from pork, beef, or fish [52], [53] and purified collagen is obtained by skin, bones or hides [19], [54]. Gelatin is obtained from collagen by acid hydrolysis [55]. Gelatin is composed of carbon (51%), oxygen (25%), hydrogen (7%) and nitrogen (17%) [53].

One important property of gelatin is gel strength partly imparted by its amphoteric property [1], [52]. Gel strength is defined in the literature and industry by the term 'Bloom,' which can be measured by the bloom test for gel firmness using a textural analyzer. In a standard Bloom test, a 112 g sample of 6.67% gelatin is prepared in a standard container then aged for 17 h at 10 °C after which the force in grams required to push a plunger into a 12.5 mm diameter sample to a 4 mm depth is the Bloom value [21], [56], [57]. Bloom range, which is shown in Table II, is between 50 and 300 and there are 3 different bloom types. High Bloom, medium Bloom and low Bloom ranges are between 200-300 Bloom, 100-200 Bloom and 50-100 Bloom, respectively [1].

TABLE II: GENERAL PROPERTIES OF GELATIN

General Properties of Gelatin	
Moisture (%)	8-13
Relative Density	1.3-1.4
Melting Temperature (°C)	~ 37
Molecular Mass (kDa)	15-400
Bloom	50-300
Isoelectric point	–
	Type A
	Type B
pH	–
	Type A
	Type B

Bloom type can affect the melting point, gelation time, taste, color, and strength. For instance, high bloom has higher melting point, strong gelation mechanism, shorter gelling time, lighter color and more natural taste than low bloom gelatins [24], [56]. There are two kinds of gelatin, Type A and Type B. Type A and Type B are defined as acid conditioned and alkaline-conditioned high Bloom, respectively [52].

Moisture content of gelatin is between 8-13%, the melting temperature of gelatin is around 37 °C, Bloom is between 50 and 300, and the other properties are shown in Table II [52].

Gelatin is a good source of protein, and it has large variety of amino acids. It has eight of the essential amino acids except tryptophan in calf skin (Type B), calf bone (Type B) and pork skin (Type A) gelatins. However, histidine, isoleucine, and methionine concentrations are very similar in those gelatin types yet in a very low amounts and do not meet the recommended adults' daily amino acid requirements [24], [52].

This may appear to be a limitation of gelatin, however; plant proteins do not contain the recommended essential amino acid content especially methionine [52]. Furthermore, gelatin has excessive amounts of proline and glycine. For example, 10 g of gelatin has an equal amount of glycine as is found in 160 g of meat. These amino acids are non-essential amino acids, yet they are crucial for the production of collagen tissues predominant in hair, skin, tendons, nails and other connective tissue [52].

The physical properties of gelatin include being odorless, tasteless, yellow in color and brittle in dried forms. It can be used in sheet, powder, or granular form [1]. It provides transparent appearance to the product which is especially desirable for gummy bears [19], [52]. Moreover, gelatin is known as being thermos-reversible [55]. This characteristic is one of the most remarkable properties of gelatin. Gelatin is water-soluble, enhances stabilization and texture, forms gels, and binds water [58]. Additionally, it can be used for the encapsulation process or can be used to improve the nutritional value of the product [52], [55]. Due to these properties, it is one of the preferred gelling agents, used for various soft candy product applications, which is shown in Table III with the choice of Bloom values, and appropriate concentrations.

TABLE II: BLOOM AND CONCENTRATIONS OF GELATIN IN VARIOUS CONFECTIONERY PRODUCT FORMULATION

Product Type	Bloom	Concentration	Reference
Jellybeans	220	7-8%	(24)
Gummy Bears	220	8%	(9)
Fruit Jelly	100-120	10-12%	(24)
Marshmallow	200-250	2-3%	(1,24)
Fruit Pastilles	100-200	4-5%	(1)
Liquorice	100-200	0.2-0.4%	(1)
Nougat	180	2%	(1)

1) Intermolecular Gelling of Gelatin

There are some intermolecular interactions in gelatin-based solutions [58]. These interactions are important in order to understand the behavior of the polymer system. Polymers may have intermolecular connections, which can be primary or secondary. Polymers have some critical points, including the sol-gel transition phase after which the gelatin has formed

[52], [59]. Hydrogen bonding is also another dominant factor making the sol-gel system more established.

Furthermore, the gel network has some important characteristics that affect the sol-gel system development and stability such as temperature during gel formation, glass transition temperature (T_g), and molecular weight (Mw) [54], [59]. Temperature during gel formation happens at aging phase of the production, which affects the gel stability. Formation of strong bonds and a well-organized three-dimensional cross linkage depends on controlling temperature during aging. Slow chilling or tempering is suggested instead of rapid chilling to form optimum gel network conditions [59], [60]. Additionally, slow chilling enhances the hydrogen bonds and hydrophobic interactions. Moreover, T_g is also directly related to the controlled temperature chilling since fine network gels have lower T_g and a broader melting point range the coarse network gels formed after rapid chilling. Another important parameter that affects the gel network stability is Mw. Thus, the smaller the polymer, the more cross-linkages needed. In addition to this, the logarithm of Mw has an almost linear relationship with $1/T_g$ [59].

2) Recent Approaches

Gelatin based gummies are formulated by using alternative ingredients such as low-calorie sugar substitutes or bioactive extracts such as red beet extract, red pitaya fruit or propolis puree in order to decrease the caloric value of the candies or enhance nutritional values [14], [61], [63]. According to a recent study, this objective was met using gelatin, low calorie polyols as a sugar replacement, propolis extract, and orange and raspberry juices. Even though, the hardness value of the orange juice candy and raspberry candy were higher than the control sample, consumer acceptance were better than the control samples in the sensory evaluation [63].

E. Starch

Starch is the primary tissue of some of the plants such as potato, corn, and rice and 70-80% of starch is comprised of carbohydrates [35]. Refined starch is usually a white, odorless powder and different origins of starches have different physical and chemical properties [1]. Starch is composed of two different molecular structures known as amylose and amylopectin [64]. In general, amylose content is around 20-30% and the chemical configuration is linear with only α -1,4 glycosidic linkages [35]. Amylopectin is highly branched glucose polymer and has both α -1,4 and α -1,6 glycosidic linkages [36]. Lastly, amylose can be associated with the firmness of the product and comprises rapid recrystallization whereas, amylopectin is related to the staling of the product and displays low recrystallization rates [24].

1) Starch Gelatinization and Retrogradation

Starch is insoluble in water but when starch and water are mixed a starch slurry is formed and when heated to a certain temperature, starch gelatinization occurs [65]. During gelatinization, granules swell with water molecules irreversibly with a dramatic increase in viscosity of the solution and loss of crystallinity [24], [36]. The gelatinization temperature depends on the origin of the starches, yet the range of starch gelatinization temperature is between 55-70 °C [36]. Gelatinization reaction is endothermic; therefore,

understanding the thermal behavior of the slurry is important. Moreover, water has a function of being a plasticizer and when a starch slurry is heated and the critical temperature is reached for the gelatinization, the plasticized granule amorphous region will have a phase transition from glassy to rubbery state [24]. Another important reaction concerning starch gel behavior is retrogradation, which affects texture and shelf life of the product [2], [36]. Retrogradation is a physical phenomenon that occurs when amylose and amylopectin disaggregate and change their structure in order to form different ordered structure during cooling after the starch gelatinization [66]. Tendency of starch gelatinization and starch retrogradation differs according to the origin of the starch, for instance common corn and wheat starch have a greater tendency to form gel and retrograde than potato and tapioca starch and yet a lower tendency to form gel and retrograde than high amylose corn starch [24]. Retrogradation is a common problem, but it can be inhibited with sugar, low water content and other gelling agents in the medium [67]. Additionally, this problem can be reduced with the use of modified instead of native starch [35], [68], [69]. Therefore, thin boiling starch or oxidized starch are commonly used in sugar-based confectionery products since thin boiling starch has greater firmness than unmodified starch while on the other hand, native starch has lower stability than oxidized starch [1]. For example, acid modified corn starch (AMCS) and gelatin have an antagonistic effect on gel formation up to the concentration of 8% gelatin and 2% AMCS. At 10% gelatin concentration and when the AMCS concentration increases above 2%, gelatin was repulsed by starch and there was segregation between the gelatin and starch matrixes according to confocal laser scanning microscopy [70].

2) Recent Approaches

Apart from producing low calorie confectionery products, different approaches to confectionery products are becoming popular such as the addition of dietary fibers to increase the nutritional value and the replacement of the starches. For instance, acid-thinned modified starch was replaced with inulin, which is a non-digestible carbohydrate resulting in a softer and stickier texture and enhanced the strawberry flavor of the candies [71]. Lastly, acid thinned modified starch can be replaced by acid thinned cassava starch which has desirable pasting properties for candy production, and the results were comparable according to physical and sensory evaluations [72].

F. Pectin

Pectin is a natural, complex, and hydrophilic polysaccharide, which can be found in the middle lamella of plant tissues [36], [73]. Pectin is a good source for confectionery applications since it is a natural compound with a reasonable cost [74]. Commercial pectin is obtained from citrus fruits such as orange peel and lemons and/or pomaceous fruits such as apple using pH 2 hydrochloric acid [1], [35]. The structural backbone of pectin polymer is d-galacturonic acid molecules which have α -1,4 glycosidic linkages with varying amounts of methyl ester groups [24], [75], [76]. Pectin is classified as either high-methoxyl pectin (HMP) or low methoxyl pectin (LMP) depending on the number of methylated monomers on the 6th carbon of the galacturonic molecules. These are classified according to the

degree of esterification values. LMPs have less than 50% and HMPs have more than a 50% degree of esterification [77]. HMPs are more suitable for the confectionery products than LMPs. HMPs form a gel when there is high amount of sugar in the system and the solution is acidic (around pH 5) [1], [61], [78]. However, a lower pH (from 2.5 to 3.3) of the gel solution with HMPs may increase hydrogen bonding and form stronger gel network [75], [78], [79].

IV. CONCLUSION

Currently the most studied sugar-based confectionery area is low-calorie soft candies owing to their high sugar content and high glycemic index. Quality parameters, techniques are significant, yet ingredient selection is impacting consumer acceptance due to the impact on microbial spoilage and shelf life of the product. Pectin and starch are also becoming popular as gelling agent types due to their softer texture than gelatin-based soft candies and due to being vegan. However, pectin and starch require specific sucrose concentration to obtain a rigid gel needed for confectionery products. On the other hand, gelatin only requires heat and provides a three-dimensional network gel in the solution and provides protein as a nutritional benefit. Producing functional, high nutritional vegan alternative candies is a potential research area warranting further study.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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