

ORIGINAL RESEARCH PAPER

**A NOVEL APPROACH TO CRAFT JELLY CANDIES WITH QUINCE
AND SEA BUCKTHORN: QUALITY AND BIOACTIVE INSIGHTS**

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Abstract

This study developed craft jelly candies using quince (*Cydonia oblonga*) puree and sea buckthorn (*Hippophae rhamnoides*) dried pomace, emphasizing by-product valorization. Five candy formulations with varying levels of sea buckthorn pomace powder (0%, 1%, 2%, 3%, and 4%) were evaluated for nutritional composition, sensory attributes, and physicochemical properties. The incorporation of sea buckthorn powder enhanced the antioxidant content of the candies. DPPH radical scavenging activity increased, reaching 91.71%, while hydrogen peroxide scavenging capacity improved to 26.67%. The fiber content varied between 7.19% and 6.61%, slightly decreasing due to the higher dilution effect from added water and honey. Total polyphenol content ranged from 633.28 mg GAE/100 g in samples with quince puree to 597.21 mg GAE/100 g in the highest sea buckthorn formulation. Formulations with 1% and 2% sea buckthorn powder achieved a well-balanced texture, taste, and appearance, whereas higher levels resulted in excessive tartness and textural changes. Sensory evaluation using the Check-All-That-Apply (CATA) method linked moderate sea buckthorn incorporation with high acceptability. The utilization of quince puree and sea buckthorn pomace in confectionery production enhanced nutritional value, contributing to sustainable food development and reducing agricultural waste.

Keywords: quince, sea buckthorn pomace, jelly candies, polyphenols, antioxidants.

Introduction

The global processed food market has expanded significantly, with confectionery products being among the most consumed categories (WHO, 2015). Among processed foods, confectioneries such as jelly candies hold a unique position due to their sensory appeal, versatility in taste, texture, and accessibility. Despite their popularity, these products are often criticized for their high sugar content, artificial additives, and minimal nutritional value. Correspondingly, the growing consumer demand for innovative, nutritious, and sustainable food products has steered the food processing industry toward developing healthier alternatives to traditional confectionery. Defined by Codex Alimentarius Standard (2009), jellies are semi-solid gelled products made from the juice and/or aqueous extracts of one or more fruits, primarily composed of sugar or sugar substitutes, combined with foodstuffs with sweetening properties such as fruit, fruit pulps, purees, and aqueous extracts, with or without the addition of water and gelling agents. However, the excessive sugar intake is closely linked to a rise in obesity rates and related health complications. This fact led organizations like the World Health Organization (WHO) to recommend limiting daily sugar consumption to less than 10% of total caloric intake (WHO, 2015), prompting a shift toward incorporating natural and bioactive ingredients in their formulation (Naughton *et al.*, 2017; Singh *et al.*, 2020; Spanemberg *et al.*, 2019).

To address these concerns, the industry is exploring alternatives such as low-calorie sweeteners and natural additives (Covaliov *et al.*, 2024; Dehghan and Mohammadi, 2023; Popovici *et al.*, 2019). The use of high-intensity sweeteners like stevia, maltitol, and isomalt has shown promise in reducing sugar content while maintaining the desired sensory attributes of candies (Singh *et al.*, 2020; Snegireva and Meleshkina, 2023). Moreover, the integration of natural colorants and bioactive ingredients derived from fruits and vegetables enhances the nutritional profile and consumer appeal of these products (Capcanari *et al.*, 2022; Samokhvalova *et al.*, 2021).

In recent years, researchers have focused on incorporating novel fruits and bioactive compounds into jelly candies. For example, Kahraman *et al.* (2023) developed probiotic-enriched jelly candies, while Sigwela *et al.* (2022) used beetroot, cactus pear, and amaranth to create naturally colored jellies and other sweet products. Similarly, Gümüş *et al.* (2024) explored wine lees as a source of natural pigmentation. These innovations align with consumer preferences for products that combine health benefits with visual and sensory appeal (Hadi *et al.*, 2024).

The choice of fruits for jelly candy production is critical. While traditional flavors such as strawberry, orange, and lemon dominate the market, there is growing interest in less conventional options, including quince and sea buckthorn. Quince is a fruit rich in organic acids, vitamins, and antioxidants, making it a functional ingredient for confectionery (Al-Zughbi and Krayem, 2022; Silva *et al.*, 2023). Sea buckthorn, often referred to as a "wonder plant," is renowned for its high vitamin C content and a plethora of bioactive compounds, including carotenoids and polyphenols (Covaliov *et al.*, 2021; Wang *et al.*, 2022). Currently, sea buckthorn is primarily utilized for its pulp and seed oil, while the remaining pomace (peel) largely remains underutilized,

despite studies demonstrating its potential bioactive profile and selected functionalities (Mihalcea *et al.*, 2021; Stanciu *et al.*, 2023). On the other hand, food waste is a significant global issue, with millions of tons of edible produce discarded annually due to aesthetic imperfections, overproduction, or supply chain inefficiencies. In the context of quince and sea buckthorn, the underutilization of these fruits presents an opportunity for value-added processing. Quince, for example, is often overlooked in favor of more commonly consumed fruits due to its astringent taste and firm texture (Najman *et al.*, 2023). Similarly, sea buckthorn berries are underexploited despite their nutritional potential, largely due to challenges in harvesting and processing (Ruan *et al.*, 2013).

The present study focused on the development of craft jelly candies made from quince (*Cydonia oblonga*) and sea buckthorn (*Hippophae rhamnoides*). In the case of sea buckthorn, secondary products derived from fruit processing were utilized, further emphasizing sustainability in the production process. Thus, the aim of the study consisted in developing a novel formulation for craft jelly candies using quince and sea buckthorn dried pomace as primary ingredients. By assessing the quality and bioactive profiles of these candies, the research sought to demonstrate the feasibility of creating healthier alternatives to traditional confectionery.

Materials and methods

For the development of biologically enriched sweet products, several primary and auxiliary materials were utilized. The primary raw materials included Bereczki variety quince fruits (*Cydonia oblonga*), which were locally sourced and selected for their desirable sensory characteristics and processing suitability.

Sea buckthorn (*Hippophae rhamnoides*) powder was prepared in the laboratory from industrially processed sea buckthorn pomace, which was dried at 50°C and finely milled (in a coffee bean miller BCG111; KitchenAid, US) to a particle size of 150 µm, ensuring uniformity and seamless integration into the final formulation. This approach was undertaken with the goal of promoting sustainability and enhancing the biological value of the developed product.

The auxiliary materials included agar-agar, a natural gelling agent sourced from the commercial market, chosen for its excellent gel-forming properties and suitability for craft jelly candy production, with a gel strength of 900 g/cm³. Furthermore, commercially available honey was incorporated solely as a sweetener.

Candy manufacture

The production of jelly candies at the laboratory scale involved a series of steps to ensure the preservation of bioactive compounds and a uniform texture achievement. The quince fruits were first washed and finely sliced to a thickness of 3 mm to ensure consistent texture. To minimize browning during thermal processing, the sliced quince was subjected to sous vide boiling, which also helped preserve bioactive compounds and enhance uniformity. After boiling, the quince slices were removed from the vacuum pouches and homogenized using an immersion blender (KHB1231, KitchenAid, US) to obtain a creamy and homogeneous puree.

Candy formulations were developed with sea buckthorn powder concentrations ranging from 0.5% to 7%. However, preliminary trials indicated that formulations containing less than 1% sea buckthorn powder did not significantly differ from the control sample (prepared solely with quince puree), while those with concentrations above 4% were too sour, necessitating a higher honey content, which contradicts current trends aimed at reducing sugar consumption. Based on these findings, sea buckthorn powder was incorporated at levels of 1%, 2%, 3% and 4% of the total ingredients mass. To maintain the desired consistency, incorporating sea buckthorn powder required reducing the quince puree proportionally. However, due to the high water retention capacity of sea buckthorn powder, the reduction in quince puree mass exceeded the amount of added powder. Since sea buckthorn powder is rich in fibers with a high water retention capacity, an increased amount of water was introduced to the formulation by reducing the quince puree proportion, ensuring the final product maintained the intended texture and consistency.

The agar-agar concentration was optimized at 3.5%, following preliminary trials that confirmed its effectiveness in achieving the desired gel structure. Lower concentrations were tested but did not yield satisfactory results, thus a uniform concentration of 3.5% was used across all formulations.

Honey was proportionally added to the formulations containing sea buckthorn powder to mitigate the tartness of the final product. Candy formulations are presented in table 1.

Table 1. Craft jelly candies formulations made from quince (*Cydonia oblonga*) and sea buckthorn (*Hippophae rhamnoides*).

Raw materials	Craft jelly candies samples				
	QSb0%	QSb1%	QSb2%	QSb3%	QSb4%
Quince puree, g	72.0	68.0	64.0	60.0	56.0
Sea buckthorn pomace powder, g	0.0	1.0	2.0	3.0	4.0
Honey, g	0.0	1.5	3.0	4.5	6.0
Agar-agar, g	3.5	3.5	3.5	3.5	3.5
Water, ml	24.5	26.0	27.5	29.0	30.5
Total, g	100.0	100.0	100.0	100.0	100.0

QSb0% - quince candies without sea buckthorn powder (control sample), QSb1% - quince candies with 1% sea buckthorn powder, QSb2% - quince candies with 2% sea buckthorn powder, QSb3% - quince candies with 3% sea buckthorn powder, QSb4% - quince candies with 4% sea buckthorn powder.

The preparation process began with the separate dissolution of agar-agar in water, which was heated to approximately 90°C. It was crucial to maintain the agar-agar solution at an initial temperature of 80-90°C to ensure proper gelation. The quince puree was blended with the sea buckthorn powder, and the agar-agar solution was incorporated. The resulting mixture was thermally processed for 120 seconds at 80°C

to achieve uniformity. The mixture was then poured into silicone molds and maintained at 20°C for 24 hours to allow the formation of the gel matrix and complete setting. Thus, five candy samples were obtained: quince candies without sea buckthorn powder - QSb0%, quince candies with 1% sea buckthorn powder - QSb1%, quince candies with 2% sea buckthorn powder - QSb2%, quince candies with 3% sea buckthorn powder - QSb3%, quince candies with 4% sea buckthorn powder - QSb4%.

Proximate composition

Proximate composition analysis was conducted following standard methods described in AOAC (2006). Moisture content was determined using the oven-drying method at 105±2°C, where approximately 5 g of each sample were placed in specialized drying chambers and subjected to heating until a constant weight was achieved, indicating complete removal of water content.

Carbohydrate content was determined using the Schoorl method, as described by Kurnia *et al.* (2021), which involves acid hydrolysis followed by titration to quantify the sugar content.

Protein content was determined using the Kjeldahl method, involving the digestion of the sample in sulfuric acid, converting organic nitrogen into ammonium sulfate, followed by distillation and titration. The crude protein content was then calculated using a nitrogen-to-protein conversion factor of 6.25.

Lipid content was assessed using the Soxhlet extraction method, which involves the continuous extraction of fats using a solvent, followed by solvent evaporation and gravimetric analysis.

Total fiber content was determined using the enzymatic-gravimetric method, following the protocol described by Garbelotti *et al.* (2003), involving enzymatic digestion of the sample, followed by filtration and weighing of the residue.

Total mineral content was determined by incinerating the samples in a furnace at 600°C, following the standardized (ISO 749:1977, 1977) method, and subsequently weighing the remaining ash.

Water activity

Water activity (aw) was determined with a LabSwift-aw analyzer (Novasina AG, Switzerland), following ISO 18787:2017 standards. Samples were placed in a controlled chamber where equilibrium relative humidity was recorded.

Bioactive potential of the jelly candies

Vitamin C content was determined following the method described by Spínola *et al.* (2013). The iodometric method was used, based on the extraction of ascorbic acid with 2% HCl, followed by titration with potassium iodate in the presence of starch as an indicator.

The total polyphenol content was determined using the Folin-Ciocalteu method, in which polyphenols react with the Folin-Ciocalteu reagent, resulting in a color change measured spectroscopically at 765 nm (Sánchez-Rangel *et al.*, 2013), using a UV-VIS T80+ Spectrometer (PG Instruments Ltd). The extraction was performed using

50% ethanol with a sample-to-solvent ratio of 1:10 w/v. The mixture was incubated for 30 min under constant agitation at 30 °C. After extraction, the samples were centrifuged at 5000 rpm for 10 min, and the supernatant was collected for further analysis. Results were expressed as mg GAE/100 g.

The assessment of antioxidant activity was performed using the DPPH radical scavenging assay, where the reduction of the stable DPPH radical by antioxidants present in the sample leads to a decrease in absorbance, measured using a spectrophotometer (Sharma and Bhat, 2009), at a wavelength of 515 nm. A 0.1 mM DPPH solution was prepared in methanol and allowed to react with the sample in the dark for 30 minutes before measuring the absorbance. The percentage of DPPH radical scavenging activity was calculated using the equation:

$$\%inhibition = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (1)$$

where $A_{control}$ is the absorbance of the DPPH solution without the sample, and A_{sample} is the absorbance of the DPPH solution after reaction with the sample.

The hydrogen peroxide inhibition capacity was evaluated using a titrimetric substitution method, in which the analyte is transformed into a titratable chemical compound (Jananie *et al.*, 2011). One milliliter of the extract at different concentrations was mixed with 1 ml of 0.1 M H_2O_2 , 10 ml of 2 M H_2SO_4 , 100 μ l of 3% ammonium molybdate, and 7 ml of 1.8 M potassium iodide. The reaction mixture was titrated with sodium thiosulfate until the yellow coloration disappeared.

Color Determination

The color of the candies was assessed by CIELAB system using a Chroma Meter CR-410 Konika Minolta. The system evaluates the lightness parameter (L^*), which spans from 0 (representing black) to 100 (representing white), along with two chromatic coordinates: a^* (ranging from green to red) and b^* (extending from blue to yellow). Additionally, the total color difference (ΔE) and Browning Index (BI) were calculated to quantify color changes among samples. ΔE was determined using Equation (2), while BI was computed according to Equation (3), with the intermediate parameter x defined in Equation (4).

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2} \quad (2)$$

The subscripts 1 and 2 correspond to two different samples being compared.

$$BI = \frac{100 \times (x - 0.31)}{0.172} \quad (3)$$

$$x = \frac{(a + 1.75L)}{(5.645L + a - 3.012b)} \quad (4)$$

To ensure precision and reproducibility, measurements were conducted in triplicate following the ISO 7724-2 standard (Pathare *et al.*, 2013; Sikora *et al.*, 2021).

Texture Analysis

Texture properties were evaluated using a TA.XT2i Texture Analyser (Stable Micro Systems Ltd., UK) equipped with a P/4 cylindrical probe (4 mm diameter). The hardness parameter was measured by compressing the samples at a pre-test and post-test speed of 2.0 mm/s, a test speed of 1.0 mm/s, a trigger force of 0.05 N, and a penetration distance of 5.0 mm. Measurements were performed after 10 days of storage at 25°C to assess product firmness and elasticity (Bourne, 1982).

Sensory Evaluation

A sensory evaluation was conducted using a panel of 10 trained assessors (aged 18 to 50) under controlled laboratory conditions, after obtaining their informed consent prior to the initiation of the testing procedures. Each sample, weighing approximately 10 g, was presented in coded plastic cups and evaluated using a 9-point hedonic scale, ranging from "dislike extremely" to "like extremely." Water was provided to cleanse the palate between samples. Sensory evaluation procedures were conducted according to the guidelines established by Meilgaard *et al.* (1999).

Check-All-That-Apply (CATA)

A Check-All-That-Apply (CATA) analysis was carried out, in which panelists were provided with a predefined list of sensory attributes (Table 1) and asked to identify all characteristics they perceived in each sample. This approach enabled a thorough evaluation of the sensory profile of the candies. A total of 15 semi-trained panelists participated in the study, assessing the quince and sea buckthorn jelly candy samples based on a set of descriptive attributes. The least frequently selected attributes that did not show statistically significant differences among samples were excluded through Cochran's Q test to ensure the accuracy and relevance of the final data.

Table 2. CATA analysis terms.

Product attribute	CATA terms
Color and appearance	Golden yellow, amber, light brown, translucent, uniform, uneven, glossy, dull, dark spots, discoloration
Texture	Smooth, sticky, firm, elastic, soft, gummy, chewy, cohesive, grainy, brittle, sandy, rubbery, tough
Aroma	Fruity, floral, citrusy, tangy, earthy, fermented, herbal, rancid, off-putting
Taste	Sweet, sour, tart, mildly bitter, fruity, honey-like taste, refreshing, astringent, too sweet, overly sour, bland

Following the evaluation of the candy samples, attributes that were selected infrequently and did not show significant statistical differences among the samples were excluded using Cochran's Q test. This approach was implemented to enhance the accuracy and reliability of the data.

Statistical analysis

All experiments were conducted in triplicate, and the results were expressed as the mean $\pm$ standard deviation (SD). Statistical analysis was carried out using ANOVA single factor followed by Tukey's post-hoc test, with a significance level of $\alpha = 0.05$. The Check-All-That-Apply (CATA) analysis was performed utilizing XLStat software, version 7.5.2, within the Excel environment.

Results and discussion

Proximate composition

The proximate composition analysis of quince-sea buckthorn jelly candies (Table 3) revealed notable nutritional changes with increasing sea buckthorn powder concentration. The dry matter content rose to 29.72%, reflecting the low moisture of sea buckthorn (93.18%), though still lower than fruit-based jelly candies enriched with strawberry and beetroot pulp (Ali *et al.*, 2021).

Table 3. Proximate composition of raw materials and quince-sea buckthorn craft jelly candies samples.

Samples	Moisture, %	Carbohydrate, %	Proteins, %	Fat, %	Fiber, %	Minerals, %
Quince puree	80.63 $\pm$ 0.18 ^a	10.03 $\pm$ 0.04 ^e	0.42 $\pm$ 0.02 ^f	1.34 $\pm$ 0.05 ^d	6.14 $\pm$ 0.12 ^f	0.35 $\pm$ 0.01 ^{bc}
Sea buckthorn powder	6.82 $\pm$ 0.09 ^e	2.81 $\pm$ 0.03 ^f	13.4 $\pm$ 0.11 ^a	31.43 $\pm$ 0.16 ^a	9.97 $\pm$ 0.14 ^a	2.03 $\pm$ 0.03 ^a
QSb0%	75.05 $\pm$ 0.25 ^b	9.81 $\pm$ 0.06 ^e	0.32 $\pm$ 0.01 ^g	0.87 $\pm$ 0.01 ^f	7.19 $\pm$ 0.09 ^b	0.29 $\pm$ 0.01 ^c
QSb1%	73.77 $\pm$ 0.34 ^{bc}	10.68 $\pm$ 0.08 ^d	0.48 $\pm$ 0.02 ^e	0.97 $\pm$ 0.04 ^e	7.04 $\pm$ 0.07 ^c	0.31 $\pm$ 0.04 ^c
QSb2%	72.53 $\pm$ 0.26 ^{bc}	11.54 $\pm$ 0.05 ^c	0.56 $\pm$ 0.03 ^d	1.39 $\pm$ 0.06 ^d	6.90 $\pm$ 0.05 ^{cd}	0.35 $\pm$ 0.02 ^{bc}
QSb3%	71.49 $\pm$ 0.15 ^c	12.4 $\pm$ 0.07 ^b	0.62 $\pm$ 0.02 ^c	1.53 $\pm$ 0.05 ^c	6.75 $\pm$ 0.07 ^c	0.38 $\pm$ 0.05 ^b
QSb4%	70.31 $\pm$ 0.23 ^d	13.25 $\pm$ 0.11 ^a	0.68 $\pm$ 0.01 ^b	1.70 $\pm$ 0.02 ^b	6.61 $\pm$ 0.21 ^e	0.41 $\pm$ 0.03 ^b

Results are presented as mean $\pm$ standard deviation of three independent measurements; in each column different letters a-g assigned to mean values indicate significant differences between samples ($P < 0.05$). QSb0% - quince candies without sea buckthorn powder (control sample), QSb1% - quince candies with 1% sea buckthorn powder, QSb2% - quince candies with 2% sea buckthorn powder, QSb3% - quince candies with 3% sea buckthorn powder, QSb4% - quince candies with 4% sea buckthorn powder.

Addition of sea buckthorn powder determined an increase in carbohydrate content up to 13.25%, aligning with quince's natural sugar content (10.03%) but slightly lower than values reported by Rasheed *et al.* (2018) (13.38%) and Ľorbová *et al.* (2024) (15.3%), likely due to fruit variety differences and peel inclusion. Protein levels also improved, reaching 0.68%, though remaining moderate compared to

passion fruit jelly candies (2.20%) (Urooj, 2021). Sea buckthorn powder, rich in protein (13.4%), contributed to this increase, in line with findings by Dienaitė *et al.* (2020) (16.74%).

The decrease in fiber content from 7.19% in QSb0% to 6.61% in QSb4% can be attributed to the proportional reduction in quince puree, which was necessary to incorporate sea buckthorn pomace powder. Although sea buckthorn pomace is naturally rich in fiber (9.97%), its addition required adjusting the formulation by increasing the amount of honey and water. This dilution effect further contributed to the overall reduction in fiber content. Similar findings were reported by Nour *et al.* (2021), who highlighted that dried sea buckthorn pomace contained 19.86% fiber and had a strong moisture retention capacity, which may influence fiber measurements in hydrated food matrices.

Although the differences in nutritional values between formulations were not substantial, the incorporation of sea buckthorn powder was primarily aimed at enhancing the biologically active potential of the final product, contributing to sustainability through the valorization of secondary by-products. Moreover, this formulation promotes the use of local, underutilized fruits such as quince, which has been described as a "forgotten fruit" (Norbová *et al.*, 2024). These aspects align with current trends in food science emphasizing the development of functional foods while reducing food waste and encouraging the utilization of regional plant resources. While the overall nutritional improvements were moderate, the unexpectedly high fiber content highlights sea buckthorn's potential as a functional ingredient in confectionery applications.

Bioactive potential of the jelly candies

The evaluation of biologically active compounds in quince-sea buckthorn jelly candies, presented in Table 4, highlights variations in ascorbic acid content, total polyphenols, and antioxidant activity across different formulations.

The incorporation of sea buckthorn powder aimed to enhance the functional properties of the candies due to its naturally high levels of bioactive compounds. The ascorbic acid content varied notably between quince puree (8.91 mg/100g) and sea buckthorn powder (25.95 mg/100g), with final formulations exhibiting a decreasing trend, reaching 5.24 mg/100g in QSb4%. This decline is likely attributed to the heat sensitivity of ascorbic acid, which degrades during thermal processing. The sous vide treatment applied to quince puree likely contributed to its lower vitamin C content compared to previously reported values for fresh quince (13 mg/100g) (Norbová *et al.*, 2024; Rather *et al.*, 2023). Additionally, quince ascorbic acid concentrations can vary significantly based on genotype, with Rop *et al.* (2011) reporting values between 41.12–79.15 mg/100g. In sea buckthorn pomace, Stanciu *et al.* (2022) found ascorbic acid levels between 28.43–48.34 mg/100g in fresh samples, decreasing to 25.49–27.49 mg/100g after drying, which aligns with the observed values in this study.

Table 4. Bioactive potential of raw material and quince-sea buckthorn craft jelly candies in terms of Ascorbic Acid, Total Phenols content and Antioxidant activity, %.

Samples	Ascorbic Acid, mg/100 g	Total Phenols, mg GAE/100 g	DPPH antioxidant activity, %	H ₂ O ₂ scavenging activity, %
Quince puree	8.91 ± 0.01 ^{bc}	920.07 ± 13.01 ^d	82.90 ± 0.92 ^a	28.24 ± 0.05 ^d
Sea buckthorn powder	25.95 ± 0.04 ^d	2618.02 ± 11.32 ^e	92.45 ± 1.11 ^c	48.83 ± 0.09 ^e
QSb0%	7.03 ± 0.08 ^b	633.28 ± 5.37 ^c	84.02 ± 0.63 ^b	22.96 ± 0.05 ^a
QSb1%	9.21 ± 0.02 ^c	624.21 ± 6.01 ^b	85.32 ± 0.42 ^b	23.98 ± 0.06 ^b
QSb2%	5.67 ± 0.04 ^a	615.56 ± 6.42 ^{ab}	88.56 ± 0.72 ^{bc}	25.78 ± 0.03 ^c
QSb3%	5.43 ± 0.01 ^a	600.54 ± 5.98 ^a	91.54 ± 0.22 ^c	26.22 ± 0.08 ^{cd}
QSb4%	5.24 ± 0.05 ^a	597.21 ± 8.32 ^a	91.71 ± 1.01 ^c	26.67 ± 0.08 ^{cd}

Results are presented as mean ± standard deviation of three independent measurements; in each column different letters a-g assigned to mean values indicate significant differences between samples ($P < 0.05$). QSb0% - quince candies without sea buckthorn powder (control sample), QSb1% - quince candies with 1% sea buckthorn powder, QSb2% - quince candies with 2% sea buckthorn powder, QSb3% - quince candies with 3% sea buckthorn powder, QSb4% - quince candies with 4% sea buckthorn powder.

The polyphenol content in the formulated candies showed a slight decrease, from 633 in the quince puree candies to 597 mg GAE/100g in QSb4%. Despite the high levels in quince puree (920.07 mg GAE/100g) and sea buckthorn powder (2618.02 mg GAE/100g), the expected increase in the final products was not observed. This suggests possible interactions between polyphenols and the formulation matrix, affecting their extractability or leading to polymerization. Wojdyło *et al.* (2013) reported quince polyphenol levels varying by genotype, emphasizing the impact of cultivar selection and processing on polyphenol retention.

The antioxidant activity, assessed through DPPH radical scavenging and H₂O₂ scavenging assays, demonstrated relatively high stability across formulations. The DPPH scavenging activity ranged from 82.90 in quince puree to 91.71% in QSb4%, indicating that processing did not significantly compromise antioxidant potential. Mir *et al.* (2016) reported comparable values in quince jam (83.56%), dehydrated quince slices (82.61%), and quince-based candy (79.91%). Manzocco *et al.* (2001) supports this by explaining that thermal processing may enhance antioxidant activity by releasing bound phenolics or generating Maillard reaction products. However, the relatively low processing temperatures used in this study suggest that non-enzymatic browning products played a minor role.

The H₂O₂ scavenging activity varied considerably among the samples, with sea buckthorn powder exhibiting the highest potential (48.83%), while quince puree demonstrated lower activity. The formulated candies displayed intermediate values, reflecting a balance between the antioxidant contributions of both ingredients. These

results align with Mir *et al.*, 2016. Given the well-documented antioxidant properties of sea buckthorn pomace (Kant *et al.*, 2012; Varshneya *et al.*, 2012), its incorporation in the candy formulation likely helped maintain radical-scavenging activity despite potential processing-induced losses. Further optimization of processing conditions could enhance the preservation and functionality of these bioactive compounds in the final product.

Physicochemical and textural properties

The incorporation of sea buckthorn powder into quince-based jelly candies introduces structural and compositional modifications, which may alter firmness, cohesiveness, and water retention capacity. Additionally, acidity levels are expected to vary due to the naturally high organic acid content of sea buckthorn, which can impact flavor perception and pH stability. Water activity, a key factor in microbial growth and texture, is also influenced by the hydrophilic nature of the ingredients, particularly the fiber content from sea buckthorn pomace.

To evaluate these aspects, the textural parameters, titratable acidity, and water activity of the formulated candies were analyzed and compared (Table 5).

Table 5. Physicochemical and textural properties of quince-sea buckthorn craft jelly candies.

Samples		QSb0%	QSb1%	QSb2%	QSb3%	QSb4%
Texture properties	Hardness, g	373.97±1.19 ^a	423.99±0.88 ^b	461.42±1.53 ^b	496.60±1.45 ^c	502.60±1.87 ^c
	Adhesiveness, (g s ⁻¹)	135.40±0.20 ^a	186.33±0.18 ^b	189.45±0.20 ^c	189.49±0.30 ^c	189.68±0.24 ^c
	Cohesiveness, %	3.49±0.03 ^d	3.11±0.06 ^c	2.82±0.08 ^b	2.66±0.11 ^{ab}	2.39±0.09 ^a
	Elasticity	3.00±0.04 ^b	2.54±0.03 ^a	2.51±0.06 ^a	2.53±0.08 ^a	2.56±0.04 ^a
	Chewiness, g	145.66±0.28 ^a	159.80±0.39 ^b	179.61±0.34 ^c	180.59±0.45 ^c	180.87±0.25 ^c
Water activity		0.513±0.003 ^a	0.518±0.001 ^a	0.540±0.001 ^b	0.532±0.003 ^{bc}	0.532±0.002 ^{bc}
Acidity, °		3.26±0.04 ^a	3.77±0.02 ^a	4.89±0.04 ^a	4.96±0.02 ^a	5.18±0.03 ^c

Results are presented as mean ± standard deviation of three independent measurements; in each row, different letters a-g assigned to mean values indicate significant differences between samples ($P < 0.05$). QSb0% - quince candies without sea buckthorn powder (control sample), QSb1% - quince candies with 1% sea buckthorn powder, QSb2% - quince candies with 2% sea buckthorn powder, QSb3% - quince candies with 3% sea buckthorn powder, QSb4% - quince candies with 4% sea buckthorn powder.

The results provide insights into how the progressive addition of sea buckthorn powder affects the structural and physicochemical profile of the final product. The incorporation of sea buckthorn powder resulted in a significant increase in hardness, from 373.97 g in the control sample (QSb0%) to 502.60 g in the highest formulation (QSb4%). This enhancement in firmness can be attributed to the high dietary fiber content of sea buckthorn powder, which contributes to a denser gel matrix. Gorjanović *et al.* (2024), who observed that the addition of apple pomace flour to jelly candies increased hardness due to the fiber's water-binding capacity, reported

similar findings. Adhesiveness initially increased up to the QSb2% formulation, after which it plateaued. This trend may result from the balance between the hydrophilic nature of the added fiber and the gel network's structural integrity. Adhesiveness initially increased up to the QSb2% formulation, after which it plateaued, indicating a possible balance between the hydrophilic nature of the added fiber and the structural integrity of the gel network. Studies on berry and herb-based jelly gums indicate that fiber-rich ingredients impact adhesiveness, depending on ingredient composition and gel formation (Guiné *et al.*, 2020). Similarly, cohesiveness and elasticity exhibited a decreasing trend with increasing sea buckthorn powder concentration, suggesting that an excessive fiber load may disrupt the gel matrix and weaken internal bonding forces. These findings align with studies on fruit-based jelly gums, where cohesiveness was found to vary significantly between formulations, with higher fiber content leading to reduced gel integrity (Guiné *et al.*, 2020). The reduction in elasticity observed in this study further supports the idea that fiber interactions may interfere with the natural resilience of the gel structure. For instance, a study on pectin gels enriched with dietary fiber found that fiber addition decreased the viscoelastic properties of the gels, indicating a reduction in their elastic behavior (Figueroa *et al.*, 2018). The structural modifications observed highlight the role of fiber incorporation in altering the mechanical properties of soft confections, reinforcing the need for optimization to balance texture and sensory properties. The chewiness of the candies increased with the addition of sea buckthorn powder, reaching a peak in the QSb3% formulation, indicating that moderate levels of fiber incorporation can enhance the textural complexity of the candies, a desirable trait in confectionery products.

The water activity values showed a slight increase from 0.513 in the control to 0.532 in the QSb4% sample. This increment is likely due to the hydrophilic nature of dietary fibers in sea buckthorn powder, which retain water within the gel matrix. Maintaining water activity below 0.6 is essential for inhibiting microbial growth, and all formulations in this study remained within safe limits. Titratable acidity increased from 3.26 degrees in the control to 5.18 degrees in the QSb4% sample, reflecting the intrinsic organic acids present in sea buckthorn. Elevated acidity can enhance flavor profiles by imparting a tangy taste, which may balance the sweetness of the candies. However, it is essential to monitor acidity levels to ensure they remain within acceptable sensory thresholds.

The color parameters of quince-sea buckthorn jelly candies provide valuable insights into the impact of sea buckthorn powder incorporation on the visual characteristics of the final product. Color is a key sensory attribute that influences consumer perception and acceptance, particularly in fruit-based confectionery. The lightness (L^*), chromatic components (a^* and b^*), total color difference (ΔE), and browning index (BI) were analyzed to evaluate the color variations between formulations. Given that fruit-derived ingredients are rich in pigments such as carotenoids and flavonoids, their incorporation into a gel matrix can lead to significant changes in colorimetric properties (Table 6).

Table 6. Colour parameters of craft quince-sea buckthorn craft jelly candies samples

Samples	L^*	a^*	b^*	ΔE	BI
QSb0%	53.33 ± 0.63 ^e	6.73 ± 0.11 ^b	20.44 ± 0.18 ^a	-	56.03 ± 0.28 ^a
QSb1%	48.52 ± 0.29 ^d	6.33 ± 0.09 ^a	21.84 ± 0.21 ^b	5.02 ± 0.07 ^a	67.13 ± 0.35 ^b
QSb2%	45.03 ± 0.34 ^c	6.66 ± 0.15 ^b	22.91 ± 0.14 ^c	8.66 ± 0.09 ^b	78.75 ± 0.46 ^c
QSb3%	42.24 ± 0.47 ^b	6.38 ± 0.06 ^a	22.40 ± 0.11 ^c	11.26 ± 0.18 ^c	83.00 ± 0.87 ^d
QSb4%	40.38 ± 0.22 ^a	6.48 ± 0.08 ^a	22.58 ± 0.17 ^c	13.12 ± 0.14 ^d	89.28 ± 0.44 ^e

Results are presented as mean ± standard deviation of three independent measurements. In each column, different letters a-g assigned to mean values indicate significant differences between samples ($P < 0.05$). QSb0% - quince candies without sea buckthorn powder (control sample), QSb1% - quince candies with 1% sea buckthorn powder, QSb2% - quince candies with 2% sea buckthorn powder, QSb3% - quince candies with 3% sea buckthorn powder, QSb4% - quince candies with 4% sea buckthorn powder.

The incorporation of sea buckthorn powder into quince-based jelly candies resulted in notable changes in color parameters. The L^* values, representing lightness, decreased progressively with increasing concentrations of sea buckthorn powder, indicating a darkening effect. This trend suggests that the high levels of carotenoids and polyphenols in sea buckthorn powder influence the lightness of the final product. Similar findings were reported by Ali *et al.* (2021) in fruit-based jelly candies, where the addition of berry pomace led to a noticeable reduction in L^* due to the presence of anthocyanins and other phenolic compounds.

The a^* parameter, representing the red-green component, showed minimal variations between formulations, remaining within a narrow range (6.33–6.73). These values indicate a slight reddish hue, likely attributed to the presence of polyphenols in quince and sea buckthorn. Studies on natural fruit colorants in confectionery suggest that a^* values in fruit-based gels can be influenced by pigment stability, oxidation, and pH fluctuations (Cano-Lamadrid *et al.*, 2020).

The yellowness (b^*) increased with sea buckthorn powder addition, peaking at QSb2% (22.91) and slightly stabilizing in higher formulations. This enhancement in yellowness aligns with previous studies on fruit-based gels, where carotenoid-rich ingredients contributed significantly to b^* values. The presence of sea buckthorn, a known source of yellow-orange carotenoids, likely played an essential role in this outcome.

The total color difference (ΔE) increased with the incorporation of sea buckthorn powder, confirming a perceptible visual distinction between formulations. The highest value (13.12) in QSb4% suggests a marked deviation from the control sample. According to the literature, ΔE values above 3 are noticeable to the human eye, and values exceeding 10 indicate significant color differences. This suggests that the presence of sea buckthorn powder strongly modified the color profile of the candies.

The browning index (BI), an indicator of non-enzymatic browning reactions, increased substantially with the addition of sea buckthorn powder, reaching 89.28 in

QSb4%. This increase may be attributed to polyphenol oxidation. Cedeño-Pinos *et al.* (2023) observed a similar trend in sage (*Salvia lavandulifolia* Vahl) by-product extracts jellies, where increased browning correlated with higher polyphenol content.

Overall, the incorporation of sea buckthorn powder significantly influenced the color parameters of the quince-based candies, primarily due to its rich polyphenol content. While the darkening effect and increased browning index may impact consumer perception, the enhanced b^* values suggest a visually appealing yellow hue, which is desirable in fruit-based confectionery. The findings align with previous research on natural fruit pigments (Popovici *et al.*, 2019), reinforcing the importance of optimizing ingredient concentrations to achieve the desired balance of color, stability, and consumer appeal.

Sensory Analysis

A sensory evaluation using the Check-All-That-Apply (CATA) method was performed to analyze the sensory attributes and consumer acceptability of quince-sea buckthorn jelly candies. This approach allowed for a detailed assessment of how different concentrations of sea buckthorn powder influenced the sensory profile. Based on Cochran's Q test, the characteristics that do not statistically separate the samples were filtered away to obtain more accurate findings. As a result, the analysis only includes the 20 key attributes that were predominantly utilized by panelists out of the initial 44 CATA terms.

The Check-All-That-Apply (CATA) analysis provided an in-depth sensory profile of the developed jelly candy samples, offering valuable insights into their sensory attributes. The symmetric plot (Figure 1) illustrates the distribution of sensory attributes and product formulations along the first two principal components, which together account for 97.88% of the total variance (F1: 89.98%, F2: 7.90%). This high percentage indicates that the two-dimensional representation adequately captures the variation in sensory characteristics among the samples.

The analysis reveals a clear differentiation between the candy formulations based on the level of sea buckthorn powder incorporation. The control sample, QSb0%, positioned in the positive F1 quadrant, is primarily associated with "sweet" and "amber" attributes, indicating that the absence of sea buckthorn powder results in a predominantly sweet taste and desirable golden hue. Formulations QSb1% and QSb2%, containing 1% and 2% sea buckthorn powder respectively, are closely linked to positive textural and taste attributes such as "smooth," "glossy," "soft," "uniform," and "honey-like taste." These findings suggest that moderate levels of sea buckthorn powder contribute positively to the texture and sweetness balance, maintaining a pleasant sensory profile without introducing undesirable characteristics. QSb3%, associated with attributes such as "fruity," "cohesive," and "tart," appears to balance the fruity notes characteristic of sea buckthorn while maintaining textural cohesiveness. However, its position further from the sweet-associated cluster indicates a noticeable reduction in perceived sweetness, aligning with expectations due to the tartness introduced by sea buckthorn. The QSb4% formulation is strongly associated with negative attributes, including "sour," "overly

sour," "rubbery," "tough," and "light brown." This confirms that higher concentrations of sea buckthorn powder introduce excessive tartness and undesirable textural experiences, likely due to the high fiber content and acidity of the ingredient. The need for increased honey content to counteract these effects contradicts the objective of sugar reduction in the formulations.

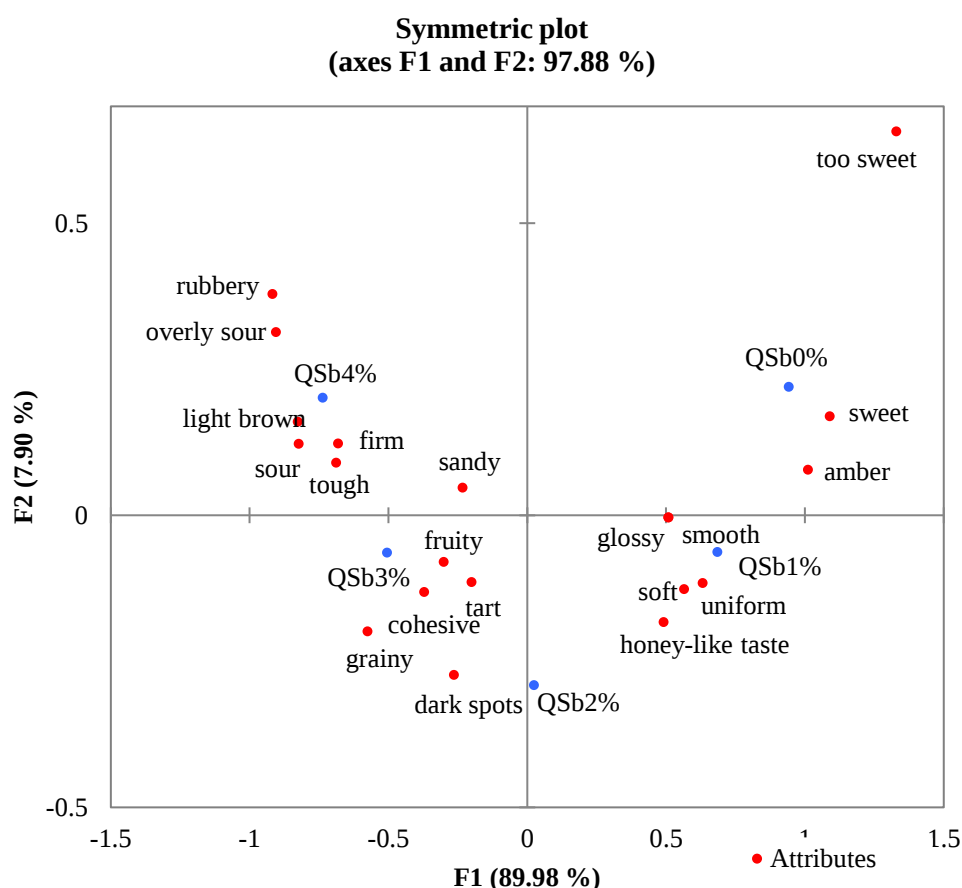


Figure 1. Visualized results of the check-all-that-apply (CATA) analysis of quince-sea buckthorn craft jelly candies samples.

QSb0% - quince candies without sea buckthorn powder (control sample), QSb1% - quince candies with 1% sea buckthorn powder, QSb2% - quince candies with 2% sea buckthorn powder, QSb3% - quince candies with 3% sea buckthorn powder, QSb4% - quince candies with 4% sea buckthorn powder.

Regarding texture and appearance, higher sea buckthorn powder levels (QSb3% and QSb4%) exhibit undesirable textural properties such as "grainy," "sandy," and "firm," attributed to the high fiber and water-binding capacity of sea buckthorn powder. In contrast, the lower concentration formulations (QSb1% and QSb2%) demonstrate more favorable texture attributes like "smooth" and "cohesive,"

indicating an optimal balance between the quince puree and sea buckthorn powder. From a taste perspective, the control sample (QSb0%) and lower sea buckthorn formulations (QSb1%) are characterized by sweetness, while higher concentrations result in increased tartness and sourness. This aligns with the perception that sea buckthorn powder, rich in organic acids, imparts a pronounced sour taste that becomes dominant at higher inclusion levels.

Based on the results, QSb1% or QSb2% appear to be the optimal formulations, balancing sweetness and texture while maintaining a pleasant sensory profile. The excessive tartness and undesirable texture of QSb4% suggest that formulations with 4% sea buckthorn powder require additional modifications, such as texture-modifying agents or sweeteners, to improve consumer acceptability.

Conclusions

This study demonstrates that quince puree and sea buckthorn dried pomace are valuable ingredients for confectionery, enabling the production of functional jelly candies with enhanced antioxidant properties and reduced sugar content. Their incorporation improves the nutritional profile and supports sustainability. The results showed that polyphenol content in quince puree reached 920.07 mg GAE/100 g, significantly contributing to the antioxidant activity of the final product. Sea buckthorn pomace, rich in fiber (9.97%) and polyphenols improved the nutritional profile. The antioxidant capacity of the candies increased with the addition of sea buckthorn powder, with DPPH radical scavenging activity rising from 84.02% to 91.71% and hydrogen peroxide scavenging capacity improving from 22.96% to 26.67%. The results indicate that moderate sea buckthorn levels (1% and 2%) ensured optimal sweetness, texture, and bioactive potential, while higher concentrations (3% and 4%) resulted in excessive tartness and undesirable textural modifications. Sensory and instrumental evaluations confirmed that these formulations align with consumer preferences for healthier confectionery products. Additionally, color analysis demonstrated a total color difference (ΔE) increase from 5.02 to 13.12, reflecting noticeable visual changes. These findings highlight the significance of using polyphenol- and fiber-rich raw materials in confectionery production to obtain functional products with enhanced health benefits. The application of quince and sea buckthorn by-products contributes to sustainability, reduces food waste, and supports the development of innovative, health-enhancing confectionery.

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