

Physico-chemical properties and sensory evaluation of kombucha tea-based gummy candy

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Abstract

Growing consumer demand for functional and health-promoting confectionery products has driven the development of innovative gummy formulations incorporating functional beverages, including kombucha tea. This study aimed to formulate and evaluate gummy candies prepared using kombucha derived from black tea, green tea, and *Strobilanthes crispus* tea. The gummies were produced using a standardized formulation consisting of kombucha tea (92.37%), bovine gelatin (7.39%), and stevia (0.24%). Physicochemical analyses included pH, total soluble solids ($^{\circ}$ Brix), water activity, moisture content, color, and texture, while sensory evaluation was conducted with 50 untrained panelists using a 9-point hedonic scale. Results showed significant differences ($p < 0.05$) among samples. The pH values ranged from 3.12 to 3.58, $^{\circ}$ Brix from 41.18 to 53.49, and water activity from 0.791 to 0.848. Moisture content exceeded 45% for all samples, and color became more vibrant and visually appealing with increasing lightness (L^*). Firmness ranged from 556.6 to 1086.1 g, while springiness exceeded 60% across samples. Sensory analysis indicated high acceptability for gummies prepared with *S. crispus* kombucha, particularly in aroma, flavor, and overall liking. The findings suggest that kombucha tea is a promising ingredient for developing functional gummy confections with desirable sensory and physicochemical properties, although further optimization is required to enhance shelf stability and texture consistency.

1. Introduction

Nowadays, most consumers are familiar with food that is easy to take anywhere, which can be known as confectionery products and has also become a snack food. Gummy candy is a popular confectionery product distinguished by its unique textural properties, determined by factors such as polymer concentration, number of crosslinks per unit volume, and amount of evaporated water. These properties can be altered by modifying ingredients like glucose syrup, sucrose, starch, and gelatin. These ingredients have been shown to affect the texture, pH, total soluble solids, moisture content, and water activity of gummy candy (Tireki *et al.*, 2021).

Based on several studies, kombucha tea is a probiotic product made through fermentation techniques (Vargas *et al.*, 2021). Kombucha tea has been known as one of the most widely sold probiotic products in the Malaysian market, especially in cafes. It is a functional drink produced by fermenting black or green tea with a

sympiotic culture of bacteria and yeast (SCOBY). The kombucha fermentation process usually lasts between 7 and 14 days. As the fermentation process goes on, the fruity, sour, and sparkling flavour of kombucha tea changes into a mild vinegar-like flavour, making for a more pleasant drink. The final product is a beverage with a sour apple cider flavour and a mild fizz (San, 2022). Its known health benefits include antioxidant and antimicrobial activities, antidiabetic effects and anticarcinogenic properties. Kombucha's health benefits come from the tea's rich organic acids, vitamins, and total phenolics, each of which is influenced by the sugar substrate used, the length of fermentation, and the temperature at which it is brewed (de Miranda *et al.*, 2022).

On the other hand, difficulty occurs in converting such a product into a gummy candy format while maintaining its nutritional value, physicochemical properties, and appealing sensory profile. The addition of gelling agents and other necessary candy components

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during the transformation process may change the original properties of the kombucha. The lack of research on the physicochemical, and sensory properties of gummies produced from kombucha tea is the gap that this research aims to address.

Therefore, this results from this study possesses the potential that may led to the development of a novel product that combines the convenience and popularity of gummy candies with the health advantages of kombucha tea (Watawana *et al.*, 2015). There might be a need in the market for healthy snacks like this, which can make them realise that there are still more confection products that are healthy and can be consumed.

This study aims to develop a novel product of gummy candies that incorporates kombucha tea as a key ingredient and assess the physicochemical and sensory properties of the gummy candies from each type of kombucha tea.

Table 1. The formulation of different teas.

Ingredient	Black tea	Green tea	<i>Strobilanthes crispus</i> tea
Water	1 L (90.58%)	1 L (90.58%)	1 L (90.58%)
Sweetener (white sugar)	100 g (9.06%)	100 g (9.06%)	100 g (9.06%)
Tea	4 g (0.36%)	4 g (0.36%)	4 g (0.36%)

2. Materials and methods

2.1 Preparation of kombucha tea

The kombucha teas were prepared using 100 g of sugar and diluted with 1 L of hot water. Then, 4 g of tea or approximately 2 tea bags were added to the hot water for about 5 minutes. Table 1 shows the formulation of tea used for kombucha tea production. Then, the tea bag is discarded when the solution is cooled down to the exact temperature, and it is transferred into a clean jar. After that, 250 mL of the previous batch of kombucha tea and 1 or 2 layers of symbiotic culture of bacteria and yeast (SCOBY) were added to the jar. The mouth of the jar was covered with muslin cloth, and a rubber band was used to tie the muslin cloth. The tea was fermented for about 7 to 14 days at room temperature, at temperatures around 20 to 25°C. In this study, green tea, black tea, and *S. crispus* tea were utilized for a variety of kombucha tea formulations. The preparation of the kombucha tea method was repeated for other types of tea examined in this study.

2.2 Preparation of gummy candy

The gummy candy was prepared by mixing the gelatine, sweetener, and kombucha tea, which was then molded into a variety of shapes and sizes. The kombucha tea was warmed over medium heat. To avoid clumping, gelatine was added to warm kombucha tea and stirred repeatedly. The mixture was stirred until completely dissolved. After that, the sweetener was added and mixed until dissolved. Once smooth, the gummy candy mixture was carefully poured into silicone candy molds. The candy was then kept at room temperature, around 20 to 25°C, for a minute to cool. It was then refrigerated for many hours or overnight. The formulation of different types of gummy candy production and also the abbreviation are shown in Table 2.

2.3 Sensory evaluation

The sensory evaluation involved 50 untrained panelists rating the taste and quality of the gummy candy products from different types of kombucha tea (Zubaidah *et al.*, 2019). On a 9-level hedonic scale, they evaluated the attributes of appearance, smell, aroma, texture, flavor, tanginess, bitterness, and overall acceptance. The test included demographic questions about gender, age, and race. The scale was assessed as the following: 1-extreme dislike, 2-very strong dislike, 3-moderate dislike, 4-slight dislike, 5-neutrality, 6-slight liking, 7-moderate liking, 8-strong liking, and 9-extreme liking (Tireki *et al.*, 2021).

2.4 pH level

The pH values of the gummy candy samples were analyzed using an electronic pH meter (Eutech, pH 700, Singapore) calibrated at pH 4.0 and 7.0 (Ahmed *et al.*, 2020). The pH was evaluated by using a pH meter after 1 g of the gummy candy samples were homogenized with 10 ml of distilled water.

2.5 Total soluble solid

The total soluble solid (TSS) content of the gummy candy samples that were analyzed reflects the sugar content and sweetness level of the gummy candy (Renaldi *et al.*, 2022). A refractometer (ATAGO 3266, Automatic Refractometer RX-5000a-Plus, Japan) was utilized to determine the TSS content of gummy candies after 2 g of the gummy sample was melted and diluted with 2 mL of distilled water using a 1:1 ratio. The unit °Brix (Brix reading) was applied to total soluble solid data (Andrade *et al.*, 2020).

Table 2. The formulation of different gummy candies.

Ingredient	Types of kombucha teas		
	Kombucha black tea (GC-KBT)	Kombucha green tea (GC-KGT)	Kombucha <i>Strobilanthes crispus</i> Tea (GC-KSCT)
Tea	250 ml (92.37%)	250 ml (92.37%)	250 ml (92.37%)
Gelatin	20 g (7.39%)	20 g (7.39%)	20 g (7.39%)
Sweetener (Stevia)	0.66 ml (0.24%)	0.66 ml (0.24%)	0.66 ml (0.24%)

Table 3. Sensory analysis of different kombucha gummy candies.

Attribute	Sample ^{*,**}		
	208 (GC-KBT)	809 (GC-KGT)	990 (GC-KSCT)
Appearance	7.80 ± 1.178 ^a	7.36 ± 1.588 ^a	7.82 ± 1.257 ^a
Aroma	4.88 ± 1.945 ^b	5.26 ± 2.068 ^{ab}	5.82 ± 1.892 ^a
Texture	6.62 ± 1.615 ^a	6.30 ± 1.729 ^a	6.64 ± 1.425 ^a
Flavour	6.52 ± 1.741 ^a	6.30 ± 1.669 ^a	7.02 ± 1.635 ^a
Tanginess	6.26 ± 2.039 ^a	6.12 ± 1.902 ^a	6.74 ± 1.664 ^a
Bitterness	5.64 ± 2.319 ^a	5.36 ± 2.371 ^a	6.26 ± 2.202 ^a
Overall acceptance	6.28 ± 1.785 ^a	6.42 ± 1.592 ^{ab}	7.18 ± 1.600 ^a

*GC = gummy candy, KBT = kombucha black tea; KGT = kombucha green tea; KPBT = kombucha *Strobilanthes crispus* tea. ** In each column, means with the same letters had no significant difference with each other ($p > 0.05$).

2.6 Water activity

The water activity of the gummy candy samples was measured at 25°C using a water activity meter (Rotronic, HygroPalm HP23-AW-A, Switzerland).

2.7 Moisture content

The moisture content of the gummy candy samples was evaluated using the moisture analyzer (A and D Weighing, MX-50 Moisture Analyzer, Japan), in which the drying temperature was set at 140°C with 1°C intervals (Renaldi *et al.*, 2022).

2.8 Colour analysis

The colour parameters of gummy candy samples was measured using a colourimeter (MRC, Colour Spectrophotometer NS8XX, United Kingdom) (Zielinska *et al.*, 2019). The colourimeter utilised the L*, a*, b* system, where L* indicated luminosity or brightness, a* represented redness (+) and greenness (-), and b* represented yellowness (+) and blueness (-).

2.9 Texture analysis

A texture analysis for gummy candy samples was conducted using a texture analyzer (TA.XTplusC Stable Micro System Ltd., Goldaming, United Kingdom), which evaluated the springiness and firmness attributes. The gummy candy samples are compressed three times for each type of sample and determined using a 35 mm diameter cylindrical plunger probe (Delgado and Banon, 2015; Tireki *et al.*, 2021).

2.10 Statistical analysis

By using Microsoft Excel 2019 and Minitab, all data were subjected to a one-way analysis of variance (ANOVA), followed by the Tukey test to determine the differences between samples. The significance level is chosen at ($p < 0.05$), and the data are presented as a mean ± standard deviation (SD) (Sun *et al.*, 2015).

3. Results and discussion

3.1 Sensory analysis

As Table 3 shows, the appearance of each sample was insignificantly different ($p > 0.05$). The L* values for GC-KBT, GC-KGT, and GC-KSCT were not significantly different ($p > 0.05$) as shown in Table 3. This similarity in lightness could explain why all samples had

comparable acceptability among consumers. The aroma scores of GC-KBT and GC-KSCT differed significantly ($p < 0.05$). The GC-KSCT sample scored the highest (5.82), indicating a more desirable aroma, while the GC-KBT sample scored the lowest (4.88), indicating a less desirable aroma. This is due to the acidic and tangy aroma presented due to some factors like ingredients used, fermentation time, or some aroma compounds like acetic acid, which is frequently present in kombucha, producing a distinctive acidic and vinegar-like aroma, which affects the aroma of gummy candy (Jayabalan *et al.*, 2014). As shown in Table 3, there is no significant difference ($p < 0.05$) in each sample score for texture attributes. The gelling agent in gummy candy is the main component that contributes to the desired texture of gummy candy.

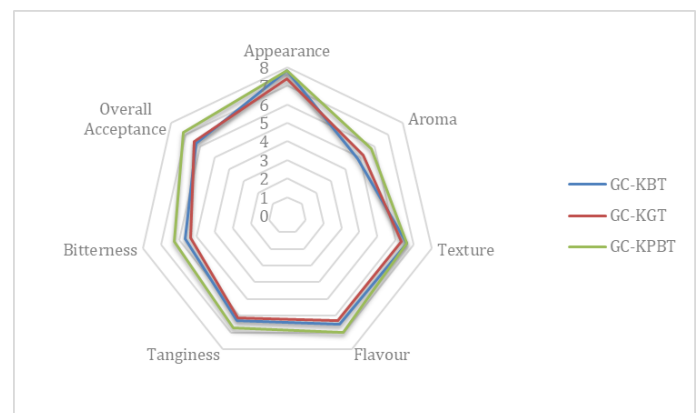


Figure 1. Sensory analysis of different kombucha gummy candies.

When gummy candies are infused with kombucha tea, their flavour acceptability is generally enhanced (Figure 1). There are no significant differences ($p < 0.05$) between these three samples' scores of flavours, tanginess, and bitterness attributes. Some factors that might be related are the kombucha tea's characteristic of tanginess and also the level of sweetness of the gummy candy itself (San, 2022). An optimally balanced gummy confection ought to exhibit a symphony of sweetness, tartness, and kombucha tea flavour. The distinctive sourness of kombucha tea is an outcome of the fermentation process and the incorporation of organic acids, including lactic acid and acetic acid. Other than that, stevia has been used as a sweetener in this research

to produce food products with low sugar content, which is known to have intense sweetness, with a slightly liquorice-like or herbal undertone, which produces a slight bitterness or lingering aftertaste of final products (Yadav *et al.*, 2011). According to the result, the attributes of flavour, tanginess, and bitterness among these three samples are still acceptable.

Based on Table 3, the overall acceptance of GC-KBT and GC-KSCT was significantly different ($p < 0.05$). The GC-KSCT sample scored the highest overall acceptability (7.18), while the GC-KBT sample scored the lowest (6.28). The panellists generally prefer gummy candies (GCs) made with kombucha *Strobilanthes crispus* tea. The panellists favored this sample across all evaluated attributes. However, GC-KBT and GC-KGT were considered acceptable by the sensory panellists, since all the samples received scores higher than 6.

Table 4. pH value of different kombucha gummy candies.

Samples*	pH**
GC-KBT	3.12 ± 0.00577c
GC-KGT	3.55 ± 0.00577b
GC-KSCT	3.58 ± 0.01000a

GC = gummy candy, KBT = kombucha black tea; KGT = kombucha green tea; KPBT = kombucha *Strobilanthes crispus* tea. ** In each column, means with the same letters had no significant difference with each other ($p > 0.05$).

3.2 pH value

The pH value of the gummy candies is shown in Table 4. There were significant differences ($p < 0.05$) between GC-KBT, GC-KGT, and GC-KSCT. The GC-KSCT sample had the highest pH (3.58), indicating slightly lower acidity, whereas the GC-KBT sample had the lowest pH (3.12), indicating higher acidity levels. This phenomenon might relate to the primary organic acids produced by the acetic acid bacteria in the kombucha culture, which contribute to the sour and tangy taste of kombucha (Mousavi *et al.*, 2020). In comparison to kombucha from green tea and *Strobilanthes crispus* tea, kombucha black tea tends to generate a greater quantity of acetic acid. Based on a previous study, the pH of approximately 14-day-fermented kombucha black tea is 2.53, while the pH of approximately 14-day-fermented kombucha green tea is 2.49 (Jakubczyk *et al.*, 2020). In contrast, most gummy candies have a pH not higher than 4 (Yamabe *et al.*, 2017). Therefore, the pH of gummy candy is influenced by the presence of kombucha tea. By adding kombucha tea to the gummy candy formula, the pH value of the final product increased.

3.3 Total soluble solid

According to Table 5, the total soluble solid (TSS) content of the GC-KBT, GC-KGT, and GC-KSCT were found to be in the range of 41.18–53.49°Brix which is lower than the normal degree Brix of the commercial gummy candies (between 60 and 80°Brix) (Delgado and

Banon, 2015). There are significant differences ($p < 0.05$) in GC-KBT indicating the highest brix value (53.49) compared to the GC-KSCT (41.18), which showed the lowest Brix value due to the duration of fermentation of kombucha black tea itself and some ingredients used in the production of kombucha tea and gummy candy itself. Therefore, low Brix value contributes to the low sugar content of the product, which may alter some attributes like flavour, and texture. The different types of based substitutions can result in different total soluble solids content.

Table 5. Total soluble solid content of different kombuchas gummy candy.

Samples*	Brix**
GC-KBT	53.49 ± 0.251 ^a
GC-KGT	41.79 ± 0.736 ^b
GC-KSCT	41.18 ± 1.168 ^b

GC = gummy candy, KBT = kombucha black tea; KGT = kombucha green tea; KPBT = kombucha *Strobilanthes crispus* tea. ** In each column, means with the same letters had no significant difference with each other ($p > 0.05$).

Table 6. Water activity of different kombucha gummy candies.

Formulation*	Water activity (AW)**
GC-KBT	0.791 ± 0.001528 ^c
GC-KGT	0.819 ± 0.00208 ^b
GC-KSCT	0.848 ± 0.00208 ^a

*GC = gummy candy, KBT = kombucha black tea; KGT = kombucha green tea; KPBT = kombucha *Strobilanthes crispus* tea. ** In each column, means with the same letters had no significant difference with each other ($p > 0.05$).

3.4 Water activity

In this study, the A_w of the gummy candy samples was high yet stable and showed a significant difference ($p < 0.05$) between GC-KBT, GC-KGT, and GC-KSCT, as shown in Table 6, ranging from 0.791 to 0.848, which was below 0.85. GC-KSCT (0.848) produces a higher water content compared to GC-KBT (0.791), which has a lower water content.

Based on a previous study, the water activity of kombucha tea was reported to be between 0.98 and 0.99 (Abaci *et al.*, 2022), and most gummy candies contain water activity ranging from 0.5 to 0.7 (Yamabe *et al.*, 2017; Buerman *et al.*, 2019). Bacteria, in principle, exhibited a growth inhibition below 0.85, while the growth of yeasts and moulds was observed to be impeded around a_w 0.7, which may influence the shelf life, quality, and taste of the gummy candy (Buerman *et al.*, 2019).

The water activity of stevia gummies was approximately 0.66 (Acemoglu and Robinson, 2010). According to this study, the samples sweetened with stevia typically have water activity values less than 0.7. However, none of these samples are capable of generating water activity values above 0.7 since kombucha tea is incapable of producing gummies with a pH below 0.7.

Table 7. Moisture content of different kombucha gummy candies.

Formulation*	Moisture (%)**
GC-KBT	47.31 ± 0.739 ^b
GC-KGT	50.65 ± 1.086 ^a
GC-KSCT	52.21 ± 0.936 ^a

*GC = gummy candy, KBT = kombucha black tea; KGT = kombucha green tea; KPBT = kombucha *Strobilanthes crispus* tea. ** In each column, means with the same letters had no significant difference with each other ($p > 0.05$).

3.5 Moisture content

Most gummy candies use gelatin as their primary gelling agent, and they have a moisture content of 9–18% by weight (Yamabe *et al.*, 2017). Based on Table 7, there are significant differences ($p < 0.05$) in the GC-KBT sample. The highest moisture content was observed on the GC-KSCT (52.21), while the lowest pH value was obtained on the GC-KBT (47.31). All the samples produce high moisture content above 45%, which may affect the shelf-life and quality of the gummy candy. Some factors that influence the moisture content are the ingredients of production, environmental contamination, and storage conditions.

Table 8. Colour analysis of different kombucha gummy candies.

Formulation*	L**	a**	b**
GC-KBT	36.20 ± 0.612 ^b	24.78 ± 1.285 ^a	43.64 ± 2.09 ^a
GC-KGT	53.88 ± 1.93 ^a	4.19 ± 0.364 ^c	33.77 ± 1.653 ^b
GC-KSCT	56.05 ± 2.03 ^a	7.94 ± 1.160 ^b	41.86 ± 1.543 ^a

*GC = gummy candy, KBT = kombucha black tea; KGT = kombucha green tea; KPBT = kombucha *Strobilanthes crispus* tea. ** In each column, means with the same letters had no significant difference with each other ($p > 0.05$).

3.6 Colour

Table 8 shows significant differences ($p < 0.05$) in GC-KBT. Therefore, the GC-KSCT (56.05) sample showed the highest L* value compared to the GC-KBT (36.20) sample, which showed the lowest L* value. The GC-KBT sample appears darker, most likely due to the naturally deeper amber-brown colour of kombucha made with black tea (Tran *et al.*, 2020). Darker hues may develop in tea as fermentation continues. This colour can range from a light amber to a deep or rich, dark brown. However, GC-KGT and GC-KPBT possess a colour that is moderately dark but not as deep as very dark colours. Kombucha produced by *Strobilanthes crispus* tea and green tea tends to have a light, pale yellow colour.

As shown in Table 8, there are significant differences ($p < 0.05$) between GC-KBT, GC-KGT, and GC-KSCT. The GC-KBT showed the highest a* value (24.78) compared to the GC-KGT, which shows the lowest a* value (4.19). The GC-KBT sample appears more reddish than GC-KGT and GC-KSCT, which are only slightly reddish.

Other than that, Table 8 showed significant differences ($p < 0.05$) in GC-KGT. The GC-KBT sample

had the highest b* value (43.64), while GC-KGT had the lowest (33.77). These results indicate that gummy candies tend to have a more intense yellow colour.

Table 9. Texture analysis of different kombucha gummy candies.

Samples*	Firmness (g)**	Springiness (%)**
GC-KBT	1086.1 ± 123.0 ^a	66.70 ± 3.32 ^a
GC-KGT	556.6 ± 51.7 ^b	68.85 ± 2.13 ^a
GC-KSCT	661.8 ± 30.7 ^b	69.87 ± 1.373 ^a

*GC = gummy candy, KBT = kombucha black tea; KGT = kombucha green tea; KPBT = kombucha *Strobilanthes crispus* tea. ** In each column, means with the same letters had no significant difference with each other ($p > 0.05$).

3.7 Texture properties

The texture properties of the selected attribute are shown in Table 9. There are significant differences ($p < 0.05$) in GC-KBT for firmness attributes, where the GC-KBT (1086.1) sample recorded the highest firmness, which indicates less firmness consistency, which may affect the chewiness and overall mouthfeel of the gummy candy. However, the GC-KGT (556.6) sample showed the lowest firmness value, which indicates high firmness consistency. The ingredients used during the production can be considered as a factor that affects the texture of the gummy. In this study, gelatine-bovine has been used as a gelling agent for the gummy candy and kombucha tea has been used as the main ingredient. According to Jakubczyk *et al.* (2020), the presence of gelatine in gummy candy can contribute to the development of firm consistency, as the gelatine molecules coil arbitrarily above the gelling temperature. Consistency in firmness is crucial for delivering a satisfying texture and ensuring the product meets consumer expectations.

Other than that, there are no significant differences ($p < 0.05$) between each sample for springiness attributes as shown in Table 8. From the results, the GCs sample has more than 60% springiness, which indicates higher springiness. A chewy consistency is frequently the result of increased springiness in gummy candies. This may have an impact on the mouthfeel of the confectionery as well as its response to biting and chewing. However, for the purpose of developing a chewy and elastic product consistency, a springiness greater than 60% may be considered favourable in the context of gummy candies.

4. Conclusion

In conclusion, the results from this study showed that kombucha tea, in combination with gelatine-bovine and sweetener, can potentially be used in gummy candy production to meet consumer demand for healthier confectionery products. The infusion of kombucha teas in gummy candy formulation increases the pH value, TSS content, water activity, and moisture content of the gummy candy, which shows a significant difference for these parameters of the gummy candy. The colour

appearance of the gummy candies became more vibrant, brown-yellow in colour, and visually appealing. The gummy candy from kombucha black tea has higher firmness, indicating less chewiness compared to other samples. In addition, the gummy candy also obtained higher springiness, which indicates a chewier texture. Other than that, the outcome of the sensory evaluation indicates that the product was highly acceptable for the sample code, with 990 by untrained panelists.

Conflict of interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

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