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Development of Functional Jelly Gums Using Blueberry Concentrate and Honey: Physicochemical and Sensory Analysis

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Abstract: The production of functional candies has garnered significant attention due to the growing consumer demand for healthier confectionery options. This study investigates the production of functional jelly gum by replacing table sugar and glucose syrup with honey and blueberry concentrate. Various formulations were developed and tested for phenolic and flavonoid content, antioxidant activity, textural properties, and consumer acceptance. Results showed that the addition of functional ingredients increased the phenolic and flavonoid content compared to the control. The modified jelly gums exhibited strong antioxidant activities, as evidenced by the DPPH assay, with significant differences ($p < 0.05$) from the control. The DPPH radical scavenging activity correlated strongly with phenolic content ($R^2 = 0.88$) and flavonoid content ($R^2 = 0.89$). Reducing power ranged from 32.31% to 78.45%, with the T5 sample (containing 30 g honey and 60 g blueberry concentrate) showing the highest activity. The reducing power of all treatments correlated significantly with flavonoid content ($R^2 = 0.75$) and phenolic content ($R^2 = 0.83$). Sensory analysis revealed that the T4 sample (containing 30 g of honey and 30 g of blueberry concentrate) was the most favorably received by consumers. These findings highlight the potential of using natural ingredients to develop healthier confectionery products that meet consumer demand for confectionery that is both nutritious and appealing.

Keywords: functional jelly gums; phenolics; flavonoids; blueberry concentrate; antioxidant activity; textural analysis

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1. Introduction

The food industry has been transforming due to technological advancements and increasing consumer awareness about the impact of food quality on health and well-being. Additionally, sustainability concerns have shaped the modern food landscape [1,2]. While honey and blueberry concentrate may have higher production and transportation

costs, they support sustainability by enabling local, small-scale sourcing and reducing the carbon footprint associated with long-distance transportation. Sustainably harvested honey benefits local ecosystems, and responsibly cultivated blueberries require fewer chemical inputs. Thus, broader ecological advantages and rising demand for eco-friendly products balance higher initial costs.

The confectionery industry, which includes products like chocolates, candies, gums, and other products, is a major sector in this transformation [3]. The global confectionery market generated an annual revenue of 586.2 billion U.S. dollars in 2024, forecasted to grow by 5.40% (Compound Annual Growth Rate (CAGR) 2024–2029). The largest market is baked goods and cakes, often called bakers' confectionery, which leads by approximately 100 billion U.S. dollars over the second-largest segment, chocolate confectionery [4]. The confectionery market has become complex, driven by cost and demand factors. Key trends include the increase in functional confectionery and a shift in consumer preferences towards healthier and more innovative products [3]. Consequently, research in the confectionery industry has shifted towards healthier fat and low-sugar options and introduced low-calorie and natural-derived sweetener materials [5,6].

Jelly gum is a typically soft confectionery product with high sucrose and glucose syrup levels, gelling agents like gelatin, artificial flavors, and coloring agents. Nevertheless, jelly gums have well-known health risks due to their high sugar and fat content, such as dental problems and bacterial infections like Streptococcus mutans [7]. Novel formulations have evolved that include alternative ingredients such as sweeteners, colorants, flavors, and gelling agents, which provide opportunities to enhance texture, taste, sensory attributes, and nutritional value [8–10]. Studies have shown that jellies with high hardness also exhibit high adhesiveness, and those with high cohesiveness are more difficult to chew and swallow [11]. Furthermore, incorporating fruit or specific gelling agents in the soft jelly gums has shown significant improvement in the mouthfeel and sensory appeal while maintaining necessary structural properties [12].

Functional gummy candies have significantly enhanced the nutritional value of typical gums by incorporating health-boosting ingredients such as fibers, proteins, antioxidants, and probiotics. Such functional gummies contribute to gut health and cardiovascular and weight management. For instance, high-fiber gummies with non-digestible fibers like inulin or konjac glucomannan have enhanced gut health and reduced cardiovascular risks [1,13,14]. Furthermore, the nutritional content has been maintained through gummies enriched by protein with legume proteins or *Spirulina* biomass [1,15]. Antioxidant-rich gummies formulated with rosemary extract, guava leaf, pineapple juice, and blackcurrant were investigated for their antioxidant capacity and promoting overall health [16–18].

Fruit-based functional foods have revolutionized the food and confectionery industries by incorporating bioactive compounds such as phenolics, dietary fiber, and essential vitamins, which provide antioxidant, anticancer, and antidiabetic benefits, promoting health and wellness [19]. Among these, blueberries are rich in flavonoids, phenolic acids, anthocyanins, and other phytochemicals and offer significant health benefits such as anti-inflammatory and antioxidant effects. Furthermore, blueberries positively impact gut microflora and degenerative diseases, promoting overall health [20,21].

Fruit-enriched jellies with ingredients like apples and psyllium have improved texture and gel strength and boost digestive health benefits [22]. Moreover, functional jellies like bananas and Malaysian stingless bee honey jelly also provide high carbohydrate content and antioxidant properties, demonstrating significant nutritional benefits [23]. Another study found that the sensory acceptance and stability of orange and raspberry jelly candies were liked by over 70% of consumers [9].

Combining fruits and honey in jelly candies has enhanced flavor and nutritional benefits. For example, a study found that probiotic-containing jelly candies using juçara and passion fruit flavors combined with honey showed high consumer acceptance and preserved their antioxidant, microbiological, and probiotic properties throughout storage, making them a valuable functional food option and an effective alternative to artificial dyes [24]. Moreover, combining honey with propolis gummy jelly has enhanced antioxidant properties up to 10 times more than similar commercial products, prolonged shelf life, and delayed fungal growth [25]. Furthermore, a study on mango jelly candy found that increasing honey concentration (up to 40%) significantly enhanced vitamin C and sugar levels, improving nutritional and sensory properties [26]. Similarly, replacing white sugar with honey in jelly marmalade reduced sugar content, boosted antioxidants, and extended shelf life by up to six months [27]. Additionally, banana and Trigona honey jelly showed strong antioxidant activity and induced apoptosis in cancer cells, suggesting therapeutic potential [28]. These findings support honey as a valuable natural ingredient for enhancing the health benefits of jelly-based products.

Recent studies also highlight blueberries' role in functional confectionery. Blueberry pomace extracts, rich in polyphenols and anthocyanins, have shown a potential to inhibit cancer cell growth [29]. Incorporating blueberries into probiotic ice cream significantly increased phenolic content and antioxidant activity while maintaining probiotic viability and sensory appeal [30]. Additionally, cryo-concentrated blueberry juice enhances antioxidant properties in confectionery while eliminating artificial additives, maintaining texture, and sensory appeal [31].

Nevertheless, the literature still needs to be enriched with studies investigating alternative sweeteners in functional jelly gums, particularly utilizing honey and blueberry concentrate instead of traditional sugar and glucose syrup. While these natural ingredients are recognized for their health benefits, few comprehensive studies have thoroughly investigated their impact on functional properties or physical product characteristics like texture and sensory appeal.

Incorporating honey and blueberry concentrate as substitutes for traditional sweeteners enhances the nutritional profile of jelly gums by increasing phenolic and flavonoid content, which contributes to antioxidant activity. These bioactive compounds offer health benefits such as anti-inflammatory and cardioprotective effects while reducing reliance on refined sugars [20,21]. Additionally, optimizing the formulation ensures that sensory properties, including taste and texture, align with consumer preferences, making the modified jelly gums both a healthier and appealing alternative to conventional confectionery.

This study explores the formulation of functional jelly gum using honey and blueberry concentrate as a partial substitute for traditional table sugar and glucose syrup. Additionally, this study aims to assess the improvements in functionality by measuring total phenolics and antioxidant activities and evaluating the effects of these modifications on the textural and sensory properties compared to a control formulation. Addressing these areas would help develop healthier and consumer-accepted jelly gums.

2. Materials and Methods

2.1. Chemicals

Sucrose–glucose syrup (Aknisasta, Istanbul, Turkey), gelatin 220 Bloom (Gelita, Cotia, Brazil), purple color (Rouge food's color, Valetta, Malta, EU), blueberry essence(Foster Clark Products Ltd., Valetta, Malta), wildflower honey (Langnese, Bargteheide, Germany), and blueberry concentrate (Pregel S.p.a, Frazione Arceto, Italy) were purchased from the local market in Amman, Jordan. Trichloroacetic acid and Folin–Ciocalteu reagent were obtained from AppliChem GmbH, Darmstadt, Germany. Sodium dihydrogen phosphate

($NaH_2PO_4 \cdot 2H_2O$) came from Fluka-Garantie, Buchs, Switzerland, while di-sodium hydrogen phosphate ($Na_2HPO_4 \cdot 2H_2O$), sodium carbonate (Na_2CO_3), and potassium ferricyanide ($K_3[Fe(CN)_6]_6$) were sourced from E. Merck, Darmstadt, Germany. ICN Biomedicals Inc., Aurora, OH, USA, provided 1,1-diphenyl-2-picrylhydrazyl (DPPH). Ascorbic acid, gallic acid, rutin, aluminum trichloride, and ferric chloride were obtained from Sigma-Aldrich, Steinheim, Germany.

2.2. Jelly Gum Confection Production

2.2.1. Traditional Jelly Gum Confection Production

Jelly gum is a chewy product with a soft texture, like jujubes, jelly gums, and gummy bears; each category can be distinguished by the ratio of sugar to glucose syrup, the concentration of the gelling agents used, and the degree of cooking of the final product.

The traditional jelly gum (control) was prepared by dissolving sucrose (50 g) in 21 g of water, followed by the addition of glucose syrup (25 g) and cooking the mixture to 116 °C or 87% Brix, determined using a handheld portable refractometer (0–90%), following the method prescribed by a local jelly gum manufacturer. After cooling the mixture to approximately 60 °C, gelatin (4 g) was added and stirred along with 0.5 mL colors (1%), flavors, and citric acid (2%). Finally, the mixture was poured into molding pans and left to cool and set. To ensure batch-to-batch consistency and accurate temperature monitoring during processing, a confection thermometer was used.

2.2.2. Modified Jelly Gums Production

Honey and blueberry concentrate were used wholly or partially to replace the glucose syrup and sucrose in the control sample jelly production. The interactions between the cooked ingredients and gelatin during mixing were monitored visually until the gel structure and setting properties were developed. Table 1 shows the different combinations used to produce traditional and modified jelly gum from honey and blueberry concentrate according to the preliminary experiments.

Table 1. Combinations used to produce control and modified jelly gum from the functional ingredients.

Treatment	Sucrose (g)	Gelatin (g)	Glucose Syrup (g)	Honey (g)	Blueberry Concentrate 60 Brix (g)	Water (g)
Control	50	4	25	-	-	21.0
T1	50	4	15	10	-	21.0
T2	50	4	5	20	-	21.0
T3	50	4	-	30	-	16.0
T4	40	4	-	30	30 (~18 g)	8.0
T5	20	4	-	30	60 (~36 g)	10.0

2.3. Physico-Chemical Characterization of the Modified Jelly Gum Products

2.3.1. Textural Analysis

The hardness of produced jelly gums was determined using a texture analyzer (Multitest 1-i, Mecmesin, Slinfold, UK) fitted with a 10 cm probe and a 2 mm diameter drilling rig. A test speed was 0.5 mm/s, and the probe was allowed to progress 15 mm in each sample. The maximum force (N) required to penetrate each sample was measured and used to express jelly gum hardness. Three repetitions were performed for each sample.

2.3.2. Phenolic Content

In this study, 10% (w/v) water extracts of honey, blueberry concentrate, and treatments were prepared for each separately. The extracts were stored in a refrigerator at 4 °C until use.

The phenolic content in the honey, blueberry concentrate, and modified jelly gums was analyzed using the Folin–Ciocalteu reagent [32]. Briefly, Folin–Ciocalteu reagent was added to each sample (0.5 mL), followed by the addition of sodium carbonate solution (10%). The absorbance was recorded at 760 nm, and the phenol content was estimated using the regression equation ($Y = 0.074X$, $R^2 = 0.996$) and presented as Gallic Acid Equivalent (GAE).

2.3.3. Flavonoid Content

The flavonoid content was measured using a previous method [33]. Briefly, aluminum trichloride (1.0 mL, 2%) was mixed with 0.5 mL of each sample and left for 40 min at room temperature (RT). The absorbance was recorded at 415 nm, and the flavonoid content was estimated from the regression equation ($Y = 1.194X + 0.0059$, $R^2 = 0.996$) and presented as Rutin Equivalent (RE).

2.3.4. Antioxidant Activities

DPPH Assay

The free radical scavenging activity in honey, blueberry concentrate, and modified jelly gum has been measured using the DPPH assay [34]. In brief, 1.0 mL of DPPH solution was added to different volumes of the modified gum samples and the functional ingredients. The absorbance was measured at 517 nm, and the scavenging activity percentage was calculated as follows:

$$\text{DPPH radical inhibition activity (\%)} = \text{Control absorbance} - (\text{Sample absorbance} - \text{Blank absorbance})/\text{Control absorbance} \times 100.$$

The IC50 values (the concentration required to inhibit 50% of DPPH) for each treatment were calculated from a dose–response curve between DPPH inhibition % and concentrations.

Reducing Power

The term 'reducing power' refers to the electron-donating ability of the samples, which is an established indicator of antioxidant potential. This method complements the DPPH assay, providing a comprehensive evaluation of antioxidant activity.

The reducing power of honey, blueberry concentrate, and modified jelly gums was assessed using a previously described method [34]. In this method, phosphate buffer and potassium ferricyanide were mixed with 0.2 mL of each sample and incubated at 50 °C for 30 min, followed by the addition of trichloroacetic acid and centrifugation. The absorbance was measured at 700 nm, and the antioxidant activity was calculated against the ascorbic acid standard as follows: Antioxidant activity (%) = (absorbance (Sample/Ascorbic acid absorbance) × 100.

2.4. Sensory Analysis

A sensory evaluation of both control and modified jelly gum samples was conducted at the University of Jordan. Evaluators (fifty participants from staff and students) who are familiar with the product and frequently consume it were requested to evaluate the sensory attributes of the samples, including overall acceptability, appearance, firmness, glossiness, flavor, and elasticity. A 9-point hedonic scale was employed, where 1 corresponded to "dislike extremely" and 9 to "like extremely" [35]. The samples were labeled with randomly assigned three-digit codes and presented in a randomized sequence. Three repetitions were performed for each sample. All tests were conducted under controlled laboratory conditions at room temperature.

2.5. Economy of Modified Jelly Gum Production

The production cost of modified jelly gums (in Jordanian Dinar (JOD) per 100 g) was calculated based on the cost and proportions of the raw materials used in various treatments, with prices determined according to local market rates.

2.6. Statistical Analysis

The results were statistically analyzed using the SAS software, 2000 (SAS Institute Inc., Cary, NC, USA). The significance of differences was estimated using Least Significant Difference (LSD) with significance set at $p < 0.05$. All experiments and treatments were conducted in triplicate to ensure data accuracy and reliability.

3. Results and Discussion

3.1. Physico-Chemical Characterization of the Modified Jelly Gum Products

Texture Analysis

The texture analysis results are presented in Figure 1. The hardness values of the samples followed a descending order: Control > T1 > T2 > T4 > T3 > T5. However, the hardness of T4, T5, and T3 is not significantly different. The force required to penetrate 15 mm through the jelly gum samples ranged from 0.40 to 1.2 N, with all modified formulations exhibiting a softer texture than the control. The control sample had the highest hardness value, likely due to the absence of functional ingredients such as honey and blueberry concentrate, contributing to a softer texture. Conversely, T5, which contained the highest proportion of these functional ingredients, displayed the lowest hardness value.

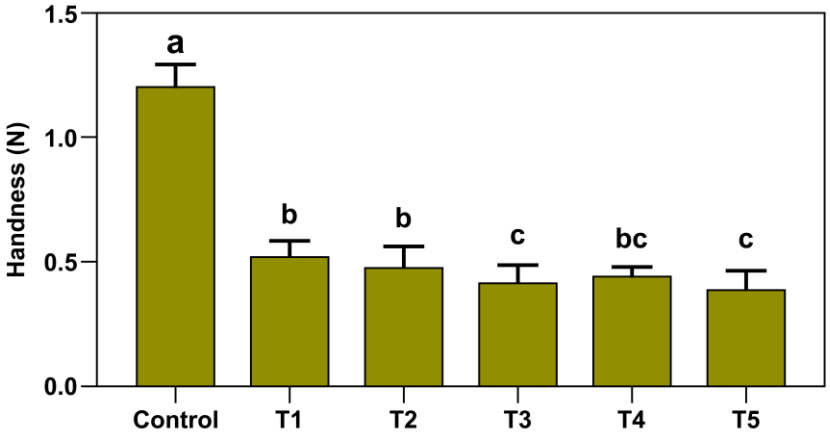

Figure 1. Average hardness values (N) of the modified jelly gums. The findings are presented as mean ± SD from three replicates. Significant differences are indicated by different letters ($p < 0.05$).

These findings align with previous studies demonstrating that fruit-based modifications influence jelly gum texture. A study evaluating different jelly gum formulations found that adding fruit affected hardness properties, with strawberry and anise formulations resulting in the softest texture, indicating that fruit components alter the textural profile of jelly gums [12]. Similarly, the impact of fruit vinegar on jelly gum characteristics showed that apple cider vinegar-based gummies exhibited increased hardness, gumminess, and chewiness, emphasizing the role of ingredient composition in textural properties [36]. Furthermore, Hani et al. reported that incorporating red pitaya fruit puree disrupted the gummy network structure, decreasing hardness [37]. Likewise, a study on jelly gums made with orange juice and berry puree, sweetened with honey, found that these formulations were softer than their commercial counterparts while offering improved nutritional profiles [38]. These results highlight the significant role of functional ingredients, particularly

fruit-based components, in modifying the texture of jelly gums. The observed softening effect suggests potential applications for enhancing sensory appeal while improving nutritional quality.

3.2. Phenolic Content

The total phenolic content of the control sample, the functional ingredients, and the percentage improvement in phenolic content for the modified jelly gum formulae are presented in Table 2. The phenolic content of control, honey, and blueberries was 27.65 mg, 41.50, and 62.70 mg GAE/100 g, respectively (Table 2).

Table 2. The average contents of phenolics and flavonoids, and IC_{50} of the control, blueberry, honey, and the different modified functional jelly gum preparations.

Sample	Phenolic Content (mg GAE/100 g)	Flavonoid Content (mg RE/100 g)	IC_{50} (mg/mL)
Control	27.65 ± 0.49^{g}	0.02 ± 0.01^{e}	$>100 \pm 0.15^{a}$
Blueberry	41.50 ± 1.83^{e}	0.28 ± 0.02^{bc}	2.00 ± 0.10^{f}
Honey	62.70 ± 0.14^{ab}	0.15 ± 0.03^{cd}	92.00 ± 0.61^{b}
T1	22.78 ± 1.96^{f}	0.04 ± 0.01^{ed}	$>100 \pm 0.20^{a}$
T2	101.80 ± 0.28^{cd}	0.16 ± 0.08^{cd}	12.50 ± 0.10^{c}
T3	81.00 ± 6.08^{d}	0.26 ± 0.04^{bc}	5.00 ± 0.10^{d}
T4	119.10 ± 2.12^{bc}	0.31 ± 0.10^{b}	3.50 ± 0.50^{e}
T5	148.00 ± 1.55^{a}	0.51 ± 0.30^{a}	5.90 ± 0.10^{d}

The results are presented as mean ± SD from three replicates. Means followed by different letters in the column are significantly different ($p < 0.05$).

The results indicate that the composition of the samples significantly influences their phenolic content. The control sample, which contained neither honey nor blueberry concentrate, exhibited the lowest phenolic content (27.65 mg GAE/100 g). Samples containing honey alone (T1-T3) showed a notable increase in phenolic content, with T3 (30 g honey) reaching 81.00 mg GAE/100 g. Adding blueberry concentrate in T4 and T5 further enhanced the phenolic content, with T5 (30 g of honey and 60 g of blueberry concentrate) achieving the highest value (148.00 mg GAE/100 g). This significant increase in phenolic content confirms that including these functional ingredients can effectively enhance the total phenolic content of jelly gums, making a compelling case for their incorporation.

Honey, produced by *Apis mellifera*, is a functional food rich in bioactive compounds and enzymes, giving it antioxidant, antimicrobial, anti-inflammatory, and anticarcinogenic properties [39]. Similarly, blueberries are recognized for their anti-inflammatory, anticarcinogenic, and cardiovascular protective effects, attributed to their phenolic content, constituting approximately 0.3% of the fruit's total composition [40,41].

Our findings align with a study that demonstrated that the total phenolic content of various types of honey ranged from 32.59 to 114.75 mg GAE/100 g [42], while the phenolic content of blueberries ranged from 0.19 to 258.90 mg/100 g on a fresh weight basis (FWB) [43]. Additionally, a recent study demonstrated that honey-based gummy jelly containing gelatin and propolis extract exhibited phenolic content ranging from 200.89 to 224.25 mg GAE/g, leading to significant antioxidant and antimicrobial activities [41].

The observed enhancement in phenolic content with increasing levels of honey and blueberry in our formulations supports the practical application of these ingredients in improving the health benefits of jelly gums.

3.3. Flavonoid Content

The flavonoid content followed a decreasing order: T5 > T4 > T3 > T2 > T1 > control, and it ranged from 0.04 to 0.51 mg RE/100 g (Table 2). The differences between the control

and the modified jelly gums were statistically significant. T5, which contained the highest concentrations of honey and blueberry, exhibited the highest flavonoid levels, whereas the control sample had minimal flavonoid content.

Among the functional ingredients, blueberries had a higher flavonoid content (0.28 mg RE/100 g) than honey (0.15 mg RE/100 g). This aligns with findings by Sellappan et al., who reported that blueberry flavonoid content ranges from 2.50 to 387.48 mg quercetin equivalent (QE)/100 g on an FWB [43]. Similarly, Pontis et al. reported total flavonoid content in honey ranging from 0.09 to 4.86 mg QE/100 g [44].

Flavonoids in honey play a crucial role in its antioxidant, anti-inflammatory, and antimicrobial properties. These polyphenolic compounds—such as quercetin, kaempferol, luteolin, and pinocembrin—originate from the nectar, pollen, and plant resins collected by bees. The flavonoid profile of honey varies based on its botanical origin, contributing to its potential health benefits. Studies suggest that flavonoids in honey can help prevent cardiovascular diseases by reducing oxidative stress and inflammation. At the same time, some evidence also points to their role in managing diabetes through antioxidant mechanisms [45,46]. Phenolics and flavonoids, both abundant in fruits and honey, serve as potent antioxidants that help mitigate oxidative stress, a key factor in metabolic disorders such as diabetes and cardiovascular diseases. These compounds scavenge free radicals, modulate oxidative enzymes, and reduce inflammation, contributing to overall metabolic health [47]. Furthermore, flavonoids have been shown to support gut microbiota balance, enhancing the brain–gut axis and metabolic regulation. Their role in improving glucose metabolism and mitigating obesity-related complications further underscores their therapeutic potential [48–51].

The results of this study confirm that incorporating honey and blueberry as functional ingredients can significantly increase the flavonoid content of jelly gums. Recent studies have explored the flavonoid content in fruit-based jelly gums and related products. For example, a study by Guiné et al. evaluated jelly gums containing berries and aromatic plants, finding that these formulations exhibited significant flavonoid content, as fruits like strawberries, blueberries, and raspberries are naturally rich in polyphenols, including flavonoids [12]. Another study on jelly containing aronia juice found that the flavonoid content increased proportionally with the concentration of the fruit juice, demonstrating the impact of fruit on the jelly's antioxidant and flavonoid content [52]. Furthermore, a study on functional jelly made from bananas and honey also confirmed measurable flavonoid content, emphasizing the benefits of incorporating bioactive compounds into confectionery products [23].

3.4. Antioxidant Activities

3.4.1. Free Radical Scavenging Activity

Figure 2 presents the free radical scavenging activities of the modified jelly gums and their functional ingredients at different concentrations. The results indicate a concentration-dependent increase in antioxidant activity, as demonstrated by the progressive decolorization of the DPPH solution [53,54]. The high anthocyanin content in blueberries may contribute significantly to the observed complete color inhibition at all tested concentrations (Figure 2) [55].

Moreover, the antioxidant activity of all formulations exhibited a strong positive correlation with total phenolic content (R^2 = 0.88) and total flavonoid content (R^2 = 0.89) at 100 mg/mL, reinforcing the relationship between these bioactive compounds and antioxidant potential. The differences in antioxidant activity across formulations can be attributed to the varying proportions of honey and blueberry, which influence their overall phenolic and flavonoid content.

Previous research has consistently demonstrated the contribution of phenolic and flavonoid compounds from fruits and honey to their antioxidant activity. A study on mangoes found high antioxidant activity closely linked to their phenolic acid and flavonoid content, with strong correlations between antioxidant assays and free radical neutralization [56]. Similarly, crude extracts from *Calotropis procera*, *Pergularia tomentosa*, and *Pentatropis* exhibited significant antioxidant activity due to their rich phenolic and flavonoid profiles [57]. Recent findings indicate that while vitamins contribute minimally to honey's antioxidant properties, phenolic acids and flavonoids play a significant role in its free radical scavenging capacity [58]. A study found that adding cryo-concentrated blueberry juice to gelatin gels and gummies significantly increased bioactive compounds, with polyphenol content ranging from 230 to 250 mg GAE/100 g. The antioxidant activity remained stable during storage, especially in non-aerated samples, highlighting blueberry's potential to enhance the nutritional profile of gummy products [59].

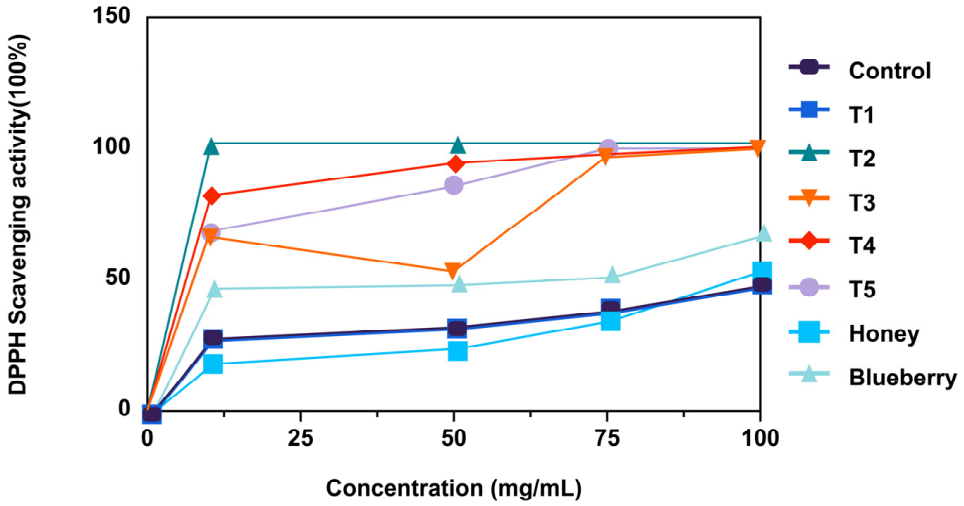

Figure 2. The DPPH free radical-scavenging activity of the different modified jelly gum samples and control and functional ingredients presented as the mean of three replicates.

3.4.2. IC50 Values

The IC_{50} values of the ingredients and modified jelly gums are presented in Table 2. As the IC50 value decreases, the antioxidant potency increases. The IC_{50} values ranged from 2 to 100 mg/mL in the following decreasing order of antioxidant activity: control = T1 > T2 > T3 > T5 > T4. The highest IC_{50} values were observed for the control and T1 (>100 mg/mL), reflecting poor antioxidant activity against DPPH free radicals. In contrast, T4 demonstrated the lowest IC50 value (3.50 mg/mL), reflecting the most potent antioxidant activity. Statistical analysis showed that all treatments exhibited significant differences ($p < 0.05$) in IC50 values compared to the control, except for T1, likely due to its low honey content in the formulation.

The IC_{50} values for honey and blueberry were 92.00 mg/mL and 2.00 mg/mL, respectively. Pontis et al. reported IC50 values for honey ranging from 3.17 to 8.79 mg/mL; the higher value in this study may be due to differences in the types of honey used [44]. The IC50 value for blueberry is consistent with Bunea et al., who found that the antioxidant activity of five blueberry varieties from Romania at 2 mg/mL ranged from 29.96% to 59.79% [60]. A recent study developed gummy candies using pistachio extract, which showed an average phenolic content of ~680.0 GAE/100 g and an antioxidant IC50 value of 0.277 mg/mL. These gummies successfully provided a reduced-sugar confectionery product with high antioxidant activity, free from artificial flavors and synthetic colorants [61].

The strong correlations between antioxidant activity and total phenolic (R^2 = 0.88) and flavonoid content (R^2 = 0.89) further confirm that including honey and blueberries in modified jelly gums enhances their free radical scavenging ability. This suggests that using these natural ingredients improves the functional properties of jelly gums and enhances their health benefits in a concentration-dependent manner.

3.4.3. Reducing Power

The reducing power measures the ability to convert Fe^{3+} to Fe^{2+} and is expressed as a percentage relative to ascorbic acid. Figure 3 shows that the T5 treatment exhibited the highest reducing power activity among all treatments, with values ranging from 32.31% to 78.45%, measured as 30 µg ascorbic acid equivalents. The control demonstrated the lowest reducing power, indicating weak antioxidant activity compared to ascorbic acid. The reducing power results followed this order: T5 > T3 > T4 > T2 > T1 > Control.

No significant differences were observed in T2, T3, T4, and T5; however, all modified jelly gums demonstrated significantly higher reducing power than the control's ($p < 0.05$). Both honey and blueberry exhibited high reducing power activities (65.83% and 60.77%, respectively). The reducing power across treatments strongly correlates with flavonoid content (R^2 = 0.75) and phenolic content (R^2 = 0.83), confirming that these bioactive compounds contribute to the enhanced antioxidant activity of the modified jelly gums.

The reducing power of blueberries and honey has been studied in the literature. Bunea et al. reported that the reducing power activities for five blueberry types ranged from 33.03 to 73.71 µM Fe^{+2}/g [60]. Similarly, adding honeyberry powder to jelly significantly increases its antioxidant activity, including reducing power, as the concentration of honeyberry powder increases [62]. Furthermore, the antioxidant ability of honey and lemon juice added to guava–pineapple jelly was measured by reducing ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}) and was recorded at 29.51 to 28.55 and 27.99 to 27.40 µM Fe_2SO_4/100 g, respectively. The strong antioxidant activity observed in these formulations was likely attributed to the high ascorbic acid, phenol, and flavonoid content derived from honey and freshly extracted lemon juice [63]. These findings reinforce the role of phenolic and flavonoid compounds in enhancing the reducing power of functional jelly gums, demonstrating their potential to improve antioxidant capacity in confectionery products.

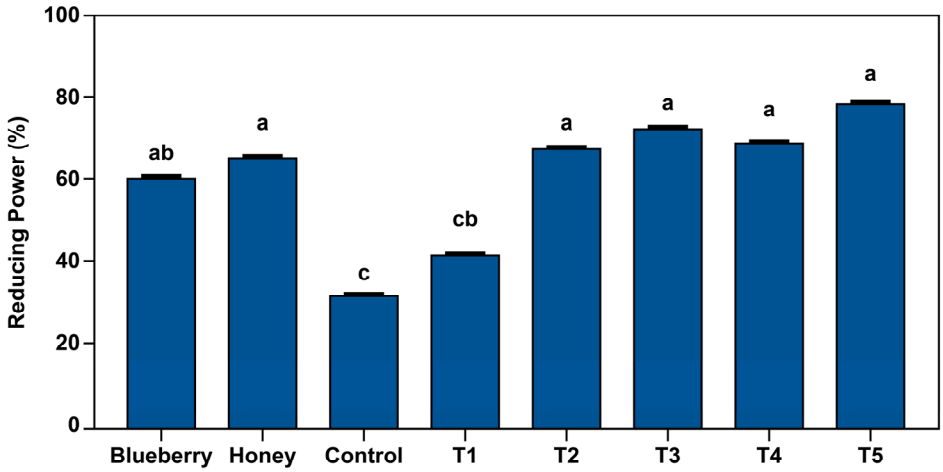

Figure 3. The reducing power percentages of the produced jelly gums, control, and the functional ingredients. The reducing powers of all modified jelly gums significantly differed from the control. The findings are presented as mean ± SD from three replicates. The significant difference was presented by different letters ($p < 0.05$).

3.5. Sensory Evaluation

Sensory characteristics, such as firmness, appearance, flavor, elasticity, and glossiness, are crucial in consumer perception and acceptance of food products. These attributes were evaluated in the modified jelly gums to assess the impact of different ingredient formulations on sensory quality.

The firmness scores revealed that T4 had the highest value while T5 was the softest. This difference may be attributed to the higher percentage of functional ingredients used in T5, which likely affected the texture (Table 3). Charoen et. Al. highlighted that the texture and color properties of gummy jelly candies are significantly influenced by processing temperatures and the Psidium guajava leaf extract levels used [17].

Among all treatments, T4 demonstrated the highest average scores in overall liking (7.20), appearance (7.48), flavor (6.86), elasticity (6.78), glossiness (7.10), and firmness (6.56). The soft texture of T4, likely due to optimal functional ingredient concentrations, may have contributed to its high ratings. However, T4 was statistically similar to T3 in elasticity, appearance, and glossiness and to T1 and T2 in appearance (Table 3).

The control group recorded the lowest average scores in appearance (5.70), elasticity (5.52), glossiness (4.47), and firmness (5.36). However, it was statistically similar to T2 and T5 in overall liking, T1 and T5 in appearance, and T3 and T5 in flavor scores. The highest elasticity score was observed in T4 (6.78), while the lowest was in T5 (6.08), both significantly different from the control group.

Interestingly, a negative correlation ($R^2 = -0.68$) was identified between firmness scores from sensory analysis and hardness values from textural analysis. This suggests a potential difference between consumer evaluations (subjective) and objective instrumental measurements. Flavor scores showed significant differences between all treatments; however, the control, T3, and T5 were not statistically different from each other ($p < 0.05$), as well as T1 and T2. The similarities in ingredient concentrations likely contributed to the inability of consumers to detect significant variations in the organoleptic properties of the samples.

Several studies have investigated the sensory attributes of jelly gums made with natural ingredients, including fruits, herbs, and honey. One study evaluated the color and sensory properties of jelly gums made with various fruit and herb combinations. The results showed that blueberry–mint and strawberry–anise jellies were the most preferred prototypes, with blueberry–mint ranking highest in aroma and strawberry–anise receiving the best overall appreciation scores [64]. Further research examined the effects of adding honeyberry powder to the jellies, significantly increasing the total polyphenol content and antioxidant activity without altering key sensory attributes like smell, taste, and texture. In consumer tests, the jellies with honeyberry powder were as acceptable as the control group. Another study aimed to create healthier jelly gums using natural ingredients such as orange juice and berry puree, without added sugars or artificial additives. Sensory evaluations showed that these jellies were well-received, particularly the orange juice and honey variant, which scored nearly as high as commercial samples in consumer tests [62]. These studies highlight the potential to enhance the health benefits and sensory qualities of jelly gums using natural ingredients.

The positive consumer reception of jelly gums made with natural ingredients highlights an opportunity to differentiate in the market. Strategic positioning is essential to capitalize on this preference and compete with existing products. To compete with existing products, leveraging sustainability using locally sourced ingredients can attract eco-conscious consumers. Highlighting health benefits, building a strong brand narrative, and offering competitive pricing can enhance market appeal. Expanding distribution through retail partnerships, e-commerce, and innovative product variants can further

differentiate the brand. These strategies collectively strengthen market positioning and consumer loyalty.

Table 3. Average scores of modified jelly gum sensory properties (overall, appearance, flavor, elasticity, glossiness, and firmness).

Treatments	Over All	Appearance	Flavor	Elasticity	Glossiness	Firmness
Control	6.10 ± 1.966 ^{b}	5.70 ± 1.76 ^{b}	6.26 ± 2.10 ^{ab}	5.52 ± 1.93 ^{b}	4.47 ± 2.12 ^{c}	5.36 ± 2.04 ^{c}
T1	6.64 ± 2.10 ^{b}	7.02 ± 1.60 ^{a}	5.98 ± 1.78 ^{b}	6.36 ± 1.71 ^{a}	6.68 ± 1.79 ^{ab}	6.20 ± 2.24 ^{ab}
T2	6.64 ± 2.01 ^{b}	7.30 ± 1.38 ^{a}	5.88 ± 1.97 ^{b}	6.20 ± 1.92 ^{ab}	6.86 ± 2.02 ^{ab}	6.08 ± 2.16 ^{abc}
T3	6.68 ± 1.87 ^{ab}	7.28 ± 1.71 ^{a}	6.45 ± 1.95 ^{ab}	6.66 ± 1.57 ^{a}	7.34 ± 1.93 ^{a}	6.12 ± 2.04 ^{ab}
T4	7.20 ± 1.30 ^{a}	7.48 ± 1.26 ^{a}	6.86 ± 1.85 ^{a}	6.78 ± 1.65 ^{a}	7.10 ± 1.75 ^{a}	6.56 ± 02.03 ^{a}
T5	6.06 ± 1.77 ^{b}	5.70 ± 1.97 ^{b}	6.14 ± 1.85 ^{ab}	6.08 ± 1.83 ^{ab}	6.32 ± 1.77 ^{b}	5.72 ± 2.18 ^{bc}

The findings are presented as mean ± SD from three replicates. The significant difference was presented by different letters ($p < 0.05$).

3.6. The Economy of Production of Modified Jelly Gums

The economic analysis of traditional and modified jelly gums, as shown in Table 4, highlights the direct relationship between adding functional ingredients and the overall production cost. The cost of raw materials for 100 g of control jelly gum (without functional ingredients) was calculated at 0.207 JOD. This serves as the baseline for comparison.

The cost increased as functional ingredients, such as honey and blueberries, were introduced into the formulations (T1 to T5). Specifically, T1, which involved a minimal addition of functional ingredients, showed a modest increase of 4.8%, raising the cost to 0.217 JOD per 100 g. Similarly, T2 exhibited a slightly higher rise of 9.66%, costing 0.227 JOD. A more significant cost increase was observed in T3, which reflected a 28.98% rise, resulting in a cost of 0.267 JOD. The significant increase indicates that as the concentration of functional ingredients rose, the cost of producing the jelly gum increased accordingly.

The most substantial cost increases occurred in T4 and T5, formulations that contained both honey and blueberries. T4 demonstrated a 78% rise, costing 0.370 JOD, while T5 showed the highest increase at 126%, bringing the production cost to 0.468 JOD. Although these costs are higher than the control and other treatments, they can be justified by the inclusion of high-value functional ingredients. Honey and blueberries enhance the jelly gums' nutritional profile and contribute to their market appeal, as consumers who care about health are likely willing to pay more for products with added health benefits.

Table 4. The cost analysis of traditional and modified jelly gum raw materials.

	Control	T1	T2	T3	T4	T5
Cost/100 g (JOD)	0.207	0.217	0.227	0.267	0.370	0.468
Cost increase (%)	-	4.80	9.66	28.98	78.0	126.0

4. Conclusions

With growing health and sustainability awareness, the functional food sector has gained strength and increased interest. Traditional sweeteners in conventional jelly gums have been associated with various health concerns. This study developed several functional jelly gums using honey and blueberry as natural sweeteners. These functional jelly gums significantly enhanced various aspects, including hardness, phenolic and flavonoid content, and resulting antioxidant activity. Consumers also received their products well in terms of sensory properties. Although the production costs of these jelly gums are expected to rise, the increased expenses are justified by their enhanced health benefits and consumer

acceptance. Notably, this study revealed a concentration-dependent relationship between the functional ingredients and antioxidant activity, providing valuable insights into how phenolics and flavonoids influence product functionality and health benefits. Although production costs are expected to rise with the inclusion of these ingredients, the added health benefits and consumer demand for functional foods justify the expense. These findings underscore the potential of functional jelly gums as a viable and appealing alternative to traditional confectionery, delivering both health benefits and a pleasing sensory experience.

This study offers a novel framework for developing sustainable, health-conscious products in the functional food and confectionery industries by demonstrating the innovative application of natural ingredients to replace traditional sweeteners.

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