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DEVELOPMENT AND EVALUATION OF FREE SUGAR JELLY MADE WITH LEAFY VEGETABLES AS A FUNCTIONAL FOOD

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ABSTRACT

Commercial jellies are infamous for their excessive sugar content and for offering no nutritional or functional benefits. Hence, this research is intended to produce sugar-free, healthy jellies utilizing leafy vegetables, including leek, Swiss chard, and celery juice. The findings demonstrated that these products were softer, less gummy, easier to chew, and had nearly the same range of springiness and cohesiveness compared with commercial ones. Also, they have an appealing green hue. Besides, these products are rich sources for manganese, magnesium, iron, zinc, potassium, and calcium, providing an average of 110, 72, 52, 30, 25, and 22.9% of the daily values (DV), respectively. They are also considered a moderate source of vitamins A, C, and B6, giving an average of 16.7, 10.36, and 8.8% DV. Moreover, they could cover up to 55% of the daily value required from dietary fibers. Conversely, they have a lower percentage of carbohydrates, energy density, and glycemic index than the commercial equivalent. Additionally, they showed a high amount of flavonoids (100–348 mg QE/100 g), total phenolic components (318–824 mg GAE/100 g), and significant antioxidant activity (112.91–255.43 mg TE/100 g). Therefore, these novel varieties of jellies provide a nutritious and multifunctional source to satisfy consumers' desire for value-added products.

1. Introduction

Malnutrition and weight growth are significant indicators of health issues in low- and middle-income countries, as highlighted by the World Health Organization (WHO, 2020). The influence of television commercials promoting unhealthy diets has made children more prone to making poor dietary choices. This, in turn, has led to an increase in obesity among children, which is associated with abnormal lipid profiles, poor glucose metabolism, and a higher risk of diabetes (Ibrahim et al., 2020). It is estimated that 300 million people will develop diabetes mellitus by 2025 (Animaw and Seyoum, 2017).

Jams and jellies are products containing sugar, sucrose syrup, or glucose with gelling agents, acids, aromas, and food colorants (Cano-Lamadrid et al., 2020). A high sugar content is a major health concern. Researchers are working on finding natural sugar substitutes that deliver sweetness without harmful effects. Stevia extract, a natural low calorie alternative from the *Stevia rebaudiana* plant, has been studied for its potential to help individuals with diabetes and obesity by positively regulating blood glucose levels (Gao et al., 2016). Using stevia as a substitute for sucrose in food products not only reduces the calorie content but also provides sweetness without the negative health effects of sugar, making it a suitable option for individuals looking to reduce their sugar intake. Moreover, the stable nature of stevia allows for a longer shelf life of the final product (Schiatti-Sisó et al., 2023).

Recent attempts have been made to make reduced or free sugar jelly, but in most cases, the texture of jelly made with gelatin or pectin was negatively affected (Riedel et al., 2015; Ben Rejeb et al., 2020). Agar agar, extracted from red algae, is a high-performance gelling agent. Its ability to produce clear, colorless, odorless, and natural gels without the support of other colloids has been exploited by the food industry as a stabilizer and gelling agent, as well as in the manufacturing of confectionery (Stephen and Phillips, 2006).

The growing public interest in healthy foods has led to the promotion of leafy vegetables, which offer essential nutrients like minerals, vitamins, dietary fibers, and phytochemicals. These vegetables can restore balance in diets, address malnutrition and chronic issues, and contribute to overall health (Ashok et al., 2020).

Among known leafy vegetables is the Chenopodiaceae plant family member Swiss chard (*Beta vulgaris* subsp. Cycla). Which is considered a rich source of vitamins like A and C as well as minerals like phosphorus (Gamba et al., 2020). Additionally, it is used as an anti-inflammatory, anti-cancer, hypoglycemic, and hematopoietic system stimulant (Gezginci-Oktayoglu et al., 2014; Zein et al., 2015).

Another valuable plant is celery (*Apium graveolens*), a biennial plant commonly referred to as karafs. It belongs to the Apiaceae family. Celery possesses antifungal, antihypertensive, hypolipidemic, hepatoprotective, and anticancer effects (Fazal and Singla, 2012). On the other hand, the leek (Allium porrum L.) displays a pronounced antioxidant and free radical scavenging activity owing to the presence of phenolic acids and flavonoids, especially rosmarinic acid and quercetin. The ethanolic extracts of *Allium porrum* L. showed favorable antimicrobial and anticancer activity when applied in vitro (Radovanovi et al., 2015).

Leafy vegetables are often sold in fresh form, and their products are rarely found in the market. This scarcity may be due to various reasons, such as their perishable nature, limited availability, and shelf life. Hence, this research investigates the possibility of utilizing leafy vegetables to create a sugar-free jelly product that will not only address the scarcity of such products in the market but also cater to the increasing demand for a healthier and more sustainable alternative to traditional jellies. The use of Agar-agar as a gelling agent and stevia for sweetness would make this jelly suitable for those with dietary restrictions or concerns about sugar intake. By studying the sensory, physicochemical, nutritional, and functional properties of these products, valuable insights can be gained to ensure their quality and appeal to consumers.

2. Materials and methods

2.1. Materials

The ingredients utilized were agar-agar powder (agar-agar food-grade powder, Foodchem, China) and Stevia powder (Mozn, Germany). Celery (*Apium graveolens*), leeks (*Allium porrum L.*), Swiss chard (*Beta vulgaris subsp. Cycla*) and peppermint (*Mentha piperita L.)* were purchased from the Egyptian market. All used vegetables were authenticated through the “Vegetable Crop Department, Faculty of Agriculture, Cairo University, Egypt”.

2.2. Preliminary formulation

Preliminary palatability tests were carried out to assess the potential of conjugation to improve the ratio of agar and the optimal flavor ratio. This combination comprises stevia (30, 60, and 90 mg/100 mL), lemon juice (1, 3, 5 mL/100 mL), and mint water extract (1, 2, 3 mL/100 mL) (results not disclosed). To accomplish the sensory attribute, the study used an acceptable blend of these additives combined with a variety of vegetable juices (10, 20, and 30%).

2.3. Development of vegetable jellies

For the production of vegetable juice, 500 g of each variety of vegetable plant (leaves and stem) was washed, sliced, and blended for 10 minutes in a typical home blender with 200 mL of distilled water. A muslin cloth filter was used to remove the final juice. At the same time, mint leaves were extracted at 10% in boiling water for 20 minutes and filtered.

Agar with a percent of 2% was prepared to be double concentrated as follows: the needed weight of the agar is dissolved in half of the required distilled water on a magnetic stirrer (60 ºC) till completely dissolved. The vials of jelly were prepared to contain the same volumes (50 mL) of agar solutions. Then, different concentrations of vegetable juice (0 as a control, 10, 20, and 30% mL/mL) with a 0.06 % stevia addition were achieved. At this point, mint extract was added at 2% mL/mL.

The volume of each type was diluted to 97 mL with water. After being pasteurized at 100°C for 1 minute, the jelly was quickly cooled to 40°C. 3% v/v of freshly prepared lemon juice was added at this point. Finally, the silicone molds were filled with jelly.

Table 1. Formulation of vegetable jelly

Percent of formulation (%)	Control	T1	T2	T3
Agar powder	2	2	2	2
Vegetable leaves juice	0	10	20	30
Stevia powder	0.06	0.06	0.06	0.06
Lemon juice	3	3	3	3
Mint extract	2	2	2	2
Water	92.94	82.94	72.94	62.94

After being completely solidified and refrigerated at 4°C for 30 minutes, the jelly beans were inverted and packaged in a plastic container. These jelly beans were examined for sensory and physical properties (Table 1, Figure 1). Other vials were created in jars that had been sanitized with hot water, cooled, and then had metal covers placed over them. For shelf life testing, these vials were kept in the refrigerator at 4 °C.

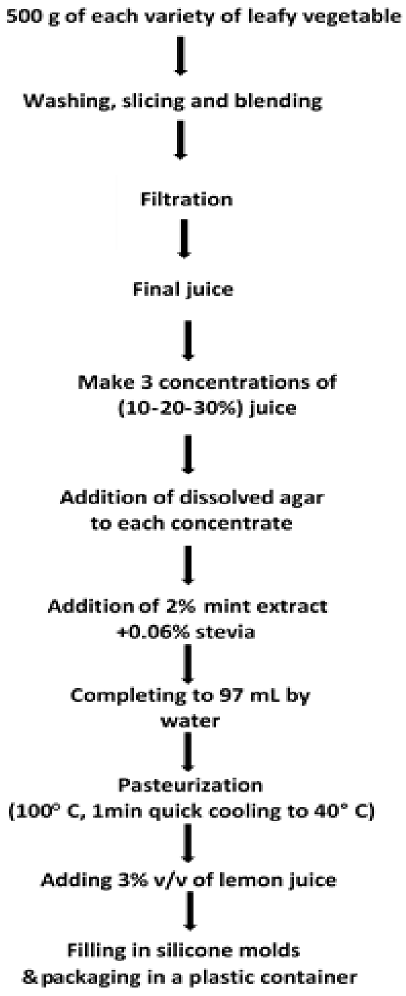

Figure 1. A Flowchart for the production of vegetable Jelly

2.4. Organoleptic evaluation of vegetable jelly

An organoleptic evaluation of nine varieties of vegetable jelly along with a control (free of vegetable juice) and a commercial jelly item was conducted. Each of the three treatment types on the panel had three different concentrations of vegetable juice. A panel of semi-trained judges performed the evaluation (including members of the Food Research Technology Institute, Egypt; 30 females and 20 males, n = 50; age: 25–60 years). The nine-point hedonic scale was used for character traits (Lawless and Heymann, 2010). All panel members were informed of the product constituents, and none of them reported any food allergies. And the sensory assessment was carried out following Regulation No. 1924/2006.

2.5. Physicochemical analysis

2.5.1. Color analysis

A homogenous sample was obtained by blending each jelly sample. Each sample received five measurements from the chromameter (CR-400, Konica Minolta) (Pathare et al., 2012). In the color system, the L-value denotes the degree of lightness, with 0 denoting complete darkness and 100 denoting complete lightness. The a and b values, meanwhile, measured the intensity of green versus red and yellow versus blue in the range of 0 to 100 and -100 to 0, respectively. Additionally, samples were examined using their chroma values ($C^* = (a^{*2} + b^{*2})^{1/2}$), which represent the intensity or color saturation, and hue angle, h (0-360°), calculated using $\tan^{-1} b^*/a^*$, and colour difference represent by delta E (ΔE) estimated using the formula:

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2} \qquad (1)$$

2.5.2 Analyses of Texture Profiles (TPA).

A TPA analysis of the jelly's consistency was performed after 24 hours of its production. The test was done at room temperature using a half-inch diameter acrylic cylinder probe and a TA.XT2 texture analyzer (Stable Micro System Ltd., Scarsdale, NY). Parameters were established as follows: a data acquisition rate of 200 pp, a trigger force of 5.0 g, a distance of 4.0 mm, a test speed of 1.0 mm/s, and a post-test speed of 1.0 mm/s. Using Texture Expert Version 1.22 Software (Stable Micro System Ltd., Scarsdale, NY), the data were examined to determine the jelly's firmness, cohesion, and springiness following the method of Bourne (1978).

The following formulas were used to determine other parameters:

A product's springiness refers to how much it physically recovers after being distorted during the initial pressure and may wait between the two strokes.

Springiness = Distance 2 traveled by the probe during the second compression cycle / Distance 2 traveled by the probe through the first compression cycle (Distance 1).

Gumminess is equal to the sum of hardness and cohesiveness. Whereas chewiness is the result of the sum of gumminess and springiness. Resilience is equal to the product of the upstroke energy (Area 4) and the downstroke energy of the initial compression (Area 3). For each item, this test was carried out in triplicate.

2.5.3. Soluble Solids Content (TSS)

The concentration of TSS in the jelly was determined using a tabletop Reichert-Jung ABBE MARK II refractometer (Cambridge Instruments, Buffalo, NY). About 1-2 droplets of chilled jelly were put into the instrument prism (Pilgrim et al. 1991). The shaded area was changed to represent the proportion of soluble solid material before the digital reading was obtained.

2.5.4. Water activity (WA)

WA readings were taken using an Aqua Laboratory (AQUALAB 4TE, Pullman, USA). Before being placed in the measurement chamber, jelly was partially poured into the sample plastic cups. At room temperature, WA values were immediately recorded from the digital display.

2.5.5. Syneresis

At room temperature, the jelly samples' syneresis was assessed after the end of their storage time (60 days). By turning the jelly jars upside down and letting the separated liquid drop into a 10-mL graduated cylinder, the amount of the separated liquid from the jelly was calculated (Khouryieh et al., 2005). The following equation was used to determine the syneresis percentage:

$$\%\ \text{Syneresis} = \text{Total weight of separated liquid (g)} / \text{Total weight of the jelly sample (g)} \times 100 \qquad (2)$$

2.5.6. pH-measurements

For evaluating acidity, a pH meter (Fisher Scientific in Pittsburgh, PA) was used. After blending 1 g of each product in 10 ml of distilled water, the pH level was monitored at ambient temperature.

2.6. The nutritional composition of vegetable jelly

2.6.1. The proximate composition analysis, energy content, and glycemic indicator.

Dry ashing, gravimetric, oven drying, soxhlet procedures, and The Kjeldahls (AOAC, 2000) were used to assess the composition of jelly products, including their, ash content, crude fibers, moisture content, fat content, and protein content after multiplying with 6.38. The difference calculation method was used to calculate the carbohydrates.

Each type of gummy jelly's energy output (kilocalories) was estimated by combining the contents of protein, carbohydrate, and fat after multiplying them by the relevant Atwater factors of 4, 4, and 9. The energy value was also multiplied by 4.184 to get the result in kilojoules. Additionally, the calculation methods recommended by Dodd et al. (2011) were used to construct the glycemic index of the meal.

$$\text{GI (product)} = \{(\text{GI}_{\text{component a}} \times \text{CHO}_{\text{Component a}}) + (\text{GI}_{\text{component b}} \times \text{CHO}_{\text{component b}}) + \ldots\ldots\}/\text{CHO}_{\text{Product}} \quad (3)$$

Whereas $\text{GI}_{\text{component a}}$ is the glycemic index of each component in the product, $\text{CHO}_{\text{component a}}$ is the available gram carbohydrate content contributed by the component a in the product, and $\text{CHO}_{\text{product}}$ is the total carbohydrates in grams of the product.

2.6.2. Estimation of minerals

The mineral quantification in jelly products was assessed using the atomic absorption spectroscopy method (AAS, Varian model) for both trace minerals (manganese (Mn), Zinc (Zn), iron (Fe), and copper (Cu)) and macro-minerals (calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na)).

2.6.3. Chromatographic determination of vitamins

Standard vitamins, including water-soluble ones (ascorbic acid-C, pyridoxine-B6, pantothenic acid-B5, nicotinamide-B3) and fat-soluble ones (vitamin A), were acquired from Sigma-Aldrich. The vitamins B3, B5, and B6 were extracted from samples according to Antakli et al. (2015). The HPLC 1200 series (Agilent Technologies, Germany) equipped with an autosampler, quaternary pump degasser, and column compartment C18 BDS (100 x 4.6 mm; 3 µm), a flow rate of 1.6 mL/min, a column temperature of 40°C, and the appropriate detection wavelength recorded at 270 nm at room temperature were used. The mobile phase's components were solvents (A): 5.84 mM of hexane-1-sulfonic acid sodium: acetonitrile (95:5,v/v) with 0.1% triethylamine at pH 2.5, and solvent (B): 5.84 mM of hexane-1-sulfonic acid sodium: acetonitrile (50:50, v/v) with 0.1% triethylamine at pH 2.5.

Whereas, a mobile phase (A/B 33/67; solvent A: 0.1 M potassium acetate, pH = 4.9; solvent B: acetonitrile: water [50: 50]) and a flow rate of 1 mL/min with a UV absorption of 254 nm at an ambient temperature were applied to measure vitamin C (Romeu-Nadal et al., 2006).

The saponification technique outlined by Dennison and Kirk (1977) was applied to calculate the vitamin A levels. A cooled autosampler at 4^{o}C and a heated column compartment at 30 ^{o}C are used in the delivery system, and a 330 nm variable wavelength detector was used. Water and methanol (5:95) flowing at a rate of 1 mL/min were used in the mobile phase. All vitamins were identified by comparing retention times to real standards.

2.7. Functional properties

2.7.1. Extraction of active compounds

Following the methodology of Cano-Lamadrid et al. (2020), phytochemical components were extracted from the jelly products. This method was used to prepare methanol extract: 1 gram of each jelly product was combined with 10 mL of an 80:20 mixture of MeOH and water, homogenized with 1% HCl, and then kept at 4°C for 24 hours (TSD-J 0.7 L, 50 W, 40 kHz) before being centrifuged at 15,000 g for 10 minutes (Sigma 3–18 K, Osterode and Harz, Germany). The recoverable supernatants were collected and stored at -20 °C in the dark pending analysis.

2.6.2. Total polyphenols content (TPC)

Using the technique developed by Singleton et al. (1999), the TPC in the previously collected supernatant was estimated. In a nutshell, 1.5 mL of distilled water, 0.1 mL of the Folin-Ciocalteu phenol reagent (1:1), and 0.1 mL of the sample or the standard dilutions (100–500 µg/mL) were combined. This was vortexed with 0.3 mL of a 20% Na2CO3 solution after homogenization for 5 minutes. After that, it was maintained at ambient temperature for 60 minutes without exposure to light. Finally, all solutions were measured at 740 nm in comparison to an acidified methanol blank using a Spectro 23 digital spectrophotometer (Labomed, Inc., Los Angeles, California, USA). The experiment was conducted three times. The findings were represented as mg gallic acid equivalents (GAE) per 100 g of dry weight, employing a standard curve of 25–2500 mg/L.

2.6.3. Total flavonoids content (TFC)

TFC was calculated using the colorimetric technique developed by Zhishen et al. (1999). 4 mL of dist. water was mixed with 1 mL of extract solution and dilutions of a standard solution (10–100 g/mL). The latter mixture was treated with 0.3 mL of 5% NaNO2. 0.3 mL of 10% $AlCl_3$ was added after 5 minutes. 2 mL of 1 M NaOH were further added after 6 minutes. Finally, dist. H_2O was then added to bring the total amount to 10 mL, and it was thoroughly mixed. At 510 nm, the absorbance of solutions was measured in comparison to a freshly prepared blank. Milligrams of quercetin equivalent per gram of dry matter (mg QE/g) were used to represent the TFC. Results were shown as the average of three replicates.

2.6.4. Antioxidant activity (AOX):

Vegetable jelly's antiradical activity was assessed using the technique outlined by Sánchez-Moreno et al. (1998). Thus, 3.9 mL of DPPH (1,1-diphenyl-2-picryl hydrazyl, 0.025/L methanol) was mixed with 0.1 mL of each extracted sample. Using a Vis spectrophotometer, absorbance was measured at 515 nm against a blank after stirring and storing in a dark place for 15 minutes. The percentage of inhibition for each sample served as a measure of the scavenging activity. Trolox, with a concentration range of 0.50 to 5.0 mM, was used as the standard. Calibration curves were used for the quantification of the antiradical activity, showing good linearity (R2 ≥ 0.998). The findings were presented in milligrams of Trolox equivalents (TE) per 100 g of gummy jelly (mg TE/100 g). The test was performed in triplicate.

2.6.4. Chromatographic analysis of the generated jelly's phenolic components

All standards have been acquired from Sigma-Aldrich (USA). The extract of the samples was first prepared for determining the phenolic compound profile of jelly via chromatography (Devi Ramaiya et al., 2013). 20 mL of 70% (v/v) HPLC-grade methanol was used to homogenize 2.5 g of the sample before it was maintained at room temperature in an ultrasonic bath for an hour to facilitate extraction. Each extract was centrifuged at 8.832 × g for 15 minutes at 4 °C and filtered through filter paper. Gradient elution with a mobile phase of a solvent A (2% acetic acid) and solvent B (0.5% acetic acid: acetonitrile (1:1)) was used to estimate phenolic chemicals. For flavonoids, a mobile phase of solvent A (2% acetic acid) and solvent B (methanol) was utilized to carry out gradient elution. The injection volume was 20 L, and the flow rate was 1 mL/min. At nm 220-365, UV absorption was measured. Phenolic compounds were identified and quantified by comparing them to a standard sample in terms of retention duration and peak area. The results were expressed as mg/100 g of vegetable jelly.

2.7. Microbiological analysis

The quality of the jelly products was assessed microbiologically along with free mint extract control on days 1, 15, 30, and 60. In 90 mL of peptone water, 10 grams of each jelly were diluted and homogenized using Stomacher® bags (Fisher Scientific, Pittsburgh, PA). For each sample, six further dilutions were made. Testing for total aerobic mesophilic bacteria (TBC) on aerobic count plates (3M

Petrifilm TM, 3M Microbiology Products, St. Paul, MN) was done after incubation at 35 °C for 48 hours. On days 3 and 5, the yeast and mold (Y&M) were counted using Y&M count plates (3M Petrifilm TM, 3M Microbiology Products, St. Paul, MN) after being kept at room temperature. Log CFU/g was used to express the counts (Salfinger and Tortorello, 2015).

2.8. Statistical analyses

The associated results were statistically assessed using SAS, the Statistical Analysis System (2017). Duncan's multiple range analysis was used to establish the significance of the discrepancy at $p < 0.05$. Different series of superscripts show the difference in significance (e.g., a, ab, b, etc.). Whereas the Pearson correlation coefficient was used to find the correlation between some variables.

3. Results and discussions

3.1. Nutritional composition of raw materials

Many individuals are interested in green, leafy vegetables because of their various health advantages. Nonetheless, children rarely eat vegetables, especially leafy ones. In the current study, the nutritional content of these vegetables was first investigated (Table 2).

Table 2. Proximate analysis of vegetable plants used through study.

Parameters (%)	Chard juice	Celery juice	Leek juice	Mint extract
Moisture	91.45 ± 0.48^{b}	93.51 ± 0.59^{a}	89.58 ± 1.52^{b}	93.53 ± 0.57^{a}
Fat	0.08 ± 0.044^{c}	$0.18 \pm 0.00d^{b}$	0.24 ± 0.00^{b}	0.55 ± 0.23^{a}
Protein	1.74 ± 0.07^{a}	0.69 ± 0.01^{c}	$1.08 + \pm 0.06^{b}$	2.01 ± 0.31^{a}
Carbohydrate	4.51 ± 0.47^{b}	4.83 ± 0.43^{b}	8.05 ± 0.23^{a}	8.03 ± 0.54^{a}
Ash	2.22 ± 0.07^{a}	0.79 ± 0.03^{c}	1.25 ± 0.12^{b}	1.91 ± 0.17^{a}
Fibre	2.7 ± 0.05^{a}	1.62 ± 0.16^{c}	1.8 ± 0.03^{b}	1.55 ± 0.07^{c}

Each value in the table was obtained by calculating the average of three experiments, and the data are presented as mean ± Standard error of the mean within the same row. Statistical significance was accepted at the $p < 0.05$ level. The superscript letters a, b, etc. denote the significance of one parameter between different vegetable types in the same raw.

Based on the proximate composition, chard substantially ($p<0.05$) had the highest protein, ash, and fiber levels and the lowest carbohydrate levels when compared to celery and leeks, which are within the range described by other authors (Gamba et al., 2020). The moisture content was the highest in celery juice (93.51%). In contrast, leek juice has the most carbohydrates (8.05 ± 0.04%), which is within the range reported by the USDA (2010) and higher than the 4.5% designated by Pak et al. (2014) (Table 2). These vegetables are recognized to be high in minerals and vitamins, as well as having a high antioxidant capacity (Fazal and Singla, 2012; Radovanovi et al., 2015; Gamba et al., 2020).

3.2. Sensory evaluation of vegetable jellies

The sensory investigation aimed to select suitable vegetable concentrations for jelly products with a suitable flavor. According to the primary investigation, the best flavors were stevia (0.06 g/100 mL), mint extract (2%), and lemon juice (3%). Stevia powder was carefully selected to prevent a bitter taste by adjusting the amount of stevia powder and lemon juice. Consequently, it was used in conjunction with all treatments. Afterwards, three concentrations of vegetable juice were made into jelly to accomplish the sensory attributes. The samples were compared to both an agar jelly sample without vegetable juice (the control) and a commercial sugar-added product.

Table 3. Sensory characteristics of three preparations of sugar-free vegetable jelly

Sample	Conc. (%)	Color	Appearance	Odour	Texture	Taste	Overall acceptability
Commercial jelly	-	8.81 ± 0.13^{A}	8.83 ± 0.12^{A}	8.01 ± 0.18^{C}	8.9 ± 0.36^{A}	8.5 ± 0.34^{A}	8.18 ± 0.35^{B}
Control	0	6.72 ± 0.18^{D}	6.18 ± 0.35^{F}	8.31 ± 0.36^{A}	8.71 ± 0.36^{A}	6.09 ± 0.34^{D}	6.18 ± 0.35^{D}
Chard jelly	10	8.5 ± 0.30^{Bc}	8.27 ± 0.35^{Db}	8.09 ± 0.34^{Cc}	8.61 ± 0.31^{Ba}	7.73 ± 0.45^{Bc}	8.12 ± 0.36^{Bb}
	20	8.73 ± 0.28^{Aa}	8.50 ± 0.29^{Ca}	8.36 ± 0.34^{Aa}	8.55 ± 0.32^{Ba}	8.23 ± 0.36^{Aa}	8.45 ± 0.34^{Aa}
	30	8.67 ± 0.33^{Bb}	8.55 ± 0.28^{Ca}	8.18 ± 0.44^{Bb}	8.27 ± 0.46^{Cb}	8.00 ± 0.42^{Ba}	7.91 ± 0.39^{Bc}
Celery jelly	10	7.2 ± 0.28^{Db}	8.64 ± 0.24^{Ba}	8.18 ± 0.31^{Bb}	$8.45\pm.312^{Ba}$	8.32 ± 0.29^{Aa}	8.09 ± 0.31^{Bb}
	20	8.22 ± 0.24^{Ca}	$8.73\pm.24^{Aa}$	8.40 ± 0.34^{Aa}	8.45 ± 0.25^{Ba}	8.45 ± 0.34^{Aa}	8.27 ± 0.33^{Aa}
	30	$8.32\pm.371^{Ca}$	8.14 ± 0.38^{Db}	8.44 ± 0.35^{Aa}	8.09 ± 0.39^{Db}	7.86 ± 0.38^{Ba}	7.95 ± 0.47^{Bb}
Leek jelly	10	8.19 ± 0.32^{Cc}	7.77 ± 0.29^{Eb}	7.59 ± 0.33^{Db}	8.49 ± 0.32^{Ba}	7.45 ± 0.43^{Cb}	7.73 ± 0.31^{Ca}
	20	$8.36\pm.39^{Cb}$	8.50 ± 0.31^{Ca}	7.95 ± 0.30^{Ca}	8.36 ± 0.39^{Ca}	8.00 ± 0.33^{Ba}	8.09 ± 0.37^{Ba}
	30	8.41 ± 0.31^{Ca}	7.55 ± 0.343^{Ea}	7.18 ± 0.40^{Dc}	8.21 ± 0.39^{Cb}	7.41 ± 0.43^{Cb}	7.55 ± 0.34^{Ca}

Control: jelly free of vegetable juice. Values are expressed as means ± standard deviations (A, B, C, etc.) donated the significant difference ($p<0.05$) between all treatments in the same column for one parameter, (a,b,c, etc.) donated the significant difference ($p < 0.05$) between different concentrations in the same treatment under the same parameter. Means sharing similar letters within a column are statistically nonsignificant ($p > 0.05$). Hedonic scale: 1, dislike extremely; 5, neither like nor dislike; 9, like extremely.

The sensory acceptability test revealed that 90% of panelists found green vegetable jellies suitable, moderately sweet, mildly sour, and fresh mint-flavored. They reported that the combination of lemon and mint gives the jelly a refreshing and zesty twist, balancing out the flavors of the vegetables. The findings showed that celery had the highest flavor rating, while chard jelly had the best color among other treatments (Table 3). The texture was acceptable for the three products as compared to the commercial product, but as the percentage of vegetable juice increased, it became less hard. The bright green color was appreciated as a healthy indication.

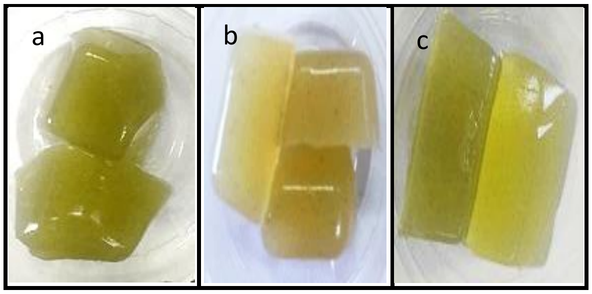

Figure 2. Vegetable jelly made from 20% of chard (a), celery (b), and leek (c) juice.

The optimal treatment was the 20% vegetable content (Figure 2), which scored higher in color, appearance, texture, flavor, taste, and overall acceptability.

3.3.Physicochemical properties of vegetable jelly

3.3.1. Texture profiles of vegetable jellies

Texture is a crucial factor in jelly production, and all produced jellies have acceptable firmness, hardness, and flexibility (Table 4). Nevertheless, commercial gelatine jelly registered the highest hardness, gumminess, and chewiness values with the lowest resilience. Increasing vegetable juice results in a less hard product, possibly due to limited free water availability (Kronberga et al., 2011). On the other hand, leafy vegetables also have soluble fibers that form a jell, boosting water retention and resulting in a stable, hard product (Chawla & Patil, 2010). Jelly with 20% vegetable juice seems to have a balanced state of stiffness. The present hardness measurements for vegetable jelly were closely in the range stated for orange jelly (4.77 N) (Teixeira-Lemos et al., 2021). Still, increasing vegetable juice lowers adhesiveness, gumminess, and chewiness while increasing resilience and cohesion values.

Table 4. Texture profile analysis of vegetable jelly

Types of jelly	Conc.	Hardness (N)	Adhesiveness (mj)	Springiness (mm)	Gumminess (N)	Chewiness (mj)	Resilience%	Cohesiveness
Commercial jelly		12.01±0.28^{a}	0.21±0.05^{e}	0.93±0.01^{Ab}	11.5±0.51^{Aa}	8.5±0.25^{Aa}	0.09±0.04^{Ae}	0.87±0.02^{Aa}
Control	0	7.74±0.23^{b}	0.33±0.03^{d}	0.92±0.04^{Aa}	6.88±0.11^{Ab}	5.26±0.14^{Ab}	0.11±0.01^{Ae}	0.89±0.01^{Aa}
Chard Jelly	10%	6.01±0.08^{Ac}	0.6±0.02^{Aa}	0.95±0.02^{Aa}	4.57±0.01^{Ac}	4.26±0.01^{Ac}	0.32±0.28^{Cc}	0.75±0.06^{Bc}
	20%	5.28±0.06^{Bd}	0.5±0.03^{Bb}	0.93±0.01^{Bb}	4.14±0.05^{Ac}	3.80±0.28^{Bd}	0.37±0.28^{Bc}	0.78±0.03^{Bc}
	30%	3.79±0.02^{Cf}	0.1±0.0^{Ce}	0.92±0.00^{Cb}	3.24±0.04^{Cd}	2.99±0.04^{Ce}	0.51±0.02^{Aa}	0.86±0.02^{Ab}
Celery Jelly	10%	4.49±0.03^{Ae}	0.4±0.02^{Ac}	0.93±0.03^{Ab}	3.99±0.04^{Ad}	3.78±0.08^{A}	0.44±0.01^{Cb}	0.88±0.04^{Aa}
	20%	3.85±0.05^{Bf}	0.2±0.05^{B}	0.90±0.02^{Bc}	3.38±0.03^{Bd}	3.04±0.05^{Be}	0.49±0.08^{Bb}	0.89±0.01^{Aa}
	30%	2.58±0.03^{Cg}	0.1±0.00^{Cc}	0.89±0.02^{Bc}	2.27±0.05^{Ce}	2.036±0.08^{Cf}	0.54±0.018^{Aa}	0.89±0.02^{Aa}
Leek jelly	10%	5.41±0.08^{Ad}	0.6±0.03^{Aa}	0.95±0.01^{Aa}	4.28±0.08^{Ac}	3.97±0.03^{Ac}	0.39±0.02^{Bb}	0.78±0.02^{Bc}
	20%	4.79±0.03^{Be}	0.5±0.01^{Ab}	0.92±0.01^{Bb}	4.07±0.06^{Bc}	3.74±0.03^{Bd}	0.41±0.02^{Bb}	0.85±0.03^{Ab}
	30%	4.14±0.02^{B}f	0.1±0.02^{Be}	0.92±0.02^{Bb}	3.52±0.08^{Bd}	3.23±0.02^{Ce}	0.45±0.02^{Ab}	0.85±0.02^{Ab}

Control: jelly free of vegetable juice; Values are expressed as means± standard deviations, (a,b,c etc.) for the significance difference (P 0.05) between all treatments in the same column for one parameter. (A, B, C, etc.) refers to the significant difference ($P < 0.05$) between different concentrations in the same treatment under the same parameter. Means sharing similar letters within a column are statistically nonsignificant ($p > 0.05$).

Consumer acceptance is influenced by cohesiveness, whose low value indicates ease of chewing and swallowing (Kawano et al., 2017). Although jelly candies have slightly different hardness values compared to commercial products, they still have nearly similar cohesiveness values and are still in the range of 0.54 to 0.82 described for jelly candies (Mutlu et al., 2018). Elasticity measures the speed at which a deformed sample returns to its original shape (Hamedi et al., 2018). As the product becomes harder, its elasticity decreases, resulting in lower spring values. Because the agar percentage is the same, the elasticity also remains consistent across products and was within the 0.90–1.50 range described for jelly candies (Khouryieh et al., 2005). Another elasticity parameter is resilience, which is the ability of a food to spring back into shape (Cruz et al., 2015). The results also showed that when hardness decreases, resilience also increases slightly.

Gumminess value represents the energy needed to reshape food into a swallowable form. Harder products have higher gumminess and chewiness (Mutlu et al., 2018). But Chewiness is more accurately attributed to gummy jelly (Delgado and Bañón 2015). According to the current findings, vegetable jellies have lower gumminess and chewiness values than commercial product. In conclusion, vegetable jellies with 20% vegetable juice were softer, less gummy, easier to chew, and had nearly the same range of springiness and cohesiveness compared with the commercial product

3.3.2. Color analysis

Vegetable jelly's color characteristics were expressed on a L*, a*, and b* scale (Table 5). Vegetable jelly had a negative (a*) value, signifying that it was greenish. It was noticed that T1 was the greenest in color, followed by T3 and T2 jelly.

Table 5. Colour parameters of vegetable jellies expressed in terms of the CIELab scale parameters:

Treatments		**Color parameters**					
		C*	**L***	**a***	**b***	**h**	**ΔE**
Control	**0**	40.49 ± 1.21^{d}	84.2±1.14a	0.5 ± 0.04^{d}	16 ± 1.55^{e}	40.05	0
Chard Jelly	**10%**	39.04 ± 1.04^{d}	56.6 ± 2.03^{c}	-9.02 ± 1.13^{c}	38.2 ± 1.03^{d}	46.01 ± 1.25^{b}	36.67 ± 0.03^{d}
	20%	65.34 ± 1.03^{b}	45.15 ± 1.53^{e}	-12.45 ± 1.03^{b}	$44.5b \pm 1.61^{b}$	48.4 ± 1.33^{b}	50.083 ± 0.04^{b}
	30%	89.99 ± 1.21^{a}	41.48 ± 2.03^{e}	-15.2 ± 1.11^{a}	46.89 ± 1.33^{a}	52.65 ± 1.23^{a}	55.03 ± 1.03^{a}
Celery Jelly	**10%**	30.04 ± 2.03^{e}	67 ± 1.06^{b}	-4.66 ± 1.08^{e}	25 ± 1.73^{e} f	43.84 ± 1.63^{e}	20.08 ± 0.03^{g}
	20%	38.81 ± 2.03^{d}	64.7 ± 1.23^{b}	-5.65 ± 1.05^{e}	29.12 ± 1.57^{e}	45.5 ± 1.25^{c}	24.34 ± 0.03^{f}
	30%	39.2 ± 1.06^{d}	60.3 ± 1.24^{c}	-6.65 ± 1.03^{e}	35.2 ± 1.23^{d}	46.86 ± 1.21^{c}	31.47 ± 0.03^{e}
Leek jelly	**10%**	33.99 ± 1.03^{e}	62.2 ± 1.21^{b}	-7.4 ± 1.25^{e}	37 ± 1.13^{d}	45.14 ± 1.24^{c}	31.42 ± 0.03^{e}
	20%	40.96 ± 1.03^{d}	60.56 ± 1.11^{c}	-9.1 ± 1.23^{c}	42.3 ± 0.03^{c}	47.15 ± 1.54^{c}	36.64 ± 0.03^{d}
	30%	44.36 ± 1.33^{c}	58.8 ± 1.23^{c}	-12.5 ± 1.06^{b}	44.2 ± 1.53^{b}	49.69 ± 1.03^{b}	40.11 ± 0.03^{c}

Control: jelly free of vegetable juice Values are expressed as means ± standard deviations (a,b,c, etc.) for the significant difference between all treatments in the same column for one parameter. Means sharing similar letters within a column are statistically nonsignificant ($p > 0.05$).

The green color in jelly was preferred in our study because it denoted a link to healthy products (Schuldt, 2013). This green hue is related to the presence of chlorophyll pigment (Khoo et al., 2011). The sensitivity of chlorophyll depends on the duration of the cooking process and the type of plant. Chard pigment exhibits the least amount of decrease (19–36%) after boiling among the numerous vegetables studied (Mitić et al., 2013). This observation was consistent with the current chard jelly's measured chlorophyll concentration, since T1, followed by T3, had the highest chlorophyll content (Table 7). The green color was marginally affected, because of the addition of vegetable juice after solubilizing the agar. However, a positive b* value indicates a yellowish degree of chlorophyll degradation, possibly caused by heat or lemon juice addition (Al-Dabbas et al., 2017). Increasing vegetable juice concentration reduces lightness (L*) and increases color saturation (C*). Chard jelly has the greatest color difference (E) due to its stable pigment after boiling. Finally it was concluded from the results that treatments with the most shine and saturated color were those with 20% juice.

3.3.3. pH, syneresis, TSS, and water activity analysis

The study investigated vegetable jelly types with 20% vegetable juice based on their organoleptic, textural, and visual characteristics. The results showed a reduction in acidity and a minor increase in total solids compared to the control (Table 6). The low TSS values (1.18 to 2.27 °Brix) were due to the absence of sucrose. Herein, stevia powder was used in place of sugar, resulting in a minimal increase in soluble solids. These results align with previous studies on porang jelly (Herawati and Kamsiati, 2022) and green tea jelly made with stevia (Akesowan and Choonhahirun, 2021).

The pH measurements indicate an acidity range of 4.36 to 4.51 due to the use of lemon juice. This range is quite comparable to Mutlu et al. (2018)'s stated range of 4.26–5.03. Since most bacteria can grow well at a pH of 7, acidity acts as a barrier to their growth (Padan et al., 2005). Additionally, it is well known that jelly desserts' microbiological viability and freshness are impacted by water activity. Vegetable jelly has a water activity index that is marginally higher than 0.7, but it is less than the 0.9 informed by Belova et al. (2021). It is stated that the use of sweeteners causes a decrease in water activity compared to sucrose, which is related to their higher osmotic pressure. This decrease in water activity can contribute to the preservation and stability of jelly desserts

Table 6. pH, TSS, water activity and syneresis values of vegetable jelly

Parameters	**Commercial product**	**Control**	**T1**	**T2**	**T3**
Water activity	0.71 ± 0.01^{c}	0.782 ± 0.01^{a}	0.751 ± 0.02^{b}	0.792 ± 0.1^{a}	0.731 ± 0.04^{b}
pH	$3.2\pm0.01^{b\ a}$	4.1 ± 0.05^{b}	4.37 ± 0.05^{b}	4.51 ± 0.03^{c}	4.36 ± 0.03^{b}
TSS (0Brix)	76.2 ± 1.9^{a}	0.92 ± 0.03^{d}	1.18 ± 0.03^{c}	2.16 ± 0.04^{b}	2.27 ± 0.03^{a}
Syneresis value (%)	0.0	0.0	0.0	0.2^{a}	0.1^{b}

Control: jelly free of vegetable juice. T1, T2 and T3: Vegetable jellies made with 20% chard, celery and leek juice. Values are expressed as means ± standard deviations, (a,b,c,..) donated the significant difference ($P<0.05$)between all treatments in the same raw for one parameter. Means sharing similar letter within a raw are statistically non significant ($p>0.05$)

The syneresis percentage, which refers to the release of liquid from the jelly, was found to be low in vegetable jelly. It was noticed that after 60 days of storage at 4ºC, the syneresis value increased slightly in celery jelly than the other treatments. This observation aligns with a study by Figueroa and Genovese (2019), who found that fibers could decrease jelly syneresis due to their water-holding capacity.

3.4.Nutritional composition of vegetable jellies

3.4.1.Proximate analysis and energy content

Table (7) summarizes the nutritional profiles of three vegetable jellies. The moisture content of the three products was similar, with celery jelly having the highest moisture content. The moisture percentage ranged from 93.70 to 96.58%, falling within the range described by Khouryieh et al. (2005) and Belova et al. (2021). That result was expected because of the reduced total solids compared to commercial jelly. There was no significant difference in fat content between treatments.

All manufactured jelly types contained a significantly lower carbohydrate and protein content compared to commercial jelly. This is because agar, the hydrocolloid used in vegetable jelly, lacks protein, and vegetables themselves have low protein content. The protein content of vegetable jelly is even lower than that of fruit jelly (Teixeira-Lemos et al., 2021). Additionally, the lower carbohydrate content in vegetable jelly is due to the absence of sugar, nonetheless its concentration is still lower than that of free sugar-berry jelly (Teixeira-Lemos et al., 2021).

Vegetable jellies are rich in dietary fiber (DF), ranging from 2.09±0.16 to 4.2±0.04 g/100g (Table 7). These fibers contribute to the soluble fraction of agar and vegetable juice, ensuring a firm texture without sugar addition (Riedel et al., 2015). It was reported that soluble agar fibers delay gastric emptying and do not affect glycemic response (Clegg and Shafat, 2014). Additionally, DF has physiological benefits, such as reducing intestinal transit time, blood cholesterol levels, and postprandial blood glucose or insulin levels (Gill et al., 2021). Consuming 7 grams of plant-based dietary fiber daily is believed to significantly reduce the risk of cardiovascular and coronary heart diseases (McRae, 2017). Hence, it is good to figure out that consuming 100 g of vegetable jelly would cover roughly a range of 30 to 55% of this daily required dosage.

Table 7. Proximate analysis, energy content, glycemic indicator and chlorophyll of vegetable jelly.

Parameters	Commercial product	Control	T1	T2	T3
Fat (%)	0.01±0.00^{b}	0.02±0.22^{b}	0.25±0.01^{a}	0.10±0.01^{a}	0.15±0.01^{a}
Protein (%)	7.9±0.12^{a}	1.3±0.002^{c}	3.7±0.54^{b}	2.2±1.02^{b}	3.4±1.03^{b}
Carbohydrate (%)	65.5±1.14^{a}	0.15±0.00^{c}	1.6±0.35^{b}	1.12±1.3^{b}	2.75±0.25^{b}
Ash (%)	-	0.085±0.00^{c}	0.47±0.004^{a}	0.24±0.01^{b}	0.29±0.00^{b}
Dietary Fibre (%)	-	1.76±0.06^{c}	4.2±0.04^{a}	2.09±0.16^{b}	3.87±0.07^{a}
Moisture content (%)	26.59±0.04^{d}	97.53±0.44^{a}	94.45±0.14^{c}	96.58±0.25^{b}	93.7±0.34^{c}
Total energy (kcal/100 g)	294.5±2.24^{a}	9.49±0.01^{c}	31.8±0.70^{d}	18.3±0.34^{c}	33.49±1.7^{b}
Total energy (kj/100 g)	1251.5±9.3^{a}	39.47±6.3^{e}	132.9±4.2^{c}	76.86±5.3^{d}	140.21±2.3^{b}
Glycemic index	78±0.22^{a}	2.26±0.11^{b}	7.45±0.13^{a}	16.4±0.12^{c}	18.78±0.14^{a}
Chlorophyll (mg/100g)	-	0.003±0.0^{d}	0.79±0.02^{a}	0.045±0.00^{c}	0.68±0.00^{b}

Control: jelly free of vegetable juice. T1, T2 and T3: Vegetable jellies made with 20% chard, celery and leek juice. Values are expressed as means ± standard deviations, (a,b,c,..) donated the significant difference ($p<0.05$)between all treatments in the same raw for one parameter. Means sharing similar letter within a raw are statistically non significant ($p>0.05$).

Consumers are commonly concerned about the calorie content of products, particularly due to obesity and related diseases. Commercial jellies are typically a high-energy products, due to their high sugar content. A zero-calorie plant extract, stevia, has been used in this study, resulting in a vegetable jelly with a low energetic density (18.3 to 33.49 kcal/100 g) (Table 7), making it designed as sugar-free according to European regulations 1924/2006 (European Commission, 2006) and 1047/2012 (European Commission, 2012). Vegetable jelly had a significantly lower glycemic indicator value ($p<0.5$) than the index of the commercial product by an average of approximately 77.97%. This decline is larger than the 40% reported by Hadjikinova et al. (2019) for reduced sugar-fruit jelly. Which is an encouraging finding for the use and marketing of that type of jelly.

Table 8. Minerals and vitamin content in the vegetable jelly

Parameters	Control	T1	T2	T3
Minerals (mg/100g)				
Cu	0.14±0.01^{b}	0.43±0.00^{a}	0.45±0.00^{a}	0.43±0.00^{a}
Fe	5.16±0.49^{c}	10.05±0.17^{a}	8.25±0.17^{b}	9.79±0.10^{a}
Mn	1.32±0.00^{c}	2.69±0.012^{a}	2.39±0.00^{b}	2.53±0.00^{a}
Zn	1.04±0.00^{b}	3.73±0.06^{c}	2.68±0.00^{b}	3.46±0.08^{a}
Ca	105.8±4.5^{d}	310.7±4.33^{a}	297.5±3.93^{c}	286.9±2.18^{b}
Mg	144.9±0.85^{d}	346.4±0.93^{a}	332.5±0.58^{c}	339.1±1.20^{b}
Na	10.9±2.6^{d}	90.3±1.6^{a}	53±2.02^{b}	35.3±1.45^{c}
K	780.3±8.9^{d}	1218±2.5^{b}	1229±3.8^{a}	1191±4.3^{c}
Vitamins				
A (IU/100g)	286.3±5.9^{d}	585±8.82^{b}	414±5.72^{c}	510±0.21^{a}
C (mg/100g)	5.24±0.23^{d}	11.13±0.18^{a}	7.41±0.18^{c}	9.45±0.36^{b}
B6 (mg/100g)	0.002±0.00^{c}	0.05±0.00^{b}	0.021±0.00^{b}	0.38±0.00^{a}
B5(mg/100g)	0.007±4.5^{c}	0.041±0.00^{b}	0.057±5.1^{a}	0.037±0.00^{c}
B3 (mg/100g)	0.035±0.08^{b}	0.08±0.00^{a}	0.10 ±0.00^{a}	0.11±0.00^{a}

Control: jelly free of vegetable juice. T1, T2 and T3: Vegetable jellies made with 20% chard, celery and leek juice. Values are expressed as means ± standard deviations (a,b,c, etc.) donated the significant difference ($p<0.05$) between all treatments in the same raw for one parameter. Means sharing similar letters within a raw are statistically nonsignificant ($p > 0.05$).

3.4.2. Minerals and vitamins

In terms of mineral content, all vegetable jellies had a significant amount of minerals, and the highest percentages were for K, Mg, and Ca (Table 8).

According to the US Food and Drug Administration (FDA, 2016), the produced vegetable jellies could cover a good percent of the DV recommended for adults and kids aged 4 and older and are considered a rich source of minerals (Figure 3). It was noticed that vegetable jelly could provide 110, 72, 52, 30, 25, and 22.9% of the daily values (DV) for Mn, Mg, Fe, Zn, K and Ca (DV: 1300 mg), respectively.

These minerals are associated with many health aspects. Magnesium, for example, is essential for energy generation, heart rhythm, bone formation, and nerve signal conduction (Ross et al., 2012). Besides being identified as a "nutrient of public health concern" (U.S. Department of Agriculture, 2015), potassium levels are linked to higher rates of type 2 diabetes, insulin resistance, and fasting blood sugar. Calcium also is essential for bone strength and osteoporosis (Song, 2017). Iron is essential for child development and female anemia prevention (Wang et al., 2019). Zinc also plays a role in cellular metabolism, cell-mediated immunity, bone formation, and acute diarrhea treatment in children (Bagherani and Smoller, 2016).

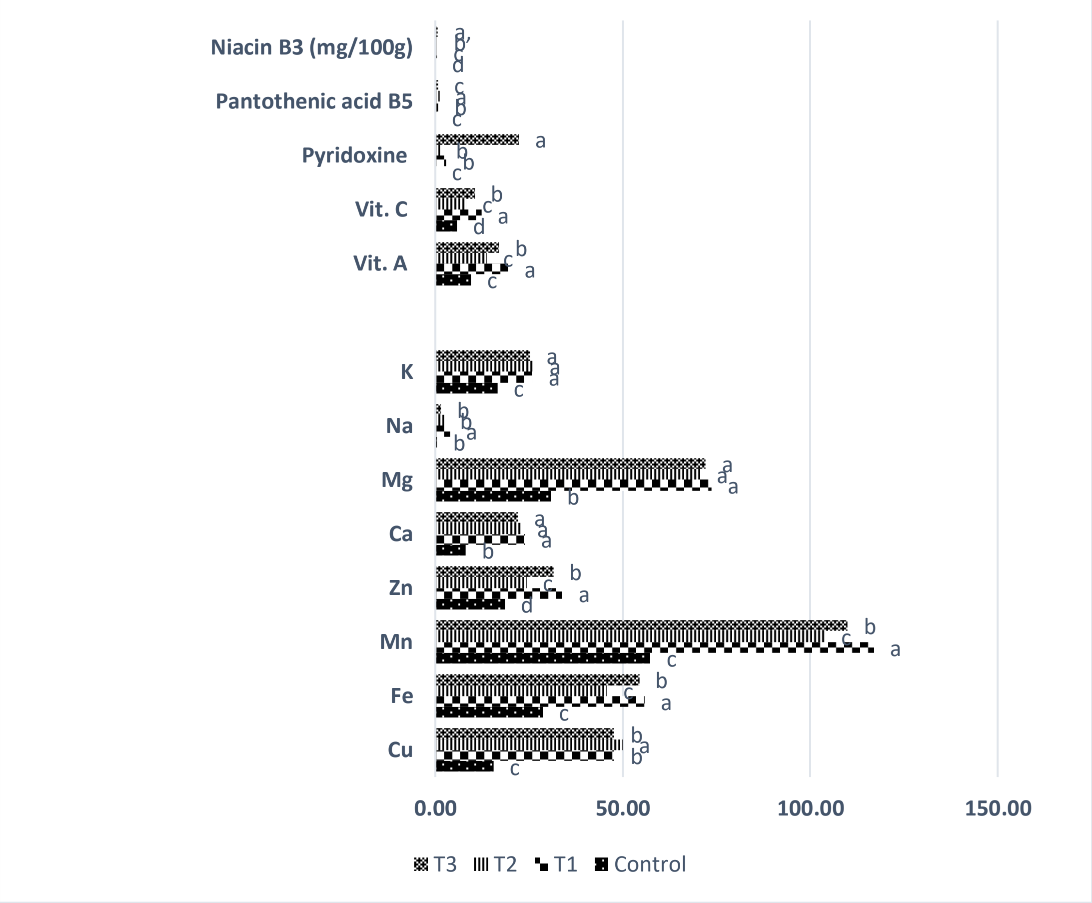

Figure 3. Vitamins and minerals expressed as a percent of the Daily Value (% DV) covered by each vegetable jelly Control: jelly free of vegetable juice T1, T2, and T3: Vegetable jellies made with 20% chard, celery, and leek juice. Results are expressed as the mean of three replicates. Significant differences ($p < 0.5$) are shown by (a, b, c, etc.) between jelly types in the same parameter.

Based on the information provided in table (8) and figure (3), T1 and T3 jelly can provide the best coverage of the recommended daily amounts for vitamins A, C, and B6. And can be considered moderately vitamin-rich foods (FDA, 2016). Since they could provide an average of 16.7, 10.36, and 8.8% of the DV% prescribed for vitamins A, C, and B6 (FDA, 2016). These vitamins are important for cellular interaction, inhibition of some cancers, IL-2 synthesis, hemoglobin production, and overall immune system function (Akram et al., 2020).

Micronutrients aid the immune system in combating viral infections, and doctors worldwide are interested in supplementing them for COVID-19 prevention or treatment (El Sabbagh et al., 2022). According to the 2020–2025 Dietary Guidelines for Americans, nutritional needs should be supplied through meals, and vegetable jellies can be a convenient and effective way to fulfill the nutritional requirements of these patients.

3.5. Functional properties of vegetable jelly

The popularity of polyphenols derived from plants, particularly vegetables, is steadily rising.

Table 9. Phytochemicals content and antioxidant activity of vegetable jelly

Parameters	Control	T1	T2	T3
TPC (mg GAE/ 100g dw)	190 ± 0.1^{d}	790 ± 0.17^{c}	318 ± 1.9^{a}	824 ± 0.3^{b}
TFC (mg QE/ 100g dw)	66 ± 0.6^{d}	236 ± 0.27^{b}	108 ± 0.01^{c}	348 ± 0.21^{a}
Antioxidant AOX (%)	9.79 ± 0.1^{c}	56.47 ± 0.06^{b}	32.67 ± 0.35^{a}	73.54 ± 0.43^{a}
AOX (mg TE/100gm)	36.4 ± 0.1^{d}	195.7 ± 0.16^{b}	112.9 ± 0.25^{c}	255.4 ± 0.65^{a}

Control: jelly free of vegetable juice. T1, T2 and T3: Vegetable jellies made with 20% chard, celery and leek juice. Values are expressed as means ± standard deviations (a,b,c, etc.) donated by the significant difference (P < 0.5) between all treatments in the same raw for one parameter. Means sharing similar letters within a raw are statistically nonsignificant (p > 0.05).

The findings for total phenolics and flavonoids differed significantly (p<0.5) among jelly samples and ranged from 8.24 to 3.18 mg GAE/g and 3.48 to 1.08 mg QE/g, respectively (Table 9).

T3 displayed the highest value in both categories. The reported range of flavonoids and phenolic compounds was higher than that established by Ben Rejeb et al. (2020) for citrus jellies (192.76 mg GAE/100 g for total phenolic and 9.06 mg QE/100 g for flavonoids, respectively). Previous studies have shown that a short heat cycle can greatly increase the levels of total phenolics and flavonoids in vegetables, but prolonged heating can have the opposite effect (Kim et al., 2008). This research also analyzed vegetable jelly's phenolic components by HPLC, revealing a rich and diverse range of compounds (Table 10). The most elevated phenolic compounds were E-vanillic and salicylic acids in T1, E-vanillic and pyrogallol in T2, and caffeine and chlorogenic acid in T3. While the predominant flavonoids in T1, T2, and T3 were luteolin, rosmarinic acid, and kaempferol, respectively. These findings align with previous studies on the phenolic profiles of Swiss chard, Egyptian leeks, and celery leaves (Zein et al., 2015; El-Rehem et al., 2013; Yao et al., 2010).

In the same manner, cooking has been found to boost antioxidant activity by softening tissues and releasing phytochemicals (Sharma et al., 2015). T3 showed the highest antioxidant activity (81.47%), followed by T1 (69.5%) and T2 (53.06%), respectively. Giving a range of 255.43 to 112.91 mg TE/100 g, which is larger than what was observed by Teixeira-Lemos et al. (2021) for the berries (83.7 mg TE/L) and the orange with honey jelly (50.4 mg TE/L).

Furthermore, the antioxidant activity of leafy vegetables has been found to be positively correlated with their flavonoid (r = 0.97, $p < 0.05$) and phenolic content (r = 0.96, $p < 0.05$). These compounds have been increasingly studied for their various health benefits, such as their potential to provide protection against allergies, inflammation, pain, heart diseases, liver damage, viral infections, and even certain types of cancer (Ghasemzadeh, 2011). Leafy vegetables' antioxidant activity is also associated with pigment content, including chlorophyll, betalains, and carotenoid content (Ivanović et al., 2019).

Table 10. HPLC analysis for phenolic profile of vegetable jelly

Compounds	**T1**	**T2**	**T3**
Phenolic compounds (mg/100g)			
Gallic	11.7±015^{a}	3.95±0.59^{c}	9.8±0.25^{b}
Pyrogallol	15.68±0.54^{b}	107.9±0.55^{a}	10.46±0.54^{c}
Caffeic Acid	11.87±0.41^{a}	7.96±0.21^{b}	6.8±0.57^{c}
Protocatchoic	45.6±1.59^{a}	9.89±0.27^{b}	5.29±0.14^{c}
Chlorogenic	5.6±0.11^{c}	44.68±0.12^{b}	60.66±1.5^{a}
Epi-Catechin	17.9±0.88^{a}	9.41±0.12^{b}	3.56±0.54^{c}
Catechin	9.5±0.33^{b}	9.85±0.45^{b}	21.13±0.51^{a}
Caffeine	9.9±0.14^{c}	22.56±0.22^{b}	50.2±0.21^{a}
P-OH.Benzoic	13.7±0.16^{c}	25.37±1.5^{a}	23.9±0.21^{b}
Vanillic	21.26±0.14^{a}	5.78±0.11^{b}	4.53±0.14^{b}
Ferulic	26.52±0.17^{b}	33.25±0.57^{a}	5.07±054^{c}
Catechol	27.7±0.21^{a}	3.44±0.14^{b}	4.73±0.41^{b}
E- Vanillic	141.8±0.39^{a}	123.3±0.71^{b}	5.4±0.77^{c}
Ellagic Acid	22.7±0.14^{b}	78.9±0.55^{a}	7.53±0.41^{c}
Benzoic	30.7±0.51^{b}	53.89±0.54^{a}	10.47±0.45^{c}
Salycillic	130±0.11^{a}	----	3.73±0.24^{b}
3,4,5 Methoxy Cinnamic	4.7±0.53^{b}	5.1±0.25^{b}	19.8±0.32^{a}
Coumarin	3.3±0.41^{c}	10.52±0.54^{a}	8.4±0.19^{b}
P- Coumaric	25.38±0.52^{a}	3.54±0.14^{c}	26.7±0.12^{b}
Cinnamic	4.72±0.55^{b}	0.77±0.04^{c}	84.6±0.07^{a}
Syringic	33.5±0.14^{a}	1.6±0.04^{b}	2.5 ±0.01^{b}
Flavonoid (mg/100g)			
Luteolin	151.39±0.51^{a}	27.21±0.11^{c}	67.98±0.45^{b}
Naringin	31.3±0.42^{a}	---	4.4±0.14^{b}
Rutin	25.6±0.22^{b}	3.34±0.02^{c}	50.02±0.52^{a}
Hesperidin	77.9±0.82^{a}	21.32±0.54^{b}	3.96±0.05^{c}
Rosmarinic	5.6±0.07^{c}	199.02±0.12^{a}	22.6±0.52^{b}
Quercetrin	10.64±0.72^{c}	32.21±0.71^{a}	23.58±0.12^{b}
Quercetin	1.2±0.02^{b}	0.35±0.02^{c}	122.32±1.7^{a}
Kaempferol	7.5±0.09^{c}	10.96±0.08^{b}	195.36±0.25^{a}
Hespertin	18.34±0.78^{a}	2.48±0.12^{c}	3.25±0.45^{b}
Apegenin	0.16±0.00^{b}	0.18±0.01^{b}	10.69±0.52^{a}

Control: jelly free of vegetable juice. T1, T2 and T3: Vegetable jellies made with 20% chard, celery and leek juice. Values are expressed as means ± standard deviations (a,b,c, etc.) donated by the significant difference ($P < 0.5$) between all treatments in the same raw for one parameter. Means sharing similar letters within a raw are statistically nonsignificant ($p> 0.05$).

3.6. Microbial analysis

Since the existing jellies didn't include any additional sugar, they should be susceptible to spoiling. But satisfactory, the current vegetable jellies had total bacterial counts ranging from 0.22 to 2.3*10^{2} CFU/g (Figure 4), which was below the 10^{3} CFU/g limits specified by EU law (2005).

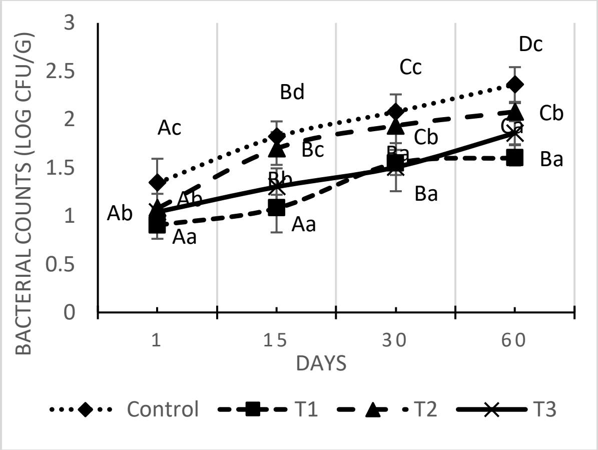

Figure 4. Total mesophilic counts during storage for two months. Control: jelly free of vegetable juice. T1, T2 and T3: Vegetable jellies made with 20% chard, celery and leek juice Results expressed as a mean of three replicates ± standard deviation. A significant difference ($p < 0.5$) is shown by different letters (A, B, C, etc.) in the same treatment for different times of storage and by (a, b, c, etc.) in the same storage day for different treatments.

Among the different vegetable jellies tested, chard jelly had the smallest bacterial population, followed by leek jelly. The bacterial counts slightly increased during storage, with celery jelly having the highest count after two months. Moreover, there was no discernible yeast or mold.

The obtained preservation period is comparable to that of sugar-free jelly preserved with chemical preservatives and a low pH (Khouryieh et al., 2005), as well as fruit jellies with or without sugar (Ben Rejeb et al., 2020). Herein, mint leaf extract is used as a flavoring and preservation element to increase safety due to its antimicrobial activity (Sugandhi and Meera, 2011). Additionally, the low pH of lemon juice creates an unfavorable environment for bacterial survival and reproduction. Other factors like low water activity, antioxidants, phenols, and flavonoids also contribute to the safety, preservation, and quality of vegetable jellies.

4. Conclusions

To the best of our knowledge, this research formulated an agar-based sugar-free jelly by incorporating leafy vegetables, including Swiss chard, celery, and leek, which is flavored with lemon and mint and sweetened with stevia. The results of this investigation showed that the incorporation of leafy vegetables not only adds nutritional value to the jelly but also enhances its physical and functional properties. Since it was found that vegetable jelly has greater amounts of dietary fiber, vitamins, minerals, and phytochemicals while still being considered a low-calorie product with a low glycemic load compared to commercial jelly. Furthermore, the jelly's texture can provide a satisfying mouthfeel, making it an appealing option for individuals with difficulty swallowing or chewing. This innovative approach could benefit individuals with diabetes, obesity, malnutrition, and cardiovascular diseases and also be a suitable option for people following vegetarian or vegan diets. Additionally, they are low-cost, multifunctional, and open up opportunities for diversifying the market for healthy, sustainable, and value-added products.

5. References

Akesowan, A., & Choonhahirun, A. (2021). The use of Stevia and monk fruit sweeteners for sugar replacement in green tea agar jellies. *Food ScienTech Journal*, 3(2), 93. https://doi.org/10.33512/fsj.v3i2.12404

Akram, M., Munir, N., Daniyal, M., Egbuna, C., Găman, M.-A., Onyekere, P. F. & Olatunde, A. (2020). Vitamins and Minerals: Types, Sources and their Functions. In Functional Foods and Nutraceuticals (pp. 149–172). Springer International Publishing.

Al-Dabbas, M., Saleh, M., Hamad, H., & Hamadeh, W. (2017). Chlorophyll color retention in green pepper preserved in natural lemon juice: Green pepper color preservation. *Journal of Food Processing and Preservation*, 41(4), e13055. https://doi.org/10.1111/jfpp.13055

Animaw, W., & Seyoum, Y. (2017). Increasing prevalence of diabetes mellitus in a developing country and its related factors. *PloS One*, 12(11), e0187670. https://doi.org/10.1371/journal.pone.0187670

Antakli S, Sarkees N, Sarraf T. (2015) Determination of water-soluble vitamins B1, B2, B3, B6, B9, B12 and C on C18 column with particle size 3um in some manufactured food products by HPLC with UV-DAD/FL detection. *International Journal of Pharmacy and Pharmaceutic Sciences*, 7(6), 219–224. https://journals.innovareacademics.in/index.php/ijpps/article/view/4465

AOAC (2000). Official Methods of Analysis. 17th Edition, The Association of Official Analytical Chemists, Gaithersburg, MD, USA. Methods 925.10, 65.17, 974.24, 992.16.

Ashok, D.A., Ravivarman, J., & Kayalvizhi, D.K. (2020) Underutilized leafy vegetables of India and their pharmaceutical value to provoke human immune system. *Journal of Pharmacognosy and Phytochemistry*, 9(3), 1319–1327.

Bagherani, N., & Smoller, B.R. (2016). An overview of zinc and its importance in dermatology- Part I: importance and function of zinc in human beings. *Glob Dermatol* 3(5), 330–336. https://doi.org/10.15761/GOD.1000185

Ben Rejeb, I., Dhen, N., Kassebi, S., & Gargouri, M. (2020). Quality evaluation and functional properties of reduced sugar jellies formulated from citrus fruits. *Journal of Chemistry*, 2020, 1–8. https://doi.org/10.1155/2020/5476872

Belova, N. M., Kutsenkova, V. S., Petrova, O. N., Popova, O. M., Yeganehzad, S., & Nepovinnykh, N. V. (2021). New insights into grain hydrogels with reinforced textural properties: design of low-calorie jelly desserts technology. IOP Conference Series. Earth and Environmental Science, 723(3), 032066. https://doi.org/10.1088/1755-1315/723/3/032066

Bourne, M.C. (1978). Texture Profile Analysis. *Food Technology*, 32, 62-66, 72

Cano-Lamadrid, M., Calín-Sánchez, Á., Clemente-Villalba, J., Hernández, F., Carbonell-Barrachina, Á. A., Sendra, E., & Wojdyło, A. (2020). Quality parameters and consumer acceptance of jelly candies based on pomegranate juice “Mollar de Elche.” *Foods* (Basel, Switzerland), 9(4).https://doi.org/10.3390/foods9040516

Chawla, R., & Patil, G. R. (2010). Soluble dietary fiber. Comprehensive Reviews in *Food Science and Food Safety*, 9(2), 178–196. https://doi.org/10.1111/j.1541-4337.2009.00099.x

Clegg, M. E., & Shafat, A. (2014). The effect of agar jelly on energy expenditure, appetite, gastric emptying and glycaemic response. *European Journal of Nutrition*, 53(2), 533–539. https://doi.org/10.1007/s00394-013-0559-x

Cruz, A. C., Guiné, R. P. F., & Gonçalves, J. C. (2015). Drying kinetics and product quality for convective drying of apples (cvs. Golden delicious and granny smith). *International Journal of Fruit Science*, 15(1), 54–78. https://doi.org/10.1080/15538362.2014.931166

Delgado, P., & Bañón, S. (2015). Determining the minimum drying time of gummy confections based on their mechanical properties. *CyTA - Journal of Food*, 13(3), 329–335. https://doi.org/10.1080/19476337.2014.974676

Dennison, D. B., & Kirk, J. R. (1977). Quantitative analysis of vitamin a in cereal products by high speed liquid chromatography. *Journal of Food Science*, 42(5), 1376–1379. https://doi.org/10.1111/j.1365-2621.1977.tb14502.x

Dodd, H., Williams, S., Brown, R., Venn, B. (2011). Calculating meal glycemic index by using measured and published food values compared with directly measured meal glycemic index. *The American Journal of Clinical Nutrition*, 94(4), 992- 996.

El Sabbagh, E., El-Sayed, M., & Elbaz, T. (2022). Vitamins and minerals: A means for surviving the COVID-19 pandemic or just a myth? *Journal of Infection in Developing Countries*, 16(5), 782–786. https://doi.org/10.3855/jidc.14692

El-Rehem, F. A. E.-R. A. A., & Ali, R. F. M. (2013). Proximate compositions, phytochemical constituents, antioxidant activities and phenolic contents of seed and leaves extracts of Egyptian leek (Allium ampeloprasum var. kurrat). *European Journal of Chemistry*, 4(3), 185–190. https://doi.org/10.5155/eurjchem.4.3.185-190.711

European Union Commission Regulation (2005). Microbiological criteria for foodstuffs. No 2073/2005 http://data.europa.eu/eli/reg/2005/2073/2014-06-01. (Accessed 28 may 2021).

EU. Regulamento (CE) No 1924/2006 – Alegações nutricionais e de saúde sobre os alimentos. Brussels, Belgium: European Commission; 2006

EU. Regulamento (EU) 1047/2012 – Alteração às alegações nutricionais e de saúde sobre os alimentos. Brussels, Belgium: European Commission; 2012.

Fazal, S. S., & K Singla, R. (2012). Review on the Pharmacognostical & Pharmacological Characterization of Apium Graveolens Linn. *Indo Global Journal of Pharmaceutical Sciences*, 02(01), 36–42. https://doi.org/10.35652/igjps.2012.03

Figueroa, L.E., & Genovese, DB (2019). Fruit jellies enriched with dietary fibre: Development and characterization of a novel functional food product. *Lebensmittel-Wissenschaft Und Technologie*, 111, 423–428. https://doi.org/10.1016/j.lwt.2019.05.031

Gamba, M., Raguindin, P. F., Asllanaj, E., Merlo, F., Glisic, M., Minder, B., Bussler, W., Metzger, B., Kern, H., & Muka, T. (2020). Bioactive compounds and nutritional composition of Swiss chard (Beta vulgaris L. var. cicla and flavescens): a systematic review. *Critical Reviews in Food Science and Nutrition*, 61(20),3465–3480. https://doi.org/10.1080/10408398.2020.1799326

Gao, J., Brenan, M.A., Mason, S.L., Brenan, C.S. (2016). Effect of Sugar Replacement with Stevianna and Inulin on the Texture and Predictive Glycaemic Response of Muffins. *International Journal of Food Science and Technology*, 51, 1979-1987

Geziginci-Oktayoglu, S., Sacan, O., Bolkent, S., Ipci, Y., Kabasakal, L., Sener, G. (2014). Chard (Beta vulgaris L. var. cicla) extract ameliorates hyperglycemia by Increasing GLUT2 through Akt2 and antioxidant defense in the liver of rats. Acta Histochemica., 116,32–39.

Ghasemzadeh, A. (2011). Flavonoids and phenolic acids: Role and biochemical activity in plants and human. *Journal of Medicinal Plant Research*, 5(31). https://doi.org/10.5897/jmpr11.1404

Gill, S. K., Rossi, M., Bajka, B., & Whelan, K. (2021). Dietary fibre in gastrointestinal health and disease. Nature Reviews. *Gastroenterology & Hepatology*, 18(2), 101–116. https://doi.org/10.1038/s41575-020-00375-4

Hamedi, F., Mohebbi, M., Shahidi, F.,& Azarpazhooh, E. (2018). Ultrasoundassisted osmotic treatment of model food impregnated with pomegranate peel phenolic compounds : Mass transfer, texture, and phenolic evaluations. *Food and Bioprocess Technology*. 11(5),1061–1074.

Herawati, H., & Kamsiati, E. (2022). The characteristics of low sugar jelly made from porang flour and agar. IOP Conference Series. *Earth and Environmental Science*, 1024(1), 012019. https://doi.org/10.1088/1755-1315/1024/1/012019

Hadjikinova, R., Stankov, S., Popova, V., Ivanova, T., Stoyanova, A., Mazova, N., Marudova, M., & Damyanova, S. (2019). Physicochemical and textural properties of reduced sugar jellies from Physalisperuviana L. fruit. *Ukrainian Food Journal*, 8(3), 560–570. https://doi.org/10.24263/2304-974x-2019-8-3-12

Ibrahim, G.A., Abdallah, A.M., & Farahaat, A.E. (2020). Lipid Profile Disorders in Type 2 Diabetic Patients among Adult Patients in Tur Sinai District. *Zumj*, 26(3), 465–473.

Ivanović, L., Milašević, I., Topalović, A., Đurović, D., Mugoša, B., Knežević, M., & Vrvić, M. (2019). Nutritional and phytochemical content of Swiss chard from Montenegro, under different fertilization and irrigation treatments. *British Food Journal* (Croydon, England), 121(2), 411–425. https://doi.org/10.1108/bfj-03-2018-0142

Kawano, Y., Kiuchi, H., Haraguchi, T., Yoshida, M., Uchida, T., Hanawa, T., & A.k, A. I. (2017). Preparation and evaluation of physicochemical properties of isosorbide gel composed of xanthan gum, locust bean gum and agar for improving the patients' adherence. *International Journal of Medicine and Pharmacy,5(1),18–32.* https://doi.org/10.15640/ijmp.v5n1a3

Khoo, H.-E., Prasad, K. N., Kong, K.-W., Jiang, Y., & Ismail, A. (2011). Carotenoids and their isomers: color pigments in fruits and vegetables. *Molecules* (Basel, Switzerland), 16(2), 1710–1738. https://doi.org/10.3390/molecules16021710

Khouryieh, H. A., Aramouni, F. M., & Thomas J. Herald. (2005). Physical, chemical and sensory properties of sugar-free jelly. *Journal of Food Quality*, 28(2), 179–190. https://doi.org/10.1111/j.1745-4557.2005.00014.x

Kim, H.-Y., Woo, K.-S., Hwang, I.-G., Lee, Y.-R., & Jeong, H.-S. (2008). Effects of heat treatments on the antioxidant activities of fruits and vegetables. *Korean Journal of Food Science and Technology*, 40(2), 166–170.

Kronberga, M., Karklina, D., Murniece, I., & Kruma, Z (2011). Changes of agar-agar gel properties after replacing sucrose by inulin syrup. In: 6th Baltic Conference on Food Science and Technology "*Innovations for Food Science and Production*. Jelgava, LLU.

Lawless, H. T., & Heymann, H. (2010). Sensory evaluation of food: Principles and practices. Springer New York.

McRae, M. P. (2017). Dietary fiber is beneficial for the prevention of cardiovascular disease: An umbrella review of meta-analyses. *Journal of Chiropractic Medicine*, 16(4), 289–299. https://doi.org/10.1016/j.jcm.2017.05.005

Mitić, V., Jovanovic, V. S., Dimitrijevic, M., Cvetkovic, J., & Stojanovic, G. (2013). Effect of food preparation technique on antioxidant activity and plant pigment content in some vegetables species. *Journal of Food and Nutrition Research*, 1(6), 121–127. https://doi.org/10.12691/jfnr-1-6-2

Mutlu, C., Tontul, S. A., & Erbaş, M. (2018). Production of a minimally processed jelly candy for children using honey instead of sugar. *Lebensmittel-Wissenschaft Und Technologie*, 93, 499–505. https://doi.org/10.1016/j.lwt.2018.03.064

Padan, E., Bibi, E., Ito, M., & Krulwich, T. A. (2005). Alkaline pH homeostasis in bacteria: new insights. *Biochimica et Biophysica Acta*, 1717(2), 67–88. https://doi.org/10.1016/j.bbamem.2005.09.010

Pak, L. M., Silva, A. J. M., & Balbi, M. E. (2014). Evaluation of nutritional composition of leek (Allium porrum, Aliaceae). *Visão Acadêmica*, 15(3). https://doi.org/10.5380/acd.v15i3.39990

Pathare, P. B., Opara, U. L., & Al-Said, F. A.-J. (2013). Colour measurement and analysis in fresh and processed foods: A review. *Food and Bioprocess Technology*, 6(1), 36–60. https://doi.org/10.1007/s11947-012-0867-9

Pilgrim, G. W., Walter, R. H., & Oakenfull, D. G. (1991). Jams, jellies, and preserves. *In The Chemistry and Technology of Pectin* (pp. 23–50). Elsevier. https://doi.org/10.1016/B978-0-08-092644-5.50007-8

Devi Ramaiya, S., Bujang, J. S., Zakaria, M. H., King, W. S., & Shaffiq Sahrir, M. A. (2013). Sugars, ascorbic acid, total phenolic content and total antioxidant activity in passion fruit

(Passiflora) cultivars: Chemical composition and antioxidant activity ofPassifloracultivars. *Journal of the Science of Food and Agriculture*, 93(5), 1198–1205. https://doi.org/10.1002/jsfa.5876

Radovanović, B., Mladenović, J., Radovanović, A., Pavlović, R., & Nikolić, V. (2015). Phenolic Composition, Antioxidant, Antimicrobial and Cytotoxic Activites of Allium porrum L. (Serbia) Extracts. *Journal of Food and Nutrition Research*, 3(9), 564–569. https://doi.org/10.12691/jfnr-3-9-1

Regulation (ec) no 1924/2006 of the European parliament and of the council on nutrition and health claims made on foods,http://data.europa.eu/eli/reg/2006/1924/oj

Riedel, R., Böhme, B., & Rohm, H. (2015). Development of formulations for reduced-sugar and sugar-free agar-based fruit jellies. *International Journal of Food Science & Technology*, 50(6), 1338–1344. https://doi.org/10.1111/ijfs.12787

Romeu-Nadal, M., Morera-Pons, S., Castellote, A. I., & López-Sabater, M. C. (2006). Rapid high-performance liquid chromatographic method for Vitamin C determination in human milk versus an enzymatic method. *Journal of Chromatography. B, Analytical Technologies in the Biomedical and Life Sciences*, 830(1), 41–46. https://doi.org/10.1016/j.jchromb.2005.10.018

Ross, A. C., Caballero, B. H., Cousins, R. J., Tucker, K. L., & Ziegler, T. R. (2012). Modern nutrition in health and disease: Eleventh edition. Wolters Kluwer Health Adis (ESP).

Salfinger, Y., & Tortorello, M. L. (Eds.). (2015). Compendium of methods for the microbiological examination of foods. American Public Health Association. https://doi.org/10.2105/MBEF.0222

Sánchez-Moreno, C., Larrauri, J. A., & Saura-Calixto, F. (1998). A procedure to measure the antiradical efficiency of polyphenols. *Journal of the Science of Food and Agriculture*, 76(2), 270–276. https://doi.org/10.1002/(sici)1097-0010(199802)76:2<270::aid-jsfa945>3.0.co;2-9

Schiatti-Sisó, I.P., Quintana, S.E. & García-Zapateiro, L.A. (2023). Stevia (Stevia rebaudiana) as a common sugar substitute and its application in food matrices: an updated review. *The Journal of Food Science and Technology*. 60, 1483–1492 https://doi.org/10.1007/s13197-022-05396-2

Schuldt, J. P. (2013). Does green mean healthy? Nutrition label color affects perceptions of healthfulness. Health Communication, 28(8), 814–821. https://doi.org/10.1080/10410236.2012.725270

Sharma, K., Ko, E. Y., Assefa, A. D., Ha, S., Nile, S. H., Lee, E. T., & Park, S. W. (2015). Temperature-dependent studies on the total phenolics, flavonoids, antioxidant activities, and sugar content in six onion varieties. *Journal of Food and Drug Analysis*, 23(2), 243–252. https://doi.org/10.1016/j.jfda.2014.10.005

Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). [14] Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In Oxidants and Antioxidants Part A (pp. 152–178). Elsevier.

Song, L. (2017). Calcium and bone metabolism indices. *Advances in Clinical Chemistry*, 82, 1–46. https://doi.org/10.1016/bs.acc.2017.06.005

Stephen, A.M., & Phillips, G.O. (Eds.). (2006). Food Polysaccharides and Their Applications (2nd ed.). CRC Press. https://doi.org/10.1201/9781420015164

Sugandhi, B. R. M., & Bai, G. M. (2011). Antimicrobial Activity of Mentha Arvensis L. (Lamiaceae). *Journal of Advanced Laboratory Research in Biology*, 2(1), 8–11.

Teixeira-Lemos, E., Almeida, A. R., Vouga, B., Morais, C., Correia, I., Pereira, P., & Guiné, R. P. F. (2021). Development and characterization of healthy gummy jellies containing natural fruits. *Open Agriculture*, 6(1), 466–478. https://doi.org/10.1515/opag-2021-0029

U.S. Department of Agriculture and U.S. Department of Health and Human Services. Dietary Guidelines for Americans, 2020–2025. 9th ed. Washington, DC: US Government Publishing Office; 2020. DietaryGuidelines.gov.

FDA: U.S. Food and Drug Administration. Food Labeling: Revision of the Nutrition and Supplement Facts Labels.external link disclaimer 2016.

USDA National Nutrient Database for Standard Reference, Release 23 (2010). Available from http://www.nal.usda.gov/fnic/foodcomp/cgi-bin/list_nut_edit.pl Accessed on 11th May 2011.

Wang, Y., Wu, Y., Li, T., Wang, X., & Zhu, C. (2019). Iron metabolism and brain development in premature infants. Frontiers in Physiology, 10, 463. https://doi.org/10.3389/fphys.2019.00463

WHO. (2020): United Nations Children's Fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: Key Findings of the 2020 Edition of the Joint Child Malnutrition Estimates. Geneva: World Health Organization; 2020. Licence: CC BY-NC-SA 3.0 IGO

Yao, Y., Sang, W., Zhou, M., & Ren, G. (2010). Phenolic composition and antioxidant activities of 11 celery cultivars. *Journal of Food Science*, 75(1), C9-13. https://doi.org/10.1111/j.1750-3841.2009.01392.x

Zein, H., Hashish, S.A, & Ismaiel, H.H.G. (2015). The antioxidant and anticancer activities of Swiss chard and red beetroot leaves. *Current Science International*. (04), 491–498.

Zhishen, J., Mengcheng, T., & Jianming, W. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chemistry*, 64(4), 555–559. https://doi.org/10.1016/s0308-8146(98)00102-2

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