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ORIGINAL RESEARCH PAPER

REPLACING UNHEALTHY SUGARS IN CHEWABLE CANDY: THE USE OF HONEY AND STEVIA AS NATURAL SWEETENERS IN CHRYSANTHEMUM-BASED GUMMY CANDY

WIMALA HARDYAWATI PUTRI APSARI[1], ZAHRA SALSABILA[1], AULIA RAHMA ARDININGSIH[1], MUHAMMAD NOVRIZAL ABDI SAHID[2], DWI UMI SISWANTI[3], CICI DARSIH[4], MARLYN DIAN LAKSITORINI[5,6*]

[1] *Undergraduate Program, Faculty of Pharmacy, Universitas Gadjah Mada, Yogyakarta, Indonesia, 55281*

[2] *Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Universitas Gadjah Mada, Yogyakarta, Indonesia, 55281*

[3] *Faculty of Biology, Universitas Gadjah Mada, Yogyakarta, Indonesia, 55281*

[4] *Center for Technology Research and Food Process, National Research and Innovation Agency, Yogyakarta, Indonesia, 55861*

[5] *Department of Pharmaceutics, Faculty of Pharmacy, Universitas Gadjah Mada, Yogyakarta, Indonesia, 55281*

[6] *Institute of Halal and Industry Systems, Universitas Gadjah Mada, Yogyakarta, Indonesia, 55281*

[*]Corresponding author*:* marlyn_fa@ugm.ac.id

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Abstract

Chewable candies are a major contributor to added sugar intake, particularly among children, and excessive consumption of such products is associated with adverse health outcomes. This study aimed to formulate a Chrysanthemum-based gummy formula with reduced sugar content and to evaluate the antioxidant activities of Indonesian forest honey. The antioxidant activities of Multiflora, Rain Forest, and Manuka honey were evaluated using the DPPH radical scavenging assay. The honey variant demonstrating the highest antioxidant activity was incorporated into the gummy formulation in combination with stevia. The resulting gummy candies were evaluated for their texture profile, hedonic test, and color measurement. Results indicated that Multiflora honey exhibited superior antioxidant activity compared to Rain Forest honey. The optimal formulation for sucrose replacement comprised 33.12% Multiflora honey and 2.59% stevia. The findings suggest that a combination of Multiflora honey and stevia is a viable alternative to sucrose in gummy candy production. The potent antioxidant activity of Chrysanthemum, along with the reduced sugar content, supports the potential development of this formulation into a child-friendly nutraceutical product.

Keywords: Honey, stevia, Chrysanthemum, gummy candy, antioxidant

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Introduction

Candy is widely consumed among children due to its sweet taste, attractive appearance, and various shapes and colors. According to the Dietary Guidelines for Americans (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020), candy ranks as the fourth-largest source of added sugar in children's diets, contributing significantly to their overall energy intake. Candy, defined as sweet confectionery primarily composed of sugar or sugar substitutes (Savage *et al*., 2019), offers minimal nutritional value and contributes approximately 5 – 9% of children's daily caloric intake, which exceeds the recommended limit (Hernandez *et al*., 2023). Excessive consumption of sugary foods such as candy has been linked to adverse health effects, including increased risk of obesity, diabetes, and dental decay due to their high carbohydrates content and lack of essential nutrients such as low vitamins and antioxidants (Cedeño-Pinos *et al*., 2020). Therefore, there is a growing need to innovate healthier candy formulations that support children's nutritional and developmental needs.

In addition to concerns surrounding candy consumption, children in developing countries face challenges related to cognitive development. Based on World Population Review (2023), 140 out of 197 countries report average intelligence quotient (IQ) scores below the global mean, based on the classification system by Woodcock-Johnson R. These data underscore the urgency of improving the quality of human capital, especially during the critical developmental stages of childhood. One bioactive compound known to enhance cognitive function of the brain is myricetin, which is found in Chrysanthemum flowers. A study of Wang *et al*. (2023) demonstrated that myricetin possesses neuroprotective activity and is capable of crossing the blood-brain barrier (BBB), a semipermeable system that regulates the ease of compounds entering or leaving the brain (Laksitorini *et al*., 2014). Chrysanthemum holds promise as a functional ingredient in various health-promoting products, such as herbal teas, chips, and instant drinks, with the flower being the most commonly utilized part (Baiti *et al*., 2024). However, processed Chrysanthemum products often retain a bitter aftertaste (Jiang *et al*., 2021), presenting a sensory challenge that calls for further product development to improve palatability.

Gummy candies are hydrocolloid-based formulations characterized by their elastic texture (Afidatus Syaifabila *et al*., 2024; Devi *et al*., 2024; Salamah *et al*., 2022). However, conventional gummy formulations typically contain high levels of concentration, often exceeding 50%, due to the substantial use of sugar and flavoring agents (Nishiyama-Hortense *et al*., 2022). Chronic intake of such high-sugar products may contribute to the development of metabolic disorders, particularly when consumed repeatedly over time. Therefore, reformulating gummy candies to reduce sugar content, while effectively masking the bitterness of Chrysanthemum flowers and preserving its antioxidant activity, is essential. Natural sweeteners such as honey and stevia represent promising alternatives to conventional sugar, offering both sweetness and functional health benefits.

The quality and bioactivity of honey vary depending on its botanical and geographical origin, as well as its chemical composition. These compositional differences directly influence the antioxidant activity, which can serve as a criterion for selecting honey in functional food formulations. In addition to its uses as a natural sweetener, honey has been investigated for its preventive and therapeutic properties. A study by Rahman et al. (2014) showed that honey possesses nootropic effects, acting as a natural agent that may improve cognitive function. This effect is attributed to the presence of bioactive compounds such as flavonoid compounds, phenolic acid, catalase, and carotenoids, which collectively contribute to its antioxidant activity (Salsabila et al., 2022). Stevia, another natural sweetener, is widely used due to its high sweetness potency—estimated to be120 - 200 times that of sucrose—while contributing no calories (Akesowan and Choonhahirun, 2021). It also contains health-promoting constituents such as terpenes, tannins, and vitamins (Carrera-Lanestosa *et al*., 2017).

Previous studies have explored the use of sweetener combinations such as honey with sucrose and stevia with xylitol and corn syrup (Samakradhamrongthai and Jannu, 2021). However, the synergistic effect and optimization of honey and stevia as dual alternative sweeteners in gummy formulations remain underexplored. Therefore, this research seeks to address this gap by investigating the antioxidant activity of various honey types and evaluating the effect of combining honey and stevia on the physical characteristics and sensory attributes of Chrysanthemum-based gummy candies. The research involves the formulation of chrysanthemum-based gummy candy and evaluates its physical characteristics, texture profile analysis, color measurement, and sensory attributes through the hedonic test.

Materials and methods

The raw materials used in the gummy candy formulation included Chrysanthemum extract, gelatin (Gelita, Germany), pectin (PT Adimitra Karunia, Indonesia), Multiflora and Rain Forest honey (PT Natura Alamindo Utama, Indonesia), Manuka honey (Comvita, New Zealand), stevia (PT Nutrifood, Indonesia), citric acid (PT Pondasi Inti Sejahtera, Indonesia), sodium benzoate (PT Pondasi Inti Sejahtera), lemon essence and yellow food coloring (Koepoe-Koepoe, PT Gunacipta Multirasa), and distilled water (CV Progo Mulyo, Indonesia).

The reagents used for analytical purposes were ascorbic acid (Sigma Aldrich, United States), 1,1-diphenyl-2-picrylhydrazyl (DPPH) (PT Smart Lab, Indonesia), methanol (Merck, Germany), silica gel F254 (Merck, Germany), *n*-butanol (Sigma Aldrich, United States), acetic acid (Sigma Aldrich, United States), and ferric chloride ($FeCl_3$, Sigma Aldrich, United States). A commercial gummy candy (Amos Gummy, PT Pandurasa Kharisma, Indonesia) was used as a reference product for comparison during sensory and physical evaluations.

Determination and bioactives extraction of Chrysanthemum indicum

The botanical identification of *Chrysanthemum indicum* was conducted to confirm the authenticity of the plant material. This procedure was carried out at the

Pharmacognosy-Phytochemical Laboratory, Faculty of Pharmacy, Universitas Gadjah Mada, Indonesia (Apsari, 2024).

The extraction process utilized the maceration method, in which dried chrysanthemum flowers were soaked in a hydro-alcoholic solvent (70% ethanol, 1:7 ratio) for 24 hours at room temperature. To ensure complete extraction of the active constituents, a re-maceration step was performed using the same solvent at a 1:3 dry material-to-solvent ratio. The macerate was filtered using sieve cloth, and the resulting filtrate was concentrated by evaporation at 40°C in a water bath until a viscous extract was obtained. The percentage yield of the extract was calculated using equation 1.

$$\text{Yield (\%)} = \frac{\text{total extracted sample mass}}{\text{total dry sample mass}} \times 100 \quad (1)$$

Honey Characterization Using TLC

To identify the presence of phenolic compounds in honey, Thin Layer Chromatography (TLC) analysis was performed. The stationary phase used was silica gel F_{254}, while the mobile phase consisted of n-butanol-acetic acid-water (3:1:1 % v/v). Quercetin was used as the standard reference compound. Visualization of phenolic compound were achieved by spraying the developed TLC plate with 5% $FeCl_3$solution, followed by heating the plate at 100°C for 5-10 minutes. The resulting spots were then observed under UV light at 366 nm. The Retardation Factor (Rf) values were calculated using equation 2 (Apsari, 2024):

$$\text{Rf} = \frac{\text{distance traveled by the solute}}{\text{distance traveled by the solvent}} \quad (2)$$

Antioxidant Activity of Chrysanthemum Extract and Honey

The antioxidant activities of Chrysanthemum extract and various honey samples were assessed using a modified 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay, as described by (Gemantari *et al*., 2021), with ascorbic acid serving as the positive control. The Chrysanthemum extract was prepared at a concentration of 5 mg/ml, while honey solution samples were prepared at 300 mg/ml. All solutions were homogenized using an ultrasonic homogenizer at 40°C for 5 minutes and then centrifuged at 10,000 rpm for 20 minutes. For the assay, 1 mL of each test solution was mixed with 1 mL of 0.4 mM DPPH solution, followed by the addition of methanol to a final volume of 5 mL. The mixtures were incubated in a dark room at room temperature for 30 minutes. Absorbance was measured at 516 nm using a UV-Visible spectrophotometer. The percentage of inhibition was calculated, and the IC_{50} values were determined using linear regression analysis based on equation 3.

$$y = bx + a \quad (3)$$

where y represents the percentage of inhibition and x denotes the concentration of the sample.

Gummy Candy Formulation

AD-optimal mixture design was used to formulate gummy candies with varying proportions of honey (15-19%) and stevia (1-5%) as natural sweeteners (Table 1). Honey and stevia were mixed at 50ºC. In a separate container, gelatin and pectin were dissolved in distilled water. The two mixtures were then combined and homogeneous at 80ºC. Subsequently, Chrysanthemum extract, citric acid, sodium benzoate, distilled water, lemon essence, and Koepoe-Koepoe yellow food coloring were mixed until homogenous. The resulting mixture was poured into gummy resulting and allowed to set for 24 hours at 4 ± 2 ºC. After solidification, the gummies were demolded and stored at room temperature for further evaluation (Apsari, 2024).

Table 1. Formulation of gummy candy obtained in the present study

Ingredient	F1	F2	F3	F4	F5	F6	F7	F8
Chrysanthemum extract (g)	4	4	4	4	4	4	4	4
Gelatin (g)	10	10	10	10	10	10	10	10
Pectin (g)	1	1	1	1	1	1	1	1
Honey (%)	26.80	33.90	26.80	28.57	30.35	32.12	30.35	33.9
Stevia (%)	8.90	1.80	8.90	7.13	5.35	3.58	5.35	1.80
Citric acid (g)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Sodium benzoate (g)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Lemon essence (g)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Yellow dye (g)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Distilled water (mL)	20	20	20	20	20	20	20	20

Moisture Content

The moisture content of the gummy candy samples was determined using a moisture analyzer (Ohaus Corporation, New Jersey, USA). Each measurement was performed in triplicate (Apsari, 2024).

Texture Profile Analysis (TPA)

The texture characteristics of the gummy candies was assessed using a texture analyzer (Ametek Brookfield, Massachusetts, USA). The measurements were performed in duplicate under controlled room temperature conditions (22 ± 2°C). The evaluated texture parameters included hardness, gumminess, chewiness, and adhesiveness. The test was conducted with a test speed of 0.5 mm/s and a waiting time 0.5 seconds (Apsari, 2024).

Sensorial analysis

A sensory evaluation was carried out to assess consumer acceptance of the gummy candies in terms of texture, color, aroma, flavor. The hedonic test involved 30 untrained panelists aged 17-23 years. Each gummy sample was assigned a three-digit code and was presented randomly to the panelists. To avoid sensory bias, a glass of water and plain crackers were provided for palate cleansing between samples. The panelists rated each attribute using 7-point hedonic scale, where 1 indicated "disliked extremely" and 7 indicated "liked extremely" (Renaldi *et al*., 2022).

Color Measurement

The color properties of the gummy samples were measured using a chroma meter (Konica Minolta, Tokyo, Japan). Measurements were performed in triplicate. The color parameters were recorded in terms of L^*, a^*, and b^* values, where L^* represents the dark-light spectrum (0: black; 100: white), a^* represents red or green color (positive= red; negative= green), and b^* represents yellow or blue color (positive= yellow; negative= blue) (Samakradhamrongthai and Jannu, 2021).

Statistical Analysis

The mean values of antioxidant activity (IC_{50}) for the different honey samples was analyzed using one way Analysis of Variance (ANOVA) followed by Tukey's post-hoc test, performed with IBM SPSS Statistics software. The optimal gummy candy formulation was determined using the Simplex Lattice Design (SLD) approach, based on responses related to flavor, texture, moisture content, hardness, gumminess, chewiness, and adhesiveness. The optimization process was conducted using the Design Expert tool. To verify the accuracy of the optimized formulation, a one-sample t-test was conducted using IBM SPSS Statistics (Apsari, 2024).

Results and discussion

Extraction of Chrysanthemum indicum

Botanical authentication confirmed that the plant material used in this study was *Chrysanthemum indicum L.,* a member of the Asteraceae family. The authenticity of the specimen was validated through a certificate of determination issued under the reference number 37.27.11/UNI/FFA.2/BF/PT/2023. The extraction process produced 697.04 grams of concentrated extract, corresponding to an extraction yield of 23.23%. The extract was stored at 4ºC to preserve its antioxidant activity, as flavonoid degradation occurs more slowly at lower temperatures.

Honey Characterization Using TLC

To characterize the bioactive compounds in honey used as a sweetener in the gummy formulations, Thin Layer Chromatography (TLC) analysis was conducted. TLC is a qualitative analytical method used for the separation, identification, and visualization of chemical constituents within complex mixtures. In this study, the presence of phenolic compounds was confirmed by the appearance of blue fluorescence on TLC plates after treatment with $FeCl_3$ reagent (Dinakaran *et al*., 2018). The elution results are illustrated in Figure 1.

Figure 1 shows that only positive control (Manuka honey) exhibited a Retardation Factor (Rf) Rf value of 0.875, which matched that of the quercetin standard. The similarity suggests the presence of quercetin as a phenolic compound in Manuka honey. While both Multiflora and Rain Forest Honey also demonstrated the presence phenolic compounds, their Rf values did not match that of quercetin, indicating that other phenolics may be the main secondary metabolites. Variability in the phenolic profiles of honey can be attributed to differences in geographical and botanical origins. Factors such as the floral source utilized by bees, weather conditions, soil composition, and regional biodiversity significantly influence both the concentration and profile of phenolic compounds in honey (Al-Farsi et al., 2018).

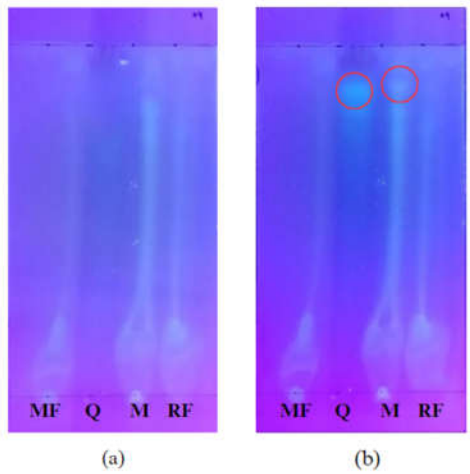


Figure 1. Qualitative analysis of Multiflora honey (MF) and Rainforest honey (RF) compared to Manuka (M) as a positive control honey. Plate (a): before being sprayed with $FeCl_3$. Plate (b): after being sprayed with $FeCl_3$

Antioxidant Activity of C. indicum Extract and Honey Samples

The *Chrysanthemum indicum* extract exhibited strong antioxidant activity, with an IC_{50} value of 67.20 ± 0.696 µg/mL. This result is consistent with the findings of Rahmasari *et al*. (2024), who reported an IC_{50} value of 67.80 µg/mL using DPPH assay method. The strong antioxidant activity of Chrysanthemum is attributed to its active compounds, including flavonoids such as quercetin, myricetin, luteolin, acacetin, as well as phenolic acids (Rahmasari et al., 2024). According to the research of Wu et al. (2010), quercetin and myricetin are abundant flavonoids in chrysanthemum flowers, together accounting for 65.3% of the total flavonoid content. Ascorbic acid, used as a positive control to validate assay performance, exhibited strong antioxidant activity with an IC_{50} value of 2.01 ± 0.018 µg/mL to the value reported by Rahmasari *et al*. (2024), which was 3.60 µg/mL. These findings support the potential application of Chrysanthemum extract in functional food or nutraceutical formulations due to its strong antioxidant activity.

In contrast to the Chrysanthemum extract, the honey samples— Manuka, Multiflora, and Rain Forest — exhibited weak antioxidant activity, with IC_{50} values of 0.79 ± 0.011 mg/mL; 8.36 ± 0.166 mg/mL; and 10.99 ± 0.07 mg/mL, respectively (Figure 2). Among them, Manuka honey showed the highest antioxidant activity. This result aligns with previous studies indicating that monofloral honeys tend to contain higher levels of phenolic compound content than multifloral variants (Pentoś *et al*., 2020). A research by Becerril-sánchez *et al*. (2021) reported that Manuka honey contains 203.5 – 217.0 mg GAE/100 g of total phenolics, while (Al-Dabbas et al., 2019) reported only 3.77 mg GAE/100 g in Multiflora honey. The IC_{50} values obtained for the honey samples in this study are consistent with the existing literature. For example, da Silva *et al.* (2013) reported an average IC_{50} of 11.025 mg/mL in honey-sweetened cashew apple nectar and *Yaacob et al*. (2020), observed an IC_{50} of 71.270 ± 2.41 mg/mL for Tualang honey —both classified as having weak antioxidant activity. Although the IC_{50} of honey is much lower compared to that of Chrysanthemum extract, honey remains a promising sweetening agent in gummy formulations due to its functional health benefits, including its natural nootropic potential and its ability to complement other antioxidant-rich ingredients.

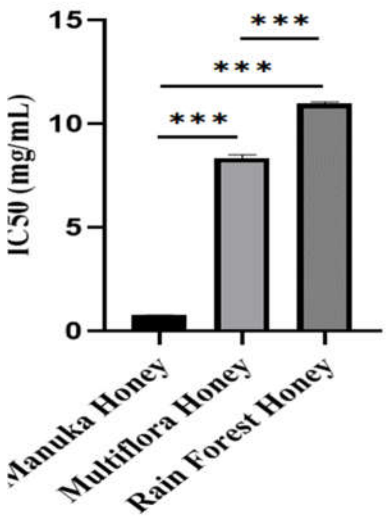
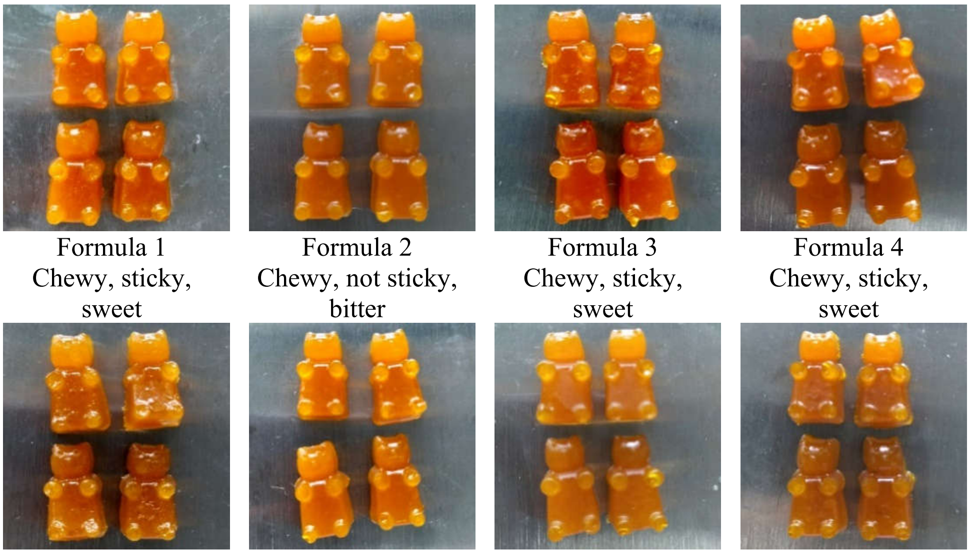


Figure 2. Antioxidant activity of honey samples evaluated using DPPH radical scavenging assay. Each bar represents mean ± SD. Data were analyzed using One way ANOVA followed by LSD Fisher test. N: 3. *** indicates a p value <0.0001. Manuka honey served as a positive control to assess the antioxidant capacity of other honey samples.

Gummy Candy Formulation

The formulation of gummy candy was conducted by optimizing the ratios of sweeteners — honey and stevia — in order to determine their effects on the product's physical characteristics and sensory attributes. The optimum variation concentration for honey and stevia was further analyzed using the Simplex Lattice Design (SLD) method. The results of the organoleptic evaluation indicated that the chrysanthemum -based gummy candies exhibited a yellow-brown coloration and a distinctive floral aroma characteristic of *Chrysanthemum indicum*. Variations in texture and flavor were observed across formulations, depending on the specific combinations and concentrations of honey and stevia used (Figure 3).



Formula 1 Chewy, sticky, sweet | Formula 2 Chewy, not sticky, bitter | Formula 3 Chewy, sticky, sweet | Formula 4 Chewy, sticky, sweet

Formula 5 Chewy, sticky, a little sweet | Formula 6 Chewy, not sticky, a little bitter | Formula 7 Chewy, sticky, a little sweet | Formula 8 Chewy, not sticky, bitter

Figure 3. Organoleptic characteristics of gummy candies with various concentrations of honey and stevia as sweeteners

Physical Characteristics of Gummy Candy

Moisture Content

The study demonstrated that the moisture content of the gummy candy was more significantly influenced by the stevia concentration than by honey. Formulations containing lower amounts of stevia and higher proportions of honey exhibited reduced moisture content (Figure 4). Although steviol glycosides are hydrophilic in nature (Jariyah *et al*., 2022), the powdered stevia used in this study contained minimal intrinsic moisture. Furthermore, stevia exhibits limited water-binding capacity compared to honey. Despite its inherent water content, honey possesses high sugar concentration and exhibits substantial osmotic pressure, enabling it to bind free water effectively. This property contributes to a lower measurable moisture content in honey-sweetened formulations (Ahmed *et al*., 2007). The moisture content of the gummy samples in this study ranged from 3.517% to 7.617%.

A commercial gummy product, Amos® (containing gelatin and pectin as gelling agents), was used as comparator. Amos® exhibited a moisture content of 1.30 ± 0.05%, which may be attributed to formulation differences—particularly the addition of carnauba wax as a moisture barrier on the product surface. In addition, variations in the bloom strength of gelatin may affect texture and water binding of gelatin. Although the experimental gummy formulations demonstrated high moisture levels, they remained within acceptable limits for product stability (<20%). Nevertheless, elevated moisture content may potentially reduce shelf life and increase susceptibility to microbial growth.

Texture Profile Analysis (TPA)

Texture profile revealed that gummy candies had hardness values ranging from 16.177 to 17.685 N, gumminess from 14.435 to 15.354 N, chewiness from 13.172 to 14.188 N, and adhesiveness between -0,049 and 0,127 Nmm (Figure 4). Statistically significant differences (p-value < 0.05) were observed among the formulations for each texture parameter. Hardness refers to the force required to compress or bite through the candy at first contact. Gumminess denotes the energy required to make the product into smaller particles, while chewiness describes the energy required to chew a solid food to the point of readiness for swallowing. Meanwhile, adhesiveness measures the degree of stickiness between the product and oral surfaces (Mutlu *et al*., 2018).

The findings suggest that increasing the concentration of stevia is associated with a decrease in hardness, gumminess, and cohesiveness of the gummy candy, likely due to the hydrophilic properties of stevia. An increase in moisture content leads to a decrease in gummy hardness (Tarahi *et al*., 2023). In addition, higher product density tends to reduce adhesiveness, as denser matrices are less prone to sticking to oral surfaces.

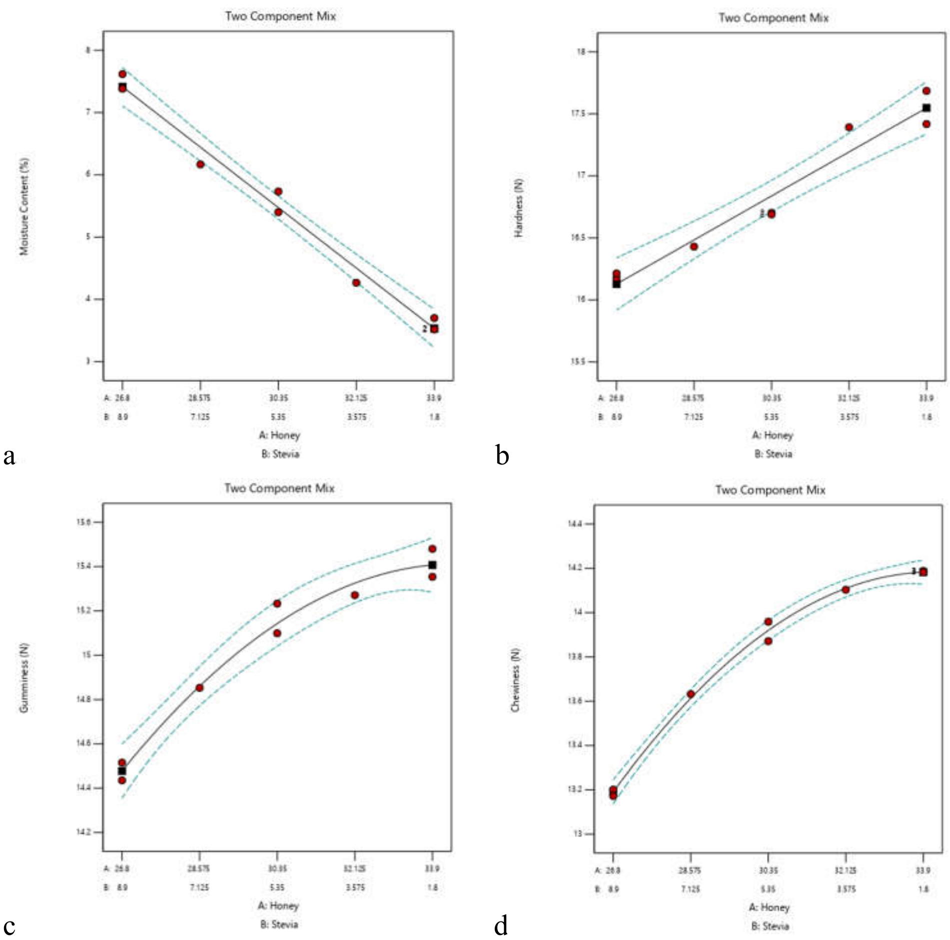
The addition of honey had a comparatively minor impact on the physical characteristics. While previous studies have reported moisture contents of 27-30% in honey-based gummy jellies (Kaewpetch *et al*., 2024), its influence in the current study was minimal in comparison to stevia. This is likely due to an interaction between stevia and gelatin, which appears to weaken the gel network. Stevia exerts an antagonist effect on gelatin, inhibiting the formation of a three-dimensional structure and thereby contributing to increased stickiness and reduced gel strength. (Cai *et al*., 2017).

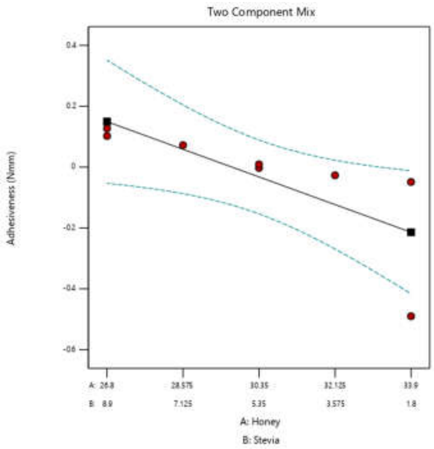
Sensorial analysis

The hedonic test was conducted to evaluate consumer acceptance and to identify quality differences among the gummy formulations. Ethical approval was granted by the Medical and Health Research Ethics Commission, Universitas Gadjah Mada (Document number: KE/FK/2031/EC/2023). The results of the average assessment are presented in Figure 4.

A reduction in stevia concentration was found to improve the texture and flavor of the gummy candy. Lower levels of stevia contributed to a firmer and denser texture, which was generally preferred by panelists. However, in terms of flavor, samples with a higher concentration of stevia received higher ratings. This can be attributed to the significantly greater sweetness intensity of stevia compared to honey. Stevia contains steviol glycosides and rebaudioside, which are approximately 200 times sweeter than sucrose (Akesowan and Choonhahirun, 2021), while honey's is sweetness only 1.2 – 1.5 times than that of sucrose (Bogdanov *et al*., 2008). In contrast, no significant differences were noted in the panelists' evaluations of color and aroma. This is likely due to the use of identical concentrations of coloring and flavoring agent across all formulations. In general, the data suggest that sensory attributes and consumer acceptance are more heavily influenced by the concentration of stevia than honey.

The hedonic test results showed moderate acceptability in some aspects, with average scores ranging between "slightly liked" and "neutral" on the 7-point scale. This suggest that further formulation optimization may be necessary to improve consumer appeal. The absence of certain ingredients commonly used in commercial products, such as carnauba wax or flavor enhancers, may have contributed to the lower scores.





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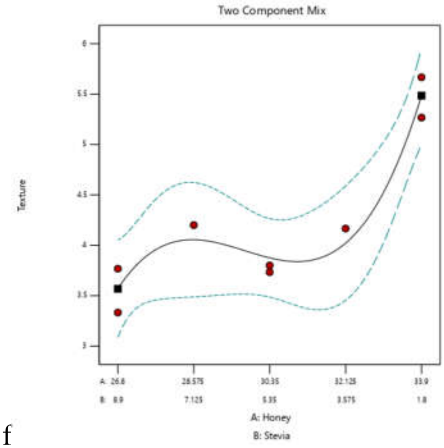

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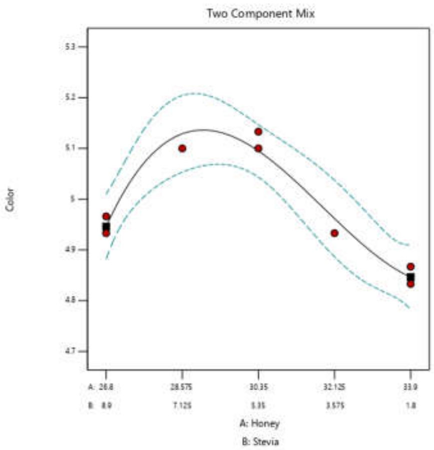

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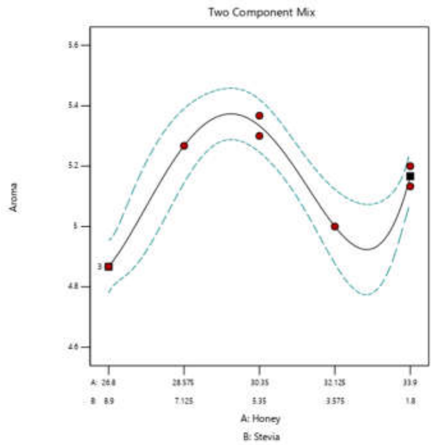

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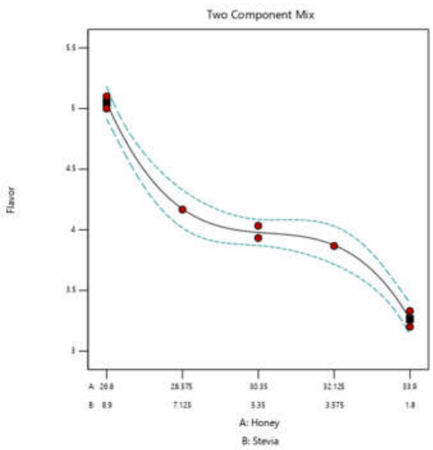

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Figure 4. Physical characteristics of gummy candy (a – e) and the results of the hedonic test on the Chrysanthemum extract-based gummy candies with different proportions of Multiflora honey and stevia as sweeteners (f – i). The respondents rated the gummy properties using a 7-point scale. (a) Moisture content. (b) Hardness. (c) Gumminess. (d) Chewiness. (e) Adhesiveness. (f) Texture. (g) Color. (h) Aroma. (i) Flavor.

Color Measurement

The color values (L^*, a^*, b^*) were in the range of 15.2 – 19.67; 6.57 – 8.43 and 20.33 – 26.5 (Figure 5). These values indicate that the color of gummy candies tended toward darker tones of red and yellow, ultimately blending into an orange hue. An increase in stevia content, accompanied by a decrease of honey, led to a darker color appearance. This is explained by the chemical properties of stevia containing steviol glycosides, which are colorless and non-reducing substances that do not participate in caramelization or Maillard reactions and have no significant impact on product browning (Lemus-Mondaca *et al*., 2012). In contrast, honey plays a more active role in color development. Its antioxidant compounds can inhibit oxidative browning by scavenging free radicals. A reduction in honey may allow for greater oxidation of phenolic compounds present in the Chrysanthemum extract, thus resulting in darker color tones (Khalil *et al*., 2010). Statistical analysis revealed no significant differences in the L^* and b^* values among the various formulations, indicating that these parameters were suitable discriminators for determining the optimal gummy formulation.

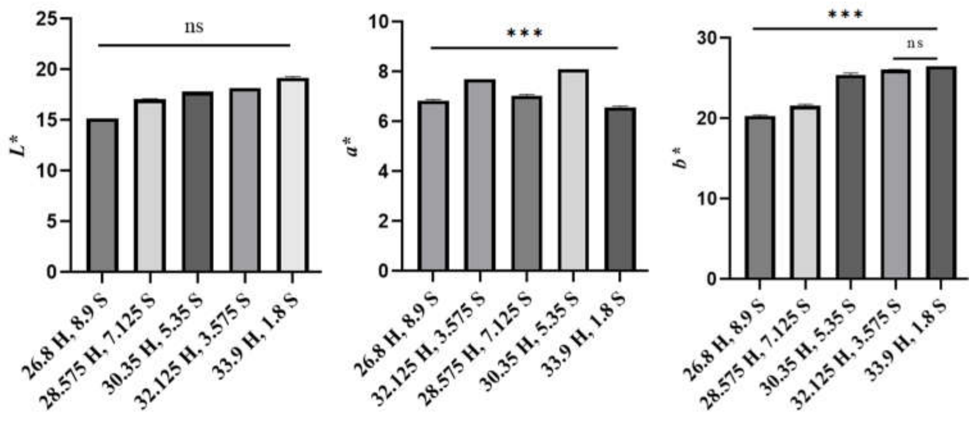

Figure 5. Color profile of gummy candies measured using a Chromameter. (a) Lightness (L^*). (b) Redness (a^*). (c) Yellowness (b^*). Color data were analyzed using one-way ANOVA. Each bar represents mean ± SD; *** indicates significant differences ($p<0.0001$). H = honey. S = stevia.

Verification of Optimum Formula

The optimum gummy candy formulation was determined using the Simplex Lattice Design (SLD) method, implemented via design expert software by entering the test response value. The response variables prioritized in the optimization process included hedonic scores for flavor and texture, followed by moisture content, hardness, gumminess, chewiness, and adhesiveness. Based on these parameters, the software calculated the optimum formulation with a desirability value of 0.542. The optimized formulation consisted of 18.547 grams of honey (33.1%) and 1.453 grams of stevia (2.6%).

The resulted response of the optimum formula was not significantly different from the predicted results of the design expert for all parameters. Increasing the proportion of stevia compared to honey greatly affects the sweetness of gummy candy. The reduction of the proportion of stevia compared to honey affects the low moisture content, high hardness, gumminess, chewiness, and adhesiveness, as well as texture. Compared to Samakradhamrongthai and Jannu (2021), the stevia sweetener variation resulted in a flavor value of 5.4 – 7.7 and chewiness of 5.5 – 6.0 rated on a 9-point hedonic scale, meaning neutral to moderately liked. This study resulted in flavor value 3.2 – 5.1 and a texture 3.3 – 5.7 rated on a 7-point hedonic scale, meaning slightly disliked to slightly liked. These findings indicate that the gummy candy was well accepted by the panelists and did not differ significantly from those reported in previous studies.

The novelty of this study lies in the identification of a honey-stevia combination which simultaneously meets sensory preferences and physical quality parameters in gummy candy. These findings contribute to the growing body of literature on strategy sugar-reduction strategies in functional confectionery, offering a potential alternative to conventional sweeteners such as sucrose and high-fructose corn syrup. Future research is recommended to further refine the formulation, particularly by adjusting the sweetener levels in relation to increasing the concentrations of Chrysanthemum extract, to ensure that both functional and sensory qualities are preserved.

Conclusions

Multiflora honey demonstrated superior antioxidant activity than rainforest honey. The variation in proportions of honey and stevia as alternative sweeteners significantly influenced both the physical characteristics and sensory attributes of Chrysanthemum-based gummy candy. The optimum formulation was identified as containing 33.12% honey and 2.59% stevia. This study contributes to the advancement of functional confectionery products by offering a formulation that is more compatible with children’s health needs. The integration of *Chrysanthemum indicum* extract, known for its potent antioxidant activity, along with the exclusion of refined sugar, supports the development of healthier gummy candies.

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