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Sucrose and glucose reduction using fructo-oligosaccharides and xylitol in pectin jelly candy

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Abstract. Confectioneries contain high amounts of sugar. High consumption frequency of candies may lead to various health risks. Sugar in jelly candy can be substituted with fructo-oligosaccharides and xylitol as a healthy sugar. This study examined the effect of using fructo-oligosaccharides and xylitol as a sugar substitute on the pH, degree of Brix, water activity, moisture content, hardness, colour, syneresis, and sensory of jelly candy from pectin. Sucrose was substituted with fructo-oligosaccharides (5.47%, 10.93%, and 16.36%) and glucose syrup was substituted with xylitol (5.47%, 10.93%, and 16.36%). The results showed that substituting sugar with fructo-oligosaccharides and xylitol affected the jelly candy's physical and chemical characteristics ($p < 0.05$). The higher the concentration of fructo-oligosaccharides and xylitol used, the lower the water activity, moisture content, and syneresis, as well as increasing the colour of the jelly candy compared to the control. Jelly candy with the highest sugar substitute concentrations obtained the softest of the jelly candy hardness. The sensory evaluation showed that panellists preferred jelly candy with sugar substitutions of 5.47% fructo-oligosaccharides and 5.47% xylitol.

1 Introduction

Candy is a sweet food product that is mainly composed of sugar. Jelly candy production utilizes pectin, starch, or carrageenan [1]. The gel formation occurs because the polymer chains merge to form a three-dimensional network that can bind water to produce a firm texture. The hydrocolloid is usually combined with large amounts of sweeteners such as sucrose and glucose syrup, flavour, colourants, and acid [2]. All ages highly favour gummies and jellies due to their chewiness, easy swallowing, and various available flavours [3].

Indonesian children aged 0 months up to 18 years old consumed gummies and jellies as a sugar source for 20–25.2 g/person/day [4]. Moreover, the average sugar consumption by men and women aged 0 to more than 55 years in Indonesia reached 25.61 g/person/day, which exceeds WHO's recommendation to consume less than 25 g [5]. Excessive sugar intake may induce non-communicable diseases such as obesity, cardiovascular disease, and diabetes. Obesity prevalence in boys and girls aged 5 to 12 years old in Indonesia are of 10.7% and 7.7%, respectively [6]. In 2018, diabetes mellitus prevalence in Indonesia reached

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8.5% and is predicted to be increased to 10.2% in 2030 [7]. Additionally, high candy consumption can cause dental caries in children [8].

Health problems start to awaken consumers' awareness to improve their health by consuming healthier foods [9]. The confectionery industry is also looking for alternative ingredients to reduce the amount of sugar used and the calories of the product produced [10]. Fructo-oligosaccharides are oligosaccharides consisting of a combination of fructose units connected by β-(2-1)-glycosidic bonds. In addition to the prebiotic effect, fructo-oligosaccharides also have low calories (2 kcal/g), increased mineral absorption, and lowered blood cholesterol [11]. Fructo-oligosaccharides have a sweetness level of 30–50% of sucrose and are widely used in food products [12]. Sugar alcohols, one of which is xylitol, are also widely used as sugar substitutes by the food industry. Xylitol has the same sweetness level as sucrose with lower calories (2.4 kcal/g), has a cold aftertaste effect, and prevents the growth of cariogenic bacteria. In addition, xylitol also has a high affinity for water [13].

Several studies have used prebiotics and polyols to substitute sugar in confectionery products [13–17]. However, from most of the literature found, there has been no research that combines the use of prebiotics and polyols to substitute sugar in jelly candy. This study aimed to substitute sucrose and glucose syrup in jelly candy using various concentrations of fructo-oligosaccharides and xylitol. The effect of using fructo-oligosaccharides and xylitol on the physical, chemical, and sensory properties of jelly candy was also observed in this study.

2 Materials and methods

The equipment used in this study were a digital scale, pan, stove, digital thermometer, jelly candy molds, expert pH pocket tester (Thermo Scientific, Singapore), refractometer (HT119, China), water activity meter (AquaLab 4TE, USA), oven (Memmert UF55, Germany), analytical balance (Ohaus PA Series Pioneer, USA), texture analyzer (Shimadzu, Japan), colourimeter (3NH Technology Co., LTD, China), and filter paper (Beimu, China). The materials used in this study included high methoxyl pectin (e-commerce, Indonesia), granulated sugar (Rose Brand, Indonesia), glucose syrup °Brix 82 (e-commerce, Indonesia), fructo-oligosaccharides (PT. Pangan Agung Sejahtera, Indonesia), xylitol (MH Foods, Malaysia), citric acid (e-commerce, Indonesia), trisodium citrate (Merck, Germany), and Mandarin orange flavor paste (Koepoe-koepoe, Indonesia).

2.1 Preparation of pectin jelly candy

The jelly candy formulas can be seen in Table 1. The formulation was based on [18] with modifications. A, B, and C treatments contained 5.47% fructo-oligosaccharides and 5.47% xylitol; 10.93% fructo-oligosaccharides and 10.93% xylitol; and 16.36% fructo-oligosaccharides and 16.36% xylitol, respectively. Fructo-oligosaccharides is used to substitute for sucrose, while xylitol is used to substitute glucose syrup.

Table 1. Pectin jelly candy formulas

Ingredients		Compositions (%)			
		Control	**A**	**B**	**C**
1	High methoxyl pectin	1.19	1.19	1.19	1.19
	Sucrose	9.14	9.12	9.11	9.09
	Trisodium citrate	0.37	0.37	0.37	0.37
2	Water	20.11	20.07	20.04	20.00

3	Sucrose	36.56	31.02	25.50	20.00
	Fructo-oligosaccharides	-	5.47	10.93	16.36
	Glucose syrup	30.16	24.63	19.12	13.64
	Xylitol	-	5.47	10.93	16.36
4	Citric acid solution	1.64	1.82	2.00	2.18
	Mandarin orange flavor	0.82	0.82	0.82	0.82
Total		**100**	**100**	**100**	**100**

2.2 Jelly candy production

The procedure for making jelly candy followed the method by [18] with modifications. The dry ingredients in part 1 were mixed. The mixed ingredients were added to the water part 2 in the mixing container. The mixture was heated to a boil and stirred until the pectin dissolved. Sucrose, glucose syrup, fructo-oligosaccharides, and xylitol in part 3 were added to the heated mixture and cooked until dissolved. The mixing pot was removed from the heater. The flavoring paste and citric acid solution were added and stirred. The pectin jelly candy mixture was deposited into the mold and stored at room temperature (25–30°C) for 48 hours to harden.

2.3 pH and degree of Brix

The pH meter was calibrated with pH 4 and 7 buffer solutions. 5 g jelly candy for each treatment was cut into small pieces and mixed with 15 mL of distilled water. The mixture was heated and stirred until the sample dissolved completely [19]. Before being measured with a pH meter, the mixture is cooled to room temperature (25–30°C). Degree of Brix analysis was carried out using a refractometer.

2.4 Water activity

The samples were cut into small pieces and placed in the sample cup container. The sample container was placed in the sample compartment in the water activity meter and analyzed [20].

2.5 Moisture content

Porcelain crucibles were weighed and dried at 105°C for 1 hour with an oven. 2 g of samples were weighed and placed into the cooled porcelain crucibles. The porcelain crucibles containing the samples were dried in an oven at 105°C for 3 hours. The porcelain crucibles containing the samples were cooled in a desiccator, weighed, and placed back into the oven for 30 minutes of drying. This step was repeated until a constant weight was achieved [21].

2.6 Texture

The texture was tested by compression using a flat probe (plate) with a 1 mm/sec speed. The texture parameter tested was hardness. The test was carried out at room temperature and assisted by software connected to the texture analyzer.

2.7 Colour

The test used the CIELAB system and was carried out three times at room temperature. The sample was placed in the sample container. The sample container was placed under the colourimeter and measured [22].

2.8 Syneresis

Jelly candy from each treatment was weighed (as initial weight) and placed on filter paper. Samples were stored at room temperature (25–30°C) for 24 hours. After 24 hours of storage on filter paper, the sample was weighed as the final weight [23,24].

2.9 Sensory analysis (hedonic test)

Fifty untrained panelists were used for the hedonic test. Four samples of jelly candy (control, A treatment, B treatment, and C treatment) were presented with a 3-digit random number. A 7-point hedonic scale (1 = dislike very much, 2 = dislike moderately, 3 = dislike slightly, 4 = neutral, 5 = like slightly, 6 = like moderately, and 7 = like very much) was used to evaluate colour, aroma, taste, texture, and overall acceptance.

2.10 Statistical analysis

All the results were analyzed using IBM SPSS Ver. 25 and presented in mean ± standard deviation from three replications. One-way ANOVA and Tukey's HSD were conducted to observe the significant difference among the samples at $p < 0.05$.

3 Results and discussion

3.1 The effects of fructo-oligosaccharides and xylitol on the pH, degree of Brix, water activity, moisture content, hardness, and syneresis of pectin jelly candies

Based on the results of the pH of the jelly candy in Table 2, the control jelly candy had the highest pH, while the C treatment jelly candy had the lowest pH. Gel formation by HMP is influenced by pH and the type of sugar used [25]. At an acidic pH, the carboxyl groups experience deionization, so the electrostatic repulsion between the pectin chains also decreases. The pectin chains experience aggregation and form junction zones [26,27]. However, suppose the pH exceeds the pKa value of the carboxyl group (about pH 3.55). In that case, it prevents the formation of gels or junction zones because the pectin molecule has a sufficient negative charge [25]. Reducing the sugar used can increase the pH to exceed 3.50, thereby reducing the strength of the gel structure [28].

The pH of the jelly candy in this study ranged from 3.07 to 3.23. Jelly candy with a higher concentration of sugar substitutes had a lower pH. The concentration of citric acid used influences the difference in pH of the jelly candy. Besides acting as a flavor enhancer, citric acid is also a pH regulator [29]. The more citric acid added, the lower the pH. In general, high methoxyl pectin (HMP) can form gels under acidic conditions at a pH of 2.50–3.50. The jelly candy in this study fulfilled the pH range required for gel formation by HMP. Jelly research by [12] also showed that jelly candy with a higher concentration of fructo-oligosaccharides had a lower pH. Gel formation by HMP also requires a minimum of 55% total solids in the form of dissolved sugar and not exceeding 85% [27]. Based on the results of °Brix in Table 3, the jelly candy in this study had a total solid ranging from 81.17–82.33, so it could influence the gel formation by HMP.

Table 2. pH of the produced jelly candies

Treatments	**Mean ± Standard Deviation***
	pH
Control	3.23±0.06^{b}
A	3.20±0.00^{b}
B	3.20±0.00^{b}
C	3.07±0.06^{a}

$^{a-c}$Different lowercase indicates significant differences between treatments at $p < 0.05$

Table 3. Degree of Brix of the produced jelly candies

Treatments	**Mean ± Standard Deviation***
	°Brix
Control	81.17±1.04^{a}
A	81.67±0.58^{a}
B	82.33±0.58^{a}
C	82.33±0,58^{a}

$^{a-c}$Different lowercase indicates significant differences between treatments at $p < 0.05$

Water activity shows the amount of free water contained in food. Free water can be used for chemical and biochemical reactions, and microbial growth. Water activity is an essential factor affecting the shelf life and spoilage of foodstuffs [30]. Based on the results of the water activity of the jelly candy in Table 4, the control jelly candy had the highest water activity, which was 0.72. In contrast, the B and C treatments jelly candies had the lowest water activity of 0.69. Based on the results in Table 4, the higher the concentration of fructo-oligosaccharides and xylitol, the lower the water activity better than the control jelly candy. The difference in the molecular weight of the humectant ingredients can cause the difference in jelly candy water activity. Sucrose has a molecular weight of 342 Da, glucose has a molecular weight of 180.18 Da, fructo-oligosaccharides has a molecular weight of 720–1296 Da, and xylitol has a molecular weight of 152 Da [31–34]. Glucose has a larger molecule than sucrose, so it has fewer binding sites than sucrose [35].

Humectants with a lower molecular weight have a better ability to absorb water and reduce water activity [36,37]. In addition, although sucrose has more OH groups in its single molecule, xylitol has more total OH groups overall. Solids with more OH groups can stabilize the water structure around solid molecules stronger due to better solubility [38]. The high number of active hydroxyl groups in xylitol can bind well to water molecules, so xylitol is very hygroscopic [39]. Adding more xylitol causes more water to be bound, reducing water activity [40]. The results of water activity obtained are similar to the research by [40], where increasing the amount of xylitol in manufacturing cantaloupe jam results in lower water activity. In addition, the water activity of jelly candy in this study generally fulfilled the water activity of jelly candy, which ranged from 0.50 to 0.75 [41].

Table 4. Water activity (a_w) of the produced jelly candies

Treatments	Mean ± Standard Deviation*
	a_w
Control	0.72±0.00^c
A	0.70±0.00^b
B	0.69±0.00^a
C	0.69±0.06^a

$^{a-c}$Different lowercase indicates significant differences between treatments at $p < 0.05$

Moisture content is the total water contained in a food ingredient [42]. Moisture content is also related to the quality and durability of foodstuffs. Foodstuffs with higher moisture content can encourage the possibility of food spoilage [43]. The results of the moisture content of jelly candy can be seen in Table 5. The control jelly candy had the highest moisture content, 18.29%, while the A treatment jelly candy had the lowest moisture content, 16.13%. All the moisture content of jelly candy in this study was able to meet the moisture content requirements set by SNI 3547-2-2008, which is a maximum of 20% [44]. Based on the moisture content results in Table 5, substituting sugar with fructo-oligosaccharides and xylitol reduced the moisture content of jelly candy. Increasing the concentration of fructo-oligosaccharides and xylitol increased the moisture content of the jelly candy. An increase in moisture content, along with an increase in the concentration of sugar substitutes, can be influenced by the ability of xylitol to absorb water. The more water absorbed or bound by xylitol, the higher the sample's moisture content [39]. An increasing number of hygroscopic components can increase the moisture content, but the water activity of food decreases [45]. This theory corresponds with the water activity and moisture content of the jelly candy obtained in this study. The hydroxyl groups in xylitol can form excellent hydrogen bonds with water molecules, thereby increasing the amount of water bound to them [40]. In addition, increasing the concentration of citric acid can also increase the moisture content because citric acid can bind water [29]. These results are similar to a study by [29], where the concentration of citric acid increased in passion fruit jelly with Dutch eggplant increased moisture content.

The molecular weight of fructo-oligosaccharides can also cause a decrease in moisture content in jelly candy with sugar substitution. Fructo-oligosaccharides have a higher molecular weight than sucrose, glucose syrup, and xylitol. Materials with a higher molecular weight can increase the viscosity of the solution [46]. Fructo-oligosaccharides produce solutions with a higher viscosity than sucrose [47]. In addition, its solubility is also lower than materials with lower molecular weights [48], so it requires a longer cooking duration. The longer the cooking duration, the more water evaporates and can reduce the moisture content [49]. Jelly candy with fructo-oligosaccharides and blueberry extract by [12] also showed an increase in moisture content as the concentration of fructo-oligosaccharides increased.

Table 5. Moisture content of the produced jelly candies

Treatments	**Mean ± Standard Deviation***
	Moisture Content (%)
Control	18.29 ± 0.38^{b}
A	16.13 ± 0.79^{a}
B	16.18 ± 0.86^{a}
C	16.80 ± 0.38^{ab}

$^{a\text{-}c}$Different lowercase indicates significant differences between treatments at $p < 0.05$

In the production of confectionery products, texture is an important parameter that can influence consumer perceptions and attitudes [50]. One of the critical texture parameters in food products is hardness. Hardness is the force required to cause deformation or change in the shape of food [51]. Based on the hardness results of jelly candy in Table 6, the A treatment jelly candy had the highest hardness (8.16 N), while the C treatment had the lowest hardness (4.40 N). C treatment jelly candy was significantly different from other jelly candies. Jelly candy hardness can be affected by its water content. The lower the moisture content, the hardness or strength of the gel increases [52]. Compared with the moisture content of jelly candy with other sugar substitutes in Table 5, C treatment jelly candy had the highest moisture content, so it had the lowest or softest hardness. In the manufacture of candy, water acts as a plasticizer, which can soften the final texture of the product through the formation of hydrogen bonds with other components [50]. Hard candy fortified with *Cudrania tricuspidata* extract by [39] also showed that increasing the concentration of xylitol decreased the hardness of hard candy.

The control jelly candy had a higher hardness ($p < 0.05$) than the C treatment jelly candy because it used 100% sucrose and glucose syrup. Sucrose can encourage hydrogen formation, form more junction zones, and stabilize junction zones [53]. Sucrose can also undergo recrystallization during the cooling stage, resulting in a denser texture [54]. The higher concentration of xylitol usage decreases the hardness of jelly candy, which can be caused by the formation of weaker junction zones in the pectin gel network [11]. In addition, the ability of xylitol to take up water can hold water molecules needed to promote the intermolecular attractions of the gelling agent. Thus, the unbound water becomes insufficient for joining the molecular chains of the gelling material and reduces the aggregation of junction zones [55].

Table 6. Hardness of the produced jelly candies

Treatments	**Mean ± Standard Deviation***

	***Hardness* (N)**
Control	7.88±0.35^{b}
A	8.16±0.21^{b}
B	7.82±0.22^{b}
C	4.40±0.33^{a}

$^{a-c}$Different lowercase indicates significant differences between treatments at $p < 0.05$

Syneresis is the separation of water from the surface of the gel that occurs during storage [23]. The separation of water and shrinkage of food products can reduce product quality [24]. During storage, pectin gels generally experience syneresis [56]. The syneresis results of jelly candy in this study can be seen in Table 7. The control jelly candy had the highest syneresis percentage (2.31%), while the B treatment jelly candy had the lowest (1.88%). Based on the results of syneresis in Table 7, sugar substitution by fructo-oligosaccharides and xylitol, as well as the addition of sugar substitute concentrations, can reduce the percentage of syneresis compared to control jelly candy. The hygroscopicity of xylitol to retain water and the ability to reduce water activity (free water) in pectin gels can reduce syneresis [56]. The syneresis percentage results obtained in this study correspond to research by [57]. In that study, the use of xylitol in carrot jelly reduced syneresis. Chewable gel with pre-emulsion using pectin and sugar alcohols (xylitol and sorbitol) by [56] also showed decreased syneresis.

Table 7. Syneresis of the produced jelly candies

Treatments	**Mean ± Standard Deviation***
	Syneresis (%)
Control	2.31±0.88^{a}
A	2.11±0.86^{a}
B	1.88±1.22^{a}
C	2.01±0.94^{a}

$^{a-c}$Different lowercase indicates significant differences between treatments at $p < 0.05$

Colour is an optical property in confectionery products, greatly influencing consumer perception and consumption [50]. Based on Table 8, C treatment jelly candy had the highest L* value. The control jelly candy had the lowest a* and b* values compared to the jelly candy with sugar substitutes. The L* value or the brightness of the control jelly candy significantly differed from the B treatment jelly candy, where the B treatment jelly candy had a lower brightness. However, the L* value was back to increase in the C treatment jelly candy. Using fructo-oligosaccharides produces a whitish and cloudy or translucent gel [58]. A cloudy solution will have a lower brightness than a colourless or transparent solution [15]. As the concentration of sugar substitutes increases, the a* (reddish) and b* (yellowish) values increase. The colour intensity of the jelly candy increased with increasing concentrations of fructo-oligosaccharides and xylitol. Research results by [58] also showed that increasing the concentration of fructo-oligosaccharides in sausages decreased brightness and increased colour intensity. However, the highest brightness value was also found in the sausages with the highest concentration of fructo-oligosaccharides. The increase in the brightness and colour of jelly candy can also be caused by the higher concentration of citric acid in the C treatment. Citric acid can increase the colour and clarity of the resulting gel [59].

Table 8. Colour analysis of the produced jelly candies

Treatments	**Mean ± Standard Deviation****		
	L*	**a***	**b***
Control	32.15 ± 1.45^{b}	6.09 ± 0.41^{a}	17.10 ± 0.59^{a}
A	30.47 ± 1.01^{ab}	7.36 ± 1.32^{a}	18.27 ± 1.19^{a}
B	28.86 ± 0.43^{a}	14.68 ± 0.67^{b}	28.08 ± 0.24^{b}
C	39.02 ± 0.58^{c}	14.04 ± 0.19^{b}	37.99 ± 0.33^{c}

$^{a-c}$Different lowercase indicates significant differences between treatments at $p < 0.05$

3.2 The effects of fructo-oligosaccharides and xylitol on the sensory of pectin jelly candies

The hedonic test was carried out to determine the level of preference of the panelists for the resulting jelly candy. The jelly candy hedonic test results can be seen in Table 9. Based on the results of one-way ANOVA, sugar substitution in jelly candy significantly affected colour attributes and overall acceptance. On both attributes, the A treatment jelly candy significantly differed from the C treatment jelly candy. The A treatment jelly candy had the highest colour preference and overall acceptance, while the C treatment obtained the lowest colour preference and overall acceptance. The low preference value of panelists for C treatment jelly candy could be caused by the more fructo-oligosaccharides added, the more turbid the resulting gel solution [58]. The characteristic of jelly candy that is commonly known by the public is that it has a transparent gel [60]. A treatment jelly candy obtained the highest preference value for colour, taste, and texture compared to other jelly candies, so it received the highest overall acceptance value. The hardness results in Table 6 showed that the A treatment jelly candy had the highest hardness. These results indicate that panelists prefer jelly candy with a texture that is not too soft.

Table 9. Sensory preference obtained from the hedonic test of the jelly candies

Sensory Attributes	**Mean ± Standard Deviation***			
	Control	**A**	**B**	**C**
Colour	5.82 ± 1.19^{b}	5.92 ± 1.10^{b}	5.90 ± 0.97^{b}	5.20 ± 1.25^{a}
Aroma	5.42 ± 1.25^{a}	5.52 ± 1.23^{a}	5.56 ± 1.05^{a}	5.56 ± 1.05^{a}
Taste	5.60 ± 0.93^{a}	5.82 ± 0.90^{a}	5.58 ± 1.26^{a}	5.38 ± 1.34^{a}
Texture	4.62 ± 1.64^{a}	5.12 ± 1.17^{a}	5.10 ± 1.37^{a}	4.64 ± 1.31^{a}
Overall acceptance	5.22 ± 1.13^{ab}	5.72 ± 0.81^{b}	5.56 ± 1.05^{ab}	5.12 ± 1.15^{a}

$^{a-c}$Different lowercase indicates significant differences between treatments at $p < 0.05$
1 = dislike very much, 2 = dislike moderately, 3 = dislike slightly, 4 = neutral, 5 = like slightly, 6 = like moderately, and 7 = like very much

4 Conclusion

Based on the research, the jelly candy produced had significant differences in pH, water activity, moisture content, hardness, L*, a*, and b*. Increasing the concentration of fructo-oligosaccharides and xylitol used resulted in lower water activity, moisture content, and syneresis percentage than the control jelly candy. The colour of the jelly candy with sugar substitutes is also getting brighter and yellower. However, sugar substitutions caused the hardness of jelly candy to decrease. Based on the hedonic test, panelists preferred A treatment jelly candy (5.47% fructo-oligosaccharides and 5.47% xylitol).

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