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Influence of gelatin and isomaltulose on gummy jelly properties

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Abstract

The purpose of this research was to study the effects of gelatin (G) content (9, 12, and 15%) and isomaltulose (IS) content (20, 30, 40, 50, and 100%) on the physical and sensory quality of gummy jelly using 3 x 5 factorial design. The response surface methodology can be used to describe the interaction between G and IS on gummy jelly properties. For chemical properties, the water activity (a_w) was in a range of 0.55 - 0.61 and the pH was 2.8 - 3.1. From the descriptive analysis, it was found that at constant IS content, increasing G content significantly decreased the intensity of sourness but significantly increased sweetness, toughness, stickiness and hardness ($p \leq 0.05$). However, in gummy jelly produced from 100% IS, the toughness and hardness decreased significantly ($p \leq 0.05$). At constant IS content, increasing G increased the intensity of the sourness, sweetness, stickiness, toughness, and hardness. Gummy jelly produced from 100% IS had a lower liking score than 40% IS. Gummy jelly containing 40% G and 12% IS gave a maximum significant score in appearance, transparency, sourness, texture and overall acceptance.

Introduction

Gummy jelly is a kind of confectionery products in a group of candy gel whose main ingredient is sugar. Traditional gummy is a product of fruit or herb juice mixed with sweeteners and substances causing gel to make product with a dry-sticky texture and are tough to chew. Gummy jelly or dry jelly is dessert products derived from the gel substances such as gelatin mixed with sweeteners including sugar and glucose syrup (Marfil *et al.*, 2012). At present, gummy jelly candy with a soft and sticky texture is popular worldwide. The consumption of this confection gives a body fat index development for type 2 diabetes (O'Neil *et al.,* 2011). Moreover, the overconsumption of confectionery products by children continues to increase gradually. This is a concern for parents and patients. Gummy confection is second in sales of all confectionery products. Commercial gummy confection consists of a gelling agent mixed with a high ratio of sucrose and glucose syrup added with artificial flavoring and a coloring agent (Marfil *et al.*, 2012). Various types of confectionery products manufacturing are made from sucrose. Gummy jelly products mainly use sucrose which has a high glycemic index and contributes to high blood sugar (Yudkin *et al.*, 1972).

Gelatin (G) is a type of product with an animal origin and derived from the collagen of leather or bones (DeMars and Ziegler, 2001; Djagny *et al.*, 2001; Tau and Gunasekaran, 2016). The role of gelatin in gummy jelly was to form a gelling network by their junction zones (Guo *et al.*, 2003). Isomaltulose (IS) is found in honey, and sugar cane (Eggleston *et al.*, 2003). Commercial isomaltulose, trade named as Palatinose®, is produced from sugar cane/sucrose by enzymatic modification of the (1,2)-fructoside to a (1,6)-fructoside glycosidic linkage followed by sugar crystallization process (Schiweck *et al.*, 1990). IS is a functional, digestible, non-cariogenic and low glycemic reducing disaccharide composed of glucose and fructose, just like sucrose (Barez *et al.*, 2000). The connected bond between glucose and fructose is a stronger α-(1-6) glycosidic linkage (Hawai *et al.*, 1989). This is the reason that oral microorganisms are unable to digest which is responsible for tooth decay (Matsuyama *et al.*, 1997). This feature also leads to controlling and maintaining sugar levels by being slowly released in the blood stream; it is also non-cariogenic (Hawai *et al.*, 1989; Barez *et al.*, 2000).

Although IS provides 4 kcal/g which is equivalent to sucrose, in terms of health benefit, a (1,6)- fructoside linkage is difficult to hydrolyze by enzymes produced by oral microorganisms (Matsuyama *et al.*, 1997). Because of its low-glycemic and low-insulinemic indexes, it is also applicable for athletes and diabetics

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(Kawai *et al*., 1989; Lina *et al*., 2002). Regarding the usage properties, it has only half the sweetness of sucrose and also low solubility of only about 30% at 25°C (Kaga and Mizutani, 1985; Schiweck *et al*., 1990). However, it is more stable under acidic conditions (Lina *et al*., 2002). IS can be absorbed slowly but can be digested completely by enzymes in the small intestine. Therefore, it does not cause diarrhea if consumed in large quantities and does not create a laxative effect (Hawai *et al.,* 1989). For toxicity, it was found that IS does not affect disorders in growth, food/water consumption, visibility, the circulatory system, urology, body weight or histopathology. This was based on an experiment by which IS was fed to rats for 13 weeks (Lina *et al.,* 2002). IS can be absorbed into the body without any irritation in the stomach (Lina *et al.*, 2002). It can be concluded that intake of IS reduces the risk of obesity, high blood pressure, high blood fat status and diabetes (Mori *et al*., 2008).

Response surface methodology (RSM) is used to consider how the factors and their interactions affect the responses and optimize properties/qualities. This research was examined the interaction of the two factors (G and IS) on the gummy jelly properties. The replacement of sucrose with healthier natural ingredients could lead to the production of value added gummy confections. IS has been mentioned as an acceptable sucrose replacer with many advantages in most snack confections (Lina *et al*., 2002). The replacement of sucrose by IS gives the product a low glycemic index. Two benefits of using IS were to improve dental hygiene because IS cannot be fermented by plaque microflora and destroys tooth enamel and to model food formulation for diabetes patients who face challenging regulation of blood sugar level. Generally, the color of commercial gummy jelly comes primarily from the synthetic/ artificial color. Fang (*Caesalpinia sappan* Linn.) was also considerable to be a suitable red dye as a natural color substance in gummy jelly. Therefore, this study aimed to investigate the effects of G and IS on the chemical and sensory quality of gummy jelly.

Materials and Methods

Materials

Isomaltulose (DPO international, Thailand), sucrose (Lin, Thailand), glucose syrup 43 DE (Fancy Craft, Thailand), gelatin A 240 Bloom (Mcgarrett, Thailand), citric acid (Best odor, Thailand), pineapple flavouring (Best odor, Thailand), natural red color from Fang (*Caesalpinia sappan* Linn) and corn starch (Xingmao, China) were used as ingredients in the formulation of gummy jelly.

Experimental procedure

The gummy jelly prepared consisted of 9-15% gelatin, 23.5% water, 33% sugars, 31.5% glucose syrup and 3% citric acid. Also, 0.2 ppm of red coloring from Fang (*Caesalpinia sappan* Linn.) and 0.5 ppm of pineapple flavoring were added in all cases. The samples were obtained by combining different G at 9, 12, and 15% and sucrose replacing isomaltulose at 20, 30, 40, 50, and 100% using a 3x5 factorial design.

The gelatin was dissolved in water in a gelling agent: a water ratio of 1:2 (w/w) was used to obtain a homogeneous mix and subsequently added to the syrup. All the ingredients were mixed in 12 cm diameter pot stirred on an electrical hot plate (ALFA Kitch, Germany) at 110°C for 5 min. The flavoring and coloring agents were added to the mixture and then poured into 15 x 10 cm plastic molds. The molds were placed in a chamber at 7°C for 18 h. The samples were removed from their molds and cut into 1x1x1 cm^3 and the surface was sprinkled with corn starch. The samples were kept for evaluation of the properties.

Physicohemical properties

Water activity (by dew point hydrometer, Aqualab, 4TE, USA) and pH (by a pH-meter, TEMP Meter Clean, Taiwan) were measured on the final products. All analyses were carried out in triplicate.

Descriptive analysis

Descriptive sensory analysis was used for 15 samples with a 15 anchored scale. The panel consisted of 10 trained panelists who are students from the Department of Home Economics at Srinakharinwirot University. All panelists had prior experience in descriptive analysis and are regular consumers of confectionery products. The training session was over 36 h. The samples were given to each panelist for vocabulary or attribute development. Panelists listed the texture, taste and flavor attributes of commercial and experimental gummy jelly. All attributes from vocabulary development was refined and selected into 5 attributes (sourness, sweetness, stickiness, toughness, and hardness) for describing the gummy characteristics. The attributes were then developed individually for a definition and the intensity of the scaling samples were placed on a 15.0 cm line scale anchored at the extremes. Four commercial gummy jellies were used for reference in a ballot as shown in Table 1. Testing sessions were conducted in a sensory evaluation laboratory room. The 8 sample treatments were prepared and evaluated in week one

Table 1. Definition of gummy jelly attributes and references with intensity for descriptive analysis

Attribute	Definition	Method	Reference (Intensity)*
Sourness	Recognition of sourness in the mouth while chewing the sample.	Chew the sample by molars 5 times and recognize the sourness in the mouth.	0.1% citric acid (0.5) 0.5% citric acid (2.5) 0.8% citric acid (14.0)
Sweetness	Recognition of sweetness in the mouth while chewing the sample.	Chew the sample by molars 5 times and recognize the sweetness in the mouth.	1% sucrose (0.5) 3% sucrose (1.5) 5% sucrose (3.5)
Stickiness	Having the property of adhering or sticking to a surface; adhesive.	Chew the sample by molars until the sample was fine and count the chewing time that recognize the stickiness.	Marshies (0.5) Mallow plus (7.0) YoYo (12.5) Jolly Bear (15.0)
Toughness	The resistance force to the tooth while chewing the sample.	Chew the sample by molars and evaluate the force while chewing.	Marshies (0.5) Mallow plus (7.0) YoYo (10.5) Jolly Bear (15.0)
Hardness	The force that breaks or ruptures the samples.	Chew the sample by molars 1 time and evaluate the force perception.	Marshies (1.5) Mallow plus (5.5) YoYo (11.0) Jolly Bear (15.0)

and 7 samples were prepared and evaluated in the following week. Each batch was evaluated twice by the panel.

Acceptance test

The gummy jelly made from 40% IS and 100% IS combined with 9-15% G was selected for the likability evaluation. The 30 panelists evaluated the samples in two sessions by different levels of IS. The 7-point hedonic scale was used to evaluate the following attributes: appearance, transparency, sweetness, sourness, texture, and overall acceptability. In each session, three samples were served in plastic cups with lids coded with 3-digit random numbers. The panel evaluated and scored the total six samples individually.

Statistical analysis

Analyses of Variance (ANOVA) in order to discern whether the effect of the G and IS content 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 6.0.0 software (State-Ease Inc., Minneapolis, MN, USA).

Results and Discussion

Water activity, a_w

Figure 1a shows the a_w of gummy jelly subjected to different levels of G and IS. The a_w of gummy jelly was found to be 0.5-0.6. The result showed that at constant G, there was no significant difference ($p>0.05$) in a_w by increasing IS. At constant IS, increasing G gave the a_w was significantly different ($p<0.05$). A a_w indicates the free water of a product which is consequently subject to the growth of microorganisms and to chemical reactions which might affect the stability of these products (Periche *et al.*, 2014). In general, gummy gels contain little moisture (<20%) and the a_w was in a range of 0.7-0.8 (Lindley, 2002; Periche *et al.*, 2014). Compared to general gummy, the a_w of the experimental gummy was lower than the gummy from previous research (Periche *et al.*, 2014). This research showed there was no increased ability of IS to bind the free water resulting in a non-significant difference in the aw by increasing IS. In contrast with the research of Periche *et al.* (2014) who reported that the gummy confectionery made up of 30% IS and 70% fructose had the least aw at 0.79, which might imply a high stability of the gummy jelly. Moreover, replacement of sucrose by IS led to the moisture content of marshmallows increasing (Periche *et al.*, 2015).

pH

The pH of gummy jelly was found to be 2.8-3.1. Figure 1b shows that at constant G, the increasing IS resulted in the acid - base (pH) not being significantly different ($p>0.05$). At constant IS, the increasing G also increased the pH of products significantly ($p<0.05$). Increasing G resulted in a significant increased acid - base of the products ($p\leq0.05$). This is because the G was extracted and derived from collagen which is a protein in connective tissue (Guo *et al.*, 2003). The subunit of G is amino acid thus increasing G increased amino acid content which caused the gummy jelly to have high pH

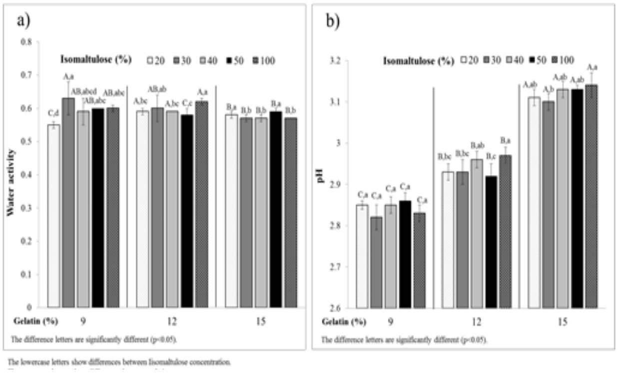

Figure 1. Effects of gelatin and isomaltulose content on a) water activity and b) pH of gummy jelly

(Periche *et al*., 2014). According to the above results, gummy jelly with different concentrations could be recommendable for gummy manufacturing in terms of a_w and pH.

Descriptive sensory test

The intensity scores of sweetness, sourness, stickiness, toughness, and hardness are shown in Figure 2. Regarding sensory attributes, the replacement of sucrose by 20-50% of IS led to gummy jelly with no difference in sensory attributes ($p>0.05$). It was concluded that at constant G, increasing 100% of IS increased the sourness but decreased sweetness, stickiness, toughness, and hardness significantly ($p<0.05$). At constant IS, increasing G decreased sourness but increased sweetness, stickiness, toughness and hardness significantly ($p<0.05$). At constant G, increasing IS did not affect sweetness significantly ($p> 0.05$). However, when G was increased at constant IS, it was found that the level of intensity of the sweetness increased significantly ($p<0.05$).

At constant IS, increasing the amount of G increased the intensity of toughness, stickiness, and hardness significantly ($p<0.05$) except for the gummy jelly made from 100% IS which decreased only toughness and stickiness significantly ($p<0.05$). The result of this research was similar to research of Periche *et al*. (2014 and 2015). The higher the proportion of IS, the lower the sweetness of the samples (Periche *et al*., 2015). Due to the IS having only half the sweetening power of sucrose (Kaga and Mizutani, 1985), the replacement of sucrose with IS in gummy jelly could be its sweetening power compare to that of common sugar. Not only is there a loss of sweetness, but possibly also a decrease the toughness, hardness and stickiness which cause by bonding among the gelatin network that could lead to easily break the structure (Tau and Gunasekaran, 2016). The role of sucrose in G products with content of high solids has been studied extensively by many research studies (Kasapis *et al.*, 1999; Kasapis, 2001 and Kasapis *et al*., 2003; Choi *et al.,* 2004; Al-Marhoobi and Kasapis, 2005). When sugar replacers are used with G, the texture of the G gel is weakened because the sugar solids are missing from the regular formulation (Kasapis, 2001 and Kasapis *et al*., 2003; Tau and Gunasekaran, 2016).

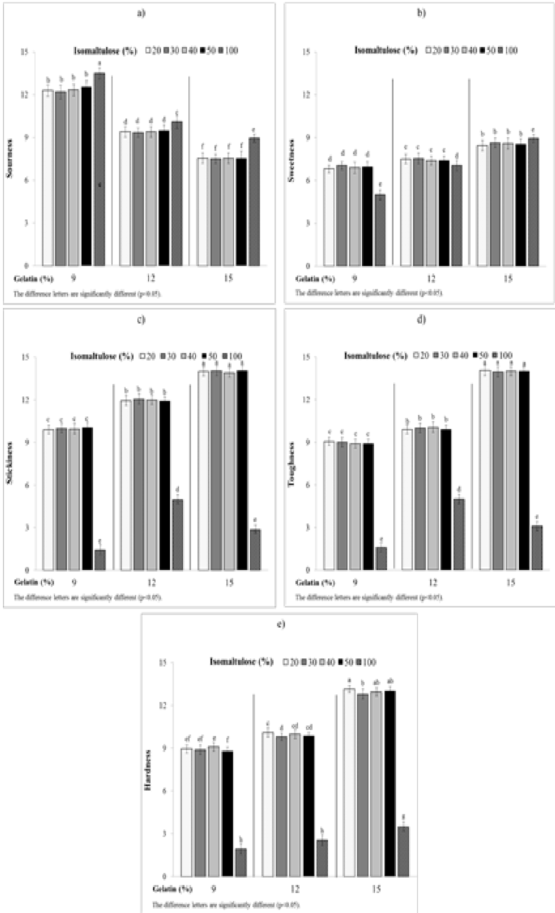

Figure 2. Effects of gelatin and isomaltulose on a) sourness, b) sweetness, c) stickiness, d) toughness, e) hardness of gummy jelly

The lower toughness, stickiness and hardness for the gummy jelly are attributed to a large amount of IS in the G. On the other hand, the side-chain of G molecules could adhere with the main ingredient in the gels by covalent bonds. The higher solids/sucrose content in the gels afford faster network development during cooling because of sufficient hydrophobic interaction shift the adjacent G portion (Tau and Gunasekaran, 2016) which could explain their higher intensity of toughness, stickiness and hardness. This result was similar to the research of Periche et al. (2014) who replaced sucrose by IS and found that IS led to gummy confections with lower hardness and gumminess than the control samples with the same concentration of G.

G is a polypeptide produced from collagen and

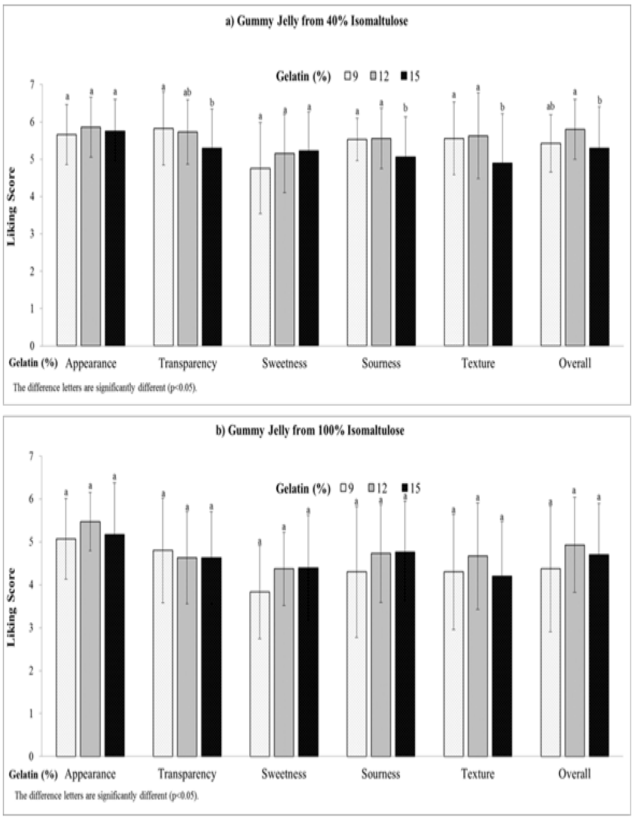

Figure 3. Acceptance of gummy jelly containing a) 40% isomaltulose and b) 100% isomaltulose

used as a main ingredient for confection products. It can form junction zones by its helix and develop a three-dimensional network (Guo *et al*., 2003). The junction zones of G can increase as the G advances. Sugars or sucrose can stabilize the structure of these proteins by strengthening hydrophobic interactions or hydration of proteins (Choi *et al*., 2004). With high sugar solids, the hardness of G-pectin gels with low pH in a range of 3.25-3.35 increased with the increasing concentration of gelling agents (Poppe, 1995).

The high molecular mass of gelatin provided more strength of the gel when dissolved in water causing adding G gave more stickiness, toughness, and hardness of the products. The involvement of G in the formulation caused an elastic texture and stable form that led to the high springiness desirable for confection products (Hamann *et al*., 2006). This research corresponded to the research of Periche *et al.* (2015); the higher the concentration of G, the higher the hardness of the samples, except for marshmallows made of 70% IS.

Consumer acceptance

The products containing 9% G and 20%, 40% and 50% IS were investigated differently among the 15 panelists using a Duo-Trio difference test. The result (data not shown) found that there was no significant difference ($p>0.05$) between different IS content. It was concluded that the content of IS did not affect the sensory perception of the test. The preference score of gummy jelly made from 40% IS was shown in Figure 3a. There were significant differences in the liking score of appearance, transparency, sourness, texture and overall satisfaction of each product. Gummy jelly containing 40% gelatin and 15% IS had the lowest preference scores for transparency, sourness, texture and overall attributes. However, gummy jelly from 100% IS with different IS content was not significantly different in all of the liking attributes (Figure 3b). The liking score of all attributes for gummy jelly products with 100% of IS was lower than the gummy jelly containing 40% IS (Figure 3). Due to crystallization, the texture score and overall acceptance gradually decreased with higher concentrations of IS.

Replacement of sucrose with IS in gummy confections could lead to its lower solubility compared to common sugar (Periche *et al.*, 2014). According to the research of Periche *et al.* (2015) who reported the highest value of hardness observed in marshmallows made with 70 g of IS with 4 and 5 g of gelatin/100g. This appearance could be related to the low solubility of IS which caused crystallization during cooling (Kaga and Mizutani, 1985; Schiweck *et al.*, 1990; Mitchell, 2006) and IS molecules achieved enough mobility to form crystals (Periche *et al*., 2015). There was a similar result with Periche *et al.* (2014) who reported gummy confectionery formulated with high IS content showed high values of luminosity. This behavior might be related to the lower solubility of IS at room temperature which could lead to crystallinization (Kaga and Mizutani, 1985; Schiweck *et al*., 1990). Therefore, the use of 100% IS resulted in crystallization on the surface of the product. The crystallization of sugar and roughness in gummy jelly would provide dissatisfaction among consumers.

Effects of gelatin and isomaltulose on physicochemical properties of gummy jelly

The statistical analysis (ANOVA) showed that the effect of the interaction between the G and IS concentration on physicochemical properties was significant as shown in Figure 4a-4b. There was an interaction of the G and IS which affected the aw of gummy jelly products (Figure 4a). When the amount of G and IS increase, aw tends to decrease significantly ($p<0.05$). According to the research of Periche *et al.* (2014), it was found that aw of gummy jelly made from different G content and the ratio of

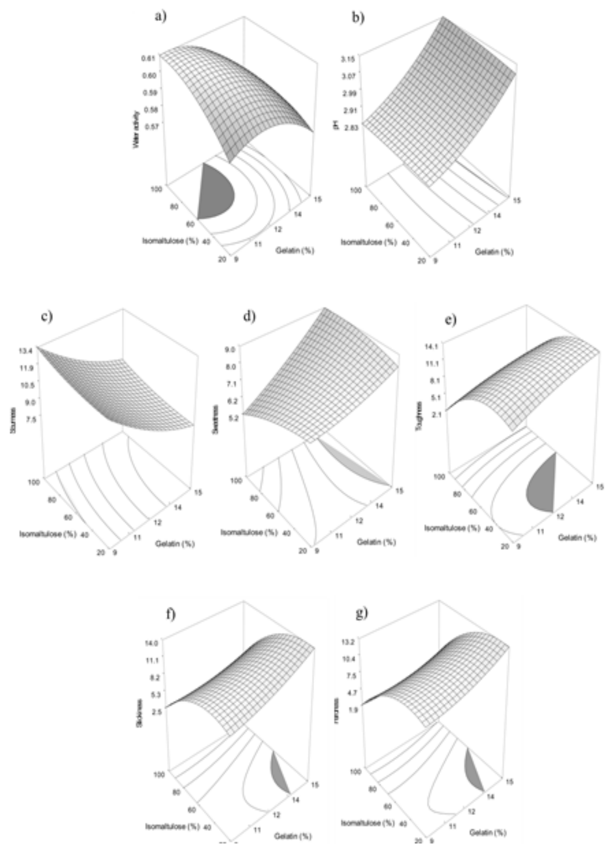

Figure 4. Response surface plot for a) water activity, b) pH, c) sourness, d) sweetness, e) stickiness, f) toughness, and g) hardness of gummy jelly

glucose/IS was in a range between 0.721 - 0.908.

Figure 4a shows the response surface graphs generated for a_w as a function of G and IS. These graphs reveal the main and interactive effects of the variables, showing an ability of G to decrease aw when increasing the IS. The model for the response surface of a_w did not fit with lower R^2 and adj-R^2 but the response of pH value can be described in the equation (1) because there was a higher R^2 value and adj-R^2 value (0.9712 and 0.9675) and also no significant ($p>0.05$) lack of fit observed for this model.

$$\text{pH of gummy jelly} = 3.0793-0.0672G-0.0004IS+0.0045G2-0.0001GIS \quad (1)$$

There was an interaction between the G and IS on the pH value. A higher amount of G and IS caused the acid - alkali to increase significantly ($p<0.05$) as shown in Figure 1d. According to the research of Periche *et al.* (2014), it was reported that the pH value increases from 5.12-6.10 when adding IS. As shown in equation 1, G was the main effect on the pH of gummy jelly. IS rarely affected this property.

Effects of gelatin and isomaltulose on sensory characteristics of gummy jelly

When the IS increased, it was found that the level of intensity of the sourness increased significantly ($p<0.05$) at constant IS (Figure 4c). At constant G, it was found that the level of intensity of the sourness decreased significantly ($p<0.05$) when G increased according to the pH (acid – alkali) value of the product. This was due to the reduction of sugar concentration in the formulation. Moreover, the sweetness of the IS was only half of the sucrose (Lina *et al.*, 2002) resulting in products with 9% G and 100% IS having no sucrose component. Therefore, the sourness of this sample was maximum vice versa sweetness. Increasing G and IS decreased the sourness. The interaction of the G and IS influenced the intensity of the sweetness. Increasing G and IS concentration tends to increase the sweetness of gummy jelly.

For sourness, the higher R^2 value ($R^2 = 0.9614$) represents that the model was accurately predicted. Also, adj-R^2 with 0.96 was high; thus this shows the significance of the model. In addition, there was also no significant ($p>0.05$) lack of fit for the sourness model as shown in the equation (2).

$$\text{Sourness}=29.5639-2.5461G-0.0148IS+0.0722G^2+0.0002IS^2+0.0004GIS \quad (2)$$

For the sweetness model, the R^2 value and adj-R^2 value were 0.876 and 0.8717, respectively. The predicted equation for sweetness was shown in the equation (3)

$$\text{Sweetness} = 9.4306-0.4574G-0.0493IS+0.0233G^2-0.0002IS^2+0.0052GIS \quad (3)$$

Regarding the texture, the response of toughness, stickiness and hardness as illustrated in the equation (4)–(6), were shown with higher R^2 (0.9706, 0.9428, 0.986) and adj-R^2 (0.9696, 0.9408, 0.9855).

$$\text{Toughness}= -9.1854+2.3452G+0.2170IS-0.0617G^2-0.0021IS^2-0.0059GIS \quad (4)$$

$$\text{Stickiness}= 6.4672-0.7304G+0.2166IS+0.0761G^2-0.0018IS^2-0.0078GIS \quad (5)$$

$$\text{Hardness}= 11.5630-1.4095G+0.1888IS+0.0944G^2-0.0018IS^2-0.0056GIS \quad (6)$$

As shown in Equation 2-6, the G content was the most important variable affecting the sensory attributes. IS also had a significant effect on the attributes of gummy jelly. However, it had an interactive effect of G and IS on the characteristics of gummy jelly. The effects of the two factors on these attributes can be better understood by representing the data in three-dimensional or response surface graphs (Figure 4).

Increasing G increased the toughness due to the increased G could making the structure of the gel junction hold the chain tightly by hydrogen bonding corresponding to a stable structure with density and a compact network (Periche *et al.,* 2014). This resulted in decreased elasticity and flexibility in accordance with the research of Periche *et al.* (2014) who stated that when the amount of G increased, the viscosity, hardness, cohesiveness, elasticity (springiness), toughness and chewiness all increased, while the 100% IS provided those attributes decreased significantly. As the G proportion increased, a greater number of available gel sites were occupied, which resulted in the generation of a strong gel texture. Moreover, the increase in G levels increased the gel hardness of gummy jelly by increasing the hydrogen bonds formed between the G molecules.

Figure 4 shows the interaction of the G and IS on textural properties. Sucrose, sugar sweetener/substitute, glucose syrup, and other minor components possibly formed intersections between two G molecules resulting in gels with both covalently cross-linked region and microcrystalline region (Tau and Gunasekaran, 2016). Therefore, using the sugar replacer could make G-based gels tougher (Tau and Gunasekaran, 2016).

Conclusion

The cause of the low glycemic index sugar is an alternative in sweet products. The replacement of sucrose by IS in gummy jelly is possible. There was an interaction between G and IS on physicochemical properties, sensory intensity, and acceptance. Interaction of G and IS concentration affected the aw and pH of gummy jelly. At constant G, increasing the IS up to 100% decreased toughness, stickiness, and hardness significantly. More specifically, the combination of 12% G and 40% IS would be recommendable to develop healthier gummy jelly in terms of low glycemic index. The gummy jelly containing 100% IS led to poor acceptance due to crystallization. It has potential to use IS in this kind of confectionary products. The response surface model can be investigated to fairly predict the intensity of the sensory attributes.

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