การพัฒนาและประเมินคุณภาพเครื่องดื่มเยลลี่ว่านหางจระเข้ผสมน้ำผลไม้สูตรลดพลังงาน

Development and Quality Evaluation of a Reduced-Energy *Aloe vera* Jelly Beverage Containing Fruit Juice

อมรรัตน์ สีสุกอง[1*] วีรชน ภูหินกอง[1] ฤทธิพันธ์ รุ่งเรือง[1] มณชัย เดชสังกรานนท์[1]
วิสาขา เทียมลม[2] และ ขวัญจิต อิสระสุข[3]

Amornrat Srisukong[1*], Weerachon Phuhinkong[1], Rittipun Rungruang[1], Monchai Dejsungranont[1], Visakha Tiemlom[2] and Khwunjit Itsarasook[3]

[1]คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยสวนดุสิต กรุงเทพมหานคร
[2]คณะวิทยาการจัดการ มหาวิทยาลัยสวนดุสิต กรุงเทพมหานคร
[3]คณะวิทยาศาสตร์ มหาวิทยาลัยรามคำแหง กรุงเทพมหานคร
[1]Faculty of Science and Technology, Suan Dusit University, Bangkok
[2]Faculty of Management Sciences, Suan Dusit University, Bangkok
[3]Faculty of Science, Ramkhamhaeng University, Bangkok
Corresponding Author: amornrats@hotmail.com

Received: May 26, 2026 **Revised:** September 21, 2026 **Accepted:** October 20, 2026

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาเครื่องดื่มเยลลี่ว่านหางจระเข้ผสมน้ำผลไม้สูตรลดพลังงาน และประเมินสมบัติทางกายภาพและเคมี ความชอบทางประสาทสัมผัส สารออกฤทธิ์ทางชีวภาพ องค์ประกอบทางโภชนาการ และความคงตัวระหว่างการเก็บรักษา โดยศึกษาคุณภาพเบื้องต้นของเจลว่านหางจระเข้สด จากนั้นพัฒนาผลิตภัณฑ์โดยศึกษาผลของอัตราส่วนคาราจีแนนและผงบุก รวมทั้งการใช้ซูคราโลสทดแทนน้ำตาลทรายที่ระดับร้อยละ 0,50 และ 100 ผลการศึกษาพบว่าเจลว่านหางจระเข้สดมีค่า ABTS$^{\bullet+}$ radical scavenging activity ร้อยละ 46.57 ± 3.62 ที่ความเข้มข้นตัวอย่าง 200 mg/mL และค่า FRAP 23.37 ± 0.81 mg TE/100 g fresh weight การศึกษาอัตราส่วนสารก่อเจลพบว่า สูตรที่ใช้คาราจีแนนร้อยละ 0.6 ร่วมกับผงบุกร้อยละ 0.07 ให้คะแนนความชอบด้านรสชาติ เนื้อสัมผัส และความชอบโดยรวมสูงที่สุด เมื่อศึกษาการทดแทนน้ำตาล พบว่าการใช้ซูคราโลสทดแทนน้ำตาลทรายร้อยละ 50 ให้คะแนนความชอบโดยรวมใกล้เคียงสูตรควบคุม พร้อมลดพลังงานของผลิตภัณฑ์จาก 94.52 เป็น 59.72 กิโลแคลอรีต่อ 100 กรัม ผลิตภัณฑ์สูตรที่เหมาะสมมีปริมาณฟีนอลิกรวม 7.18 mg GAE/g sample ปริมาณฟลาโวนอยด์รวม 5.88 mg QE/g sample มีค่า DPPH radical scavenging activity ร้อยละ 34.81 ที่ความเข้มข้นตัวอย่าง 1,000 mg/mL และมีปริมาณอะโลอิน 1.25 mg/kg sample ระหว่างการเก็บรักษาที่อุณหภูมิ 4 ± 2 °C เป็นเวลา 4 สัปดาห์ ผลิตภัณฑ์มีสมบัติทางกายภาพและเคมีค่อนข้างคงตัว ขณะที่จำนวนจุลินทรีย์ทั้งหมด ยีสต์และราโคลิฟอร์ม *Escherichia coli* และ *Staphylococcus aureus* อยู่ในระดับต่ำตลอดการเก็บรักษา โดยสรุปสูตรที่ใช้คาราจีแนนร้อยละ 0.6 ร่วมกับผงบุกร้อยละ 0.07 และทดแทนน้ำตาลทรายด้วยซูคราโลสร้อยละ 50 เป็นสูตรที่เหมาะสมที่สุดในกลุ่มที่ศึกษา โดยสามารถลดพลังงานของผลิตภัณฑ์ ขณะที่ยังคงคะแนนความชอบโดยรวมใกล้เคียงสูตรควบคุม และมีสมบัติทางกายภาพ เคมี และคุณภาพทางจุลชีววิทยาค่อนข้างคงตัวภายใต้การเก็บรักษาแบบแช่เย็นเป็นเวลา 4 สัปดาห์

คำสำคัญ: ว่านหางจระเข้, เครื่องดื่มเยลลี่, ซูคราโลส, การทดแทนน้ำตาลทราย, สารออกฤทธิ์ทางชีวภาพ

Abstract

This study aimed to develop a reduced-energy *Aloe vera* jelly beverage containing fruit juice and to evaluate its physicochemical properties, sensory liking, bioactive compounds, nutritional composition, and storage stability. The effects of carrageenan and konjac powder ratios, together with sucrose

replacement with sucralose at levels of 0, 50, and 100%, were investigated. Fresh *Aloe vera* gel exhibited an ABTS•$^{+}$ radical scavenging activity of 46.57 ± 3.62% at a sample concentration of 200 mg/mL and a FRAP value of 23.37 ± 0.81 mg TE/100 g fresh weight. The formulation containing 0.6% (w/w) carrageenan and 0.07% (w/w) konjac powder achieved the highest scores for taste, texture, and overall liking. Replacing 50% of sucrose with sucralose was considered the most appropriate level among those tested, providing overall liking comparable to the control while reducing the energy content from 94.52 to 59.72 kcal/100 g. The selected formulation contained a total phenolic content of 7.18 mg GAE/g sample, a total flavonoid content of 5.88 mg QE/g sample, DPPH radical scavenging activity of 34.81% at a sample concentration of 1000 mg/mL, and an aloin content of 1.25 mg/kg sample. During refrigerated storage at 4 ± 2 °C for 4 weeks, the product maintained relatively stable physicochemical properties, while total microbial counts, yeasts and molds, coliforms, *Escherichia coli*, and *Staphylococcus aureus* remained at low levels throughout storage. Overall, the formulation containing 0.6% carrageenan and 0.07% konjac powder with 50% sucrose replacement by sucralose was the most appropriate among those tested, reducing the energy content while maintaining overall liking comparable to the control and relatively stable physicochemical and microbiological quality during 4 weeks of refrigerated storage.

Keywords: *Aloe vera*, Jelly beverage, Sucralose, Sucrose replacement, Bioactive compounds

1. Introduction

Aloe vera (*Aloe barbadensis* Mill.) is a succulent plant whose inner gel has been widely utilized in the food, beverage, cosmetic, and pharmaceutical industries. Fresh *Aloe vera* gel consists predominantly of water, accounting for approximately 99% of its composition, but also contains several bioactive constituents, including polysaccharides such as glucomannan and acemannan, phenolic compounds, flavonoids, vitamins, minerals, enzymes, amino acids, and anthraquinone-related compounds (Hamman, 2008; Maan et al., 2018). These constituents have been associated with various biological activities, including antioxidant and anti-inflammatory effects, making *Aloe vera* a potentially useful plant-based ingredient for the development of functional foods and beverages (Sánchez et al., 2020). However, the sensory characteristics of *Aloe vera*, particularly its mild flavor and the possible bitterness associated with residual latex-derived compounds, may limit its palatability when used as a major beverage ingredient. Careful processing is therefore required because the yellow latex located beneath the outer rind contains anthraquinones, particularly aloin, which may adversely affect sensory quality and product safety if not adequately removed (Maan et al., 2018).

The incorporation of fruit juice into *Aloe vera*-based beverages may improve both sensory and physicochemical characteristics. Fruit juice can contribute natural sweetness, characteristic flavor and aroma, color, organic acids, soluble solids, and additional phytochemicals, thereby improving palatability and consumer liking. Previous studies have demonstrated the feasibility of combining *Aloe vera* with fruit-derived ingredients. Mishra and Sangma (2017) developed a ready-to-serve beverage containing *Aloe vera*, sweet lime, amla, and ginger and reported favorable sensory, physicochemical, phytochemical, microbiological, and storage characteristics. Sharma et al. (2022) developed a low-calorie *Aloe vera*-based beverage blended with apricot and aonla juice and showed that fruit blending and partial replacement of sucrose with a high-intensity sweetener could improve sensory quality while reducing energy content. More recently, an *Aloe vera* ready-to-drink beverage containing ginger and lemon was evaluated for sensory, biochemical, microbiological, and refrigerated storage characteristics, further supporting the use of

fruit-derived ingredients in *Aloe vera*-based beverage development. These findings support the incorporation of fruit juice as a practical approach to improving the sensory characteristics and overall quality of *Aloe vera*-based beverages.

Jelly beverages are ready-to-consume products characterized by a soft gel-like texture, and their quality is strongly influenced by the type and concentration of hydrocolloids used. Carrageenan is widely used as a gelling agent in food systems, whereas konjac glucomannan provides water-holding, thickening, and texture-modifying properties. The combination of carrageenan and konjac glucomannan can exhibit synergistic gelation, resulting in improved gel strength, elasticity, and rheological properties (Saha & Bhattacharya, 2010; Li et al., 2024). In addition to texture optimization, reducing sugar and energy content is increasingly important in the development of healthier food products. Sucralose is a high-intensity sweetener approximately 600 times sweeter than sucrose and can therefore be used at substantially lower concentrations. However, sucrose contributes not only sweetness but also flavor balance, mouthfeel, total soluble solids, and textural properties. Consequently, partial or complete replacement of sucrose with sucralose may affect both physicochemical characteristics and consumer liking (Di Monaco et al., 2018).

Although several *Aloe vera*-based beverages containing fruit-derived ingredients have been developed, previous studies have mainly focused on conventional liquid, ready-to-serve, or ready-to-drink beverages. Mishra and Sangma (2017) emphasized formulation, sensory, physicochemical, microbiological, and storage characteristics, whereas Sharma et al. (2022) investigated a reduced-energy fruit-blended *Aloe vera* beverage and sweetener replacement. A recent study by Martinez et al. (2026) integrated *Aloe vera* gel with cashew and acerola juices and evaluated formulation optimization, aloin content, physicochemical properties, and shelf-life behavior, demonstrating increasing interest in more comprehensive evaluation of *Aloe vera*-fruit beverages. Nevertheless, comparatively fewer studies have focused on *Aloe vera*-based jelly beverages containing fruit juice, particularly reduced-energy formulations. Limited information is available on studies integrating gelling-agent formulation, sucrose replacement with sucralose, consumer liking, bioactive compounds, aloin content, nutritional composition, microbiological quality, and refrigerated storage stability within a single *Aloe vera* jelly beverage development framework. Such an integrated evaluation is important because product quality and consumer liking depend simultaneously on gel structure, sweetness, energy content, bioactive composition, residual aloin, microbiological quality, and stability during storage.

In addition to addressing this research gap, the present study aimed to promote the value-added utilization of locally available *Aloe vera*. The fresh *Aloe vera* leaves used in this study were obtained from Homkhajorn Farm, Suan Dusit University, Suphan Buri Campus, Thailand. Developing a value-added food product from this university-grown raw material may provide an additional approach for expanding its utilization beyond fresh plant material. Therefore, this study aimed to develop and evaluate a reduced-energy *Aloe vera* jelly beverage containing fruit juice. The effects of carrageenan–konjac glucomannan formulation and sucrose replacement with sucralose were investigated, followed by evaluation of physicochemical properties, consumer liking, bioactive compounds, aloin content, nutritional composition, microbiological quality, and refrigerated storage stability to identify the optimal formulation among those tested.

2. Materials and methods

2.1 Raw materials and chemicals

Fresh Aloe vera leaves (*Aloe barbadensis* Mill.) were obtained from Homkhajorn Farm, Suan Dusit University, Suphan Buri Campus, Suphan Buri, Thailand. Other ingredients used for product preparation included food-grade carrageenan, konjac powder, fruit juice concentrate, sucrose, citric acid, and malic acid.

Analytical chemicals included 2,2-diphenyl-1-picrylhydrazyl (DPPH; ≥90%, Sigma-Aldrich, St. Louis, MO, USA), ethanol (analytical grade, QRec, New Zealand), Folin–Ciocalteu reagent (Fluka, USA), sodium carbonate (Na_2CO_3; Fluka, USA), gallic acid (Fluka, USA), and Trolox (Sigma-Aldrich, USA).

2.2 Quality analysis of *Aloe vera* gel

The *Aloe vera* gel was characterized for its proximate composition, bioactive compound contents, antioxidant activity, and aloin content prior to product development. Prior to analysis, fresh *Aloe vera* leaves were thoroughly washed with clean water, and the outer green rind was carefully removed to minimize contamination of the inner gel with the yellow latex-containing tissues. The inner gel was separated, washed three times with clean water to remove residual latex and surface mucilage, drained, cut into small pieces, and homogenized to obtain a uniform sample for subsequent analyses. Unless otherwise stated, analytical results for fresh *Aloe vera* gel were expressed on a fresh-weight basis.

2.2.1 Determination of chemical composition

The prepared *Aloe vera* gel was analyzed for proximate composition, including moisture, protein, fat, ash, crude fiber, and carbohydrate contents, according to the AOAC International Official Methods of Analysis (2019).

2.2.2 Determination of total phenolic content

Total phenolic content (TPC) was determined using the Folin–Ciocalteu colorimetric method, modified from Maizura et al. (2011). The homogenized *Aloe vera* gel sample was prepared at approximately 1 g/mL. Briefly, 25 µL of the sample was mixed with 125 µL of 10% (v/v) Folin–Ciocalteu reagent and allowed to react for 4 min at room temperature. Subsequently, 100 µL of 5% (w/v) sodium carbonate solution was added, and the mixture was incubated at room temperature for 30 min. Absorbance was measured at 765 nm using a microplate reader (EZ Read 2000, Biochrom Ltd., UK). All measurements were performed in triplicate. Gallic acid (0.01–0.25 mg/mL) was used to construct the calibration curve, and the results were expressed as mg gallic acid equivalents (GAE)/100 g fresh weight.

2.2.3 Determination of total flavonoid content

Total flavonoid content (TFC) was determined using the aluminium chloride colorimetric method, modified from Itsarasook et al. (2021). The *Aloe vera* gel sample solution was prepared at a concentration of 10 mg/mL. Briefly, 25 µL of the sample solution was mixed with 75 µL of 95% (v/v) ethanol, followed by the addition of 10 µL of 10% (w/v) aluminium chloride solution, 10 µL of 1.0 M potassium acetate, and 140 µL of distilled water in a 96-well microplate. The reaction mixture was incubated in the dark at room temperature for 40 min. Absorbance was measured at 415 nm using a microplate reader (EZ Read 2000, Biochrom Ltd., UK). All measurements were performed in triplicate. Total flavonoid content was calculated from a quercetin calibration curve and expressed as mg quercetin equivalents (QE)/100 g fresh weight.

2.2.4 Determination of antioxidant activity by ABTS assay

Antioxidant activity was evaluated using the ABTS radical cation decolorization assay, as modified from Vongsak et al. (2018). The $ABTS^{\bullet+}$ working solution was prepared by mixing 14 mM ABTS solution with 4.9 mM potassium persulfate solution at a ratio of 1:1 (v/v) and incubating the mixture in the

dark at room temperature for 16–20 h. The resulting ABTS•$^{+}$ solution was diluted with ethanol to obtain an absorbance of 0.70 ± 0.02 at 734 nm.

For the assay, 100 µL of the ABTS•$^{+}$ working solution was mixed with 100 µL of the *Aloe vera* gel sample solution at a concentration of 200 mg/mL. The reaction mixture was vortex-mixed and incubated in the dark at room temperature for 6 min. Absorbance was measured at 734 nm using a microplate reader (EZ Read 2000, Biochrom Ltd., UK). All measurements were performed in triplicate.

ABTS•$^{+}$ radical scavenging activity was calculated using the following equation:

ABTS•$^{+}$ radical scavenging activity (%) = [(Acontrol − Asample) / Acontrol] × 100

where *A*sample is the absorbance of the ABTS•$^{+}$ working solution mixed with the sample, and *A*control is the absorbance of the ABTS•$^{+}$ working solution without the sample. The results were expressed as percentage ABTS•$^{+}$ radical scavenging activity at a sample concentration of 200 mg/mL.

2.2.5 Determination of antioxidant activity by FRAP assay

Ferric reducing antioxidant power (FRAP) was determined using the method of Tananuwong and Tewaruth (2010), with minor modifications. The FRAP reagent was freshly prepared by mixing 300 mM acetate buffer (pH 3.6), 20 mM ferric chloride hexahydrate solution, and 10 mM TPTZ solution prepared in 40 mM HCl at a ratio of 10:1:1 (v/v/v). Subsequently, 190 µL of freshly prepared FRAP reagent was mixed with 10 µL of the *Aloe vera* gel sample solution in a 96-well microplate. The reaction mixture was incubated at 37 °C for 30 min. Absorbance was measured at 593 nm using a microplate reader (EZ Read 2000, Biochrom Ltd., UK).

Trolox was used to construct the calibration curve. FRAP values were calculated from the Trolox calibration curve and expressed as mg Trolox equivalents (TE)/100 g fresh weight. All measurements were performed in triplicate.

2.2.6 Determination of aloin content

Aloin content was determined by the Department of Medical Sciences, Ministry of Public Health, Thailand, using an in-house high-performance liquid chromatography (HPLC) method based on the procedure described by Yamamoto et al. (1985). Results were expressed as milligrams per kilogram of sample (mg/kg).

2.3 Development of *Aloe vera* jelly beverage containing fruit juice

2.3.1 Preparation of *Aloe vera* juice

Fresh *Aloe vera* leaves were washed thoroughly with tap water and cut into approximately 2-cm pieces. The outer green rind was carefully removed to prevent contamination of the inner gel with the yellow latex (aloin-containing exudate). The obtained gel was washed three times with clean water to remove residual latex and mucilage. The gel was then drained, cut into small pieces, homogenized using a blender, and filtered through a fine mesh to obtain *Aloe vera* juice for use as an ingredient in jelly beverage production.

2.3.2 Basic formulation of *Aloe vera* jelly beverage

The *Aloe vera* jelly beverage containing fruit juice was prepared using a basic formulation adapted from Phoonphu (2004), with minor modifications. The formulation consisted of *Aloe vera* juice, white grape juice concentrate (24 °Brix), carrageenan, konjac powder, sweetener, citric acid, and malic acid. White grape juice concentrate (24 °Brix) was selected as the fruit juice source.

Dry ingredients (sweetener, carrageenan, and konjac powder) were first blended to ensure uniform dispersion before being added to the heated *Aloe vera* juice. *Aloe vera* juice was heated to 80–85 °C before the dry ingredients were gradually added under continuous stirring. The mixture was

stirred continuously for 5 min until completely dissolved. White grape juice concentrate was subsequently incorporated, and stirring was continued for 2 min. After cooling to 75–80 °C, citric acid and malic acid were incorporated and mixed until completely dissolved. The resulting mixture was filled into screw-cap pouches, sealed, and allowed to gel at room temperature. The jelly beverage was then stored under refrigerated conditions (4 ± 2 °C).

This basic formulation was used as the starting formulation for investigating the effects of gelling agent ratios and sucrose replacement with sucralose on the quality of the *Aloe vera* jelly beverage.

2.3.3 Determination of the appropriate gelling agent ratio

The effects of carrageenan and konjac glucomannan concentrations on the quality of an *Aloe vera* jelly beverage containing fruit juice were investigated. Carrageenan and konjac glucomannan concentrations were varied between 0.6–0.8% (w/w) and 0.07–0.10% (w/w), respectively, based on the total formulation weight. Four formulations were prepared according to a completely randomized design (CRD), while all other ingredients were kept constant. Each formulation was evaluated for its physicochemical and sensory properties.

Each jelly beverage formulation was analyzed for physicochemical properties. Physical properties included color parameters (L*, a*, and b*), which were measured using a colorimeter (CR-400, Konica Minolta, Osaka, Japan). Total soluble solids (TSS) were determined using a hand refractometer and expressed as °Brix. Chemical properties included pH and titratable acidity (expressed as % citric acid), determined according to AOAC Official Methods (2019). All physicochemical analyses were performed in triplicate.

Consumer sensory evaluation was conducted using a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely). Fifty untrained consumers evaluated the products for color, aroma, taste, texture, and overall liking. The formulation with the highest overall liking score was selected for the subsequent sweetener optimization study.

2.3.4 Determination of the appropriate level of sucrose replacement with sucralose

The *Aloe vera* jelly beverage formulation containing the selected gelling-agent ratio from the previous experiment was used to investigate sucrose replacement with sucralose for the development of a reduced-energy jelly beverage. Three levels of sucrose replacement were evaluated: 0% replacement (control), 50% replacement, and 100% replacement. Because sucralose is a high-intensity sweetener, the amount used in each formulation was calculated based on its relative sweetness compared with sucrose to provide an approximately equivalent level of sweetness. In the 50% replacement formulation, half of the sucrose was retained and the sweetness corresponding to the remaining sucrose was provided by sucralose, whereas in the 100% replacement formulation, sucrose was completely removed and sweetness was provided by sucralose. All other ingredients in the formulation were kept constant.

The three jelly beverage formulations were analyzed for physical quality, including L*, a*, and b* color values and total soluble solids. Chemical and nutritional qualities, including pH, titratable acidity, total energy, energy from fat, carbohydrate, total fat, moisture, protein, and ash, were analyzed according to AOAC International (2019) and the laboratory's in-house methods based on Methods of analysis for nutrition labeling (Sullivan & Carpenter, 1993).

Sensory evaluation was conducted using a randomized complete block design (RCBD), with the jelly beverage formulations as treatments and consumers as blocks. Fifty untrained consumers evaluated all formulations using a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely) for color,

aroma, taste, texture, and overall liking. The appropriate formulation was selected based on overall liking and energy content.

2.3.5 Evaluation of quality changes during storage

The selected formulation was packaged in 150-g screw-cap aluminum foil pouches and stored under refrigerated conditions (4 ± 2 °C) for 4 weeks. Sample were collected at week 0 (initial value) and week 4 to evaluate changes in product quality during refrigerated storage.

Quality changes during storage were evaluated by determining physicochemical, bioactive, and microbiological properties. Physicochemical properties included color (L*, a*, b*), total soluble solids (°Brix), pH, and titratable acidity (% citric acid). Bioactive properties included total phenolic content, total flavonoid content, and DPPH radical scavenging activity. Microbiological quality was evaluated by determining total viable count (TVC), yeasts and molds, coliforms, *Escherichia coli*, and *Staphylococcus aureus*, according to the APHA (2015) and AOAC Official Methods (2019).

2.3.6 Quality analysis of the final product

The selected formulation was analyzed for total phenolic content, total flavonoid content, antioxidant activity, aloin content, and nutritional composition.

2.3.6.1 Total phenolic content

Total phenolic content (TPC) of the final jelly beverage was determined according to the method described in Section 2.2.2. The results were expressed as mg gallic acid equivalents (GAE)/g sample.

2.3.6.2 Total flavonoid content

Total flavonoid content (TFC) of the final jelly beverage was determined according to the method described in Section 2.2.3. The results were expressed as mg quercetin equivalents (QE)/g sample.

2.3.6.3 DPPH radical scavenging activity

Antioxidant activity of the final jelly beverage was evaluated using the DPPH radical scavenging assay following the method of Itsarasook et al. (2021), with minor modifications. A 0.2 mM DPPH solution was prepared in ethanol. The jelly beverage samples were extracted with 70% (v/v) ethanol. In a 96-well microplate, 75 µL of the sample extract was mixed with 150 µL of DPPH solution and incubated in the dark at room temperature for 30 min. Absorbance was measured at 515 nm using a microplate reader (EZ Read 2000, Biochrom Ltd., UK). DPPH radical scavenging activity was calculated using the following equation:

$$\%\ \text{DPPH scavenging} = \frac{Abs_{blank} - Abs_{sample}}{Abs_{blank}} \times 100 \quad (1)$$

where Abs_{sample} is the absorbance of the DPPH solution mixed with the sample extract, and $Abs_{control}$ is the absorbance of the DPPH solution without the sample extract.

The results were expressed as percentage DPPH radical scavenging activity at a sample concentration of 1000 mg/mL.

2.3.6.4 Aloin content

Aloin content in the final jelly beverage was determined by the Department of Medical Sciences, Ministry of Public Health, Thailand, using the same in-house HPLC method described in Section 2.2.6. Results were expressed as mg/kg of sample.

2.3.6.5 Nutritional composition

The selected formulation was submitted to Central Laboratory (Thailand) Co., Ltd., Thailand, for nutritional analysis. Energy, energy from fat, total fat, saturated fat, cholesterol, protein, carbohydrate, dietary fiber, sugars, sodium, calcium, iron, ash, and moisture contents were determined according to AOAC standard methods (AOAC International, 2019) and the laboratory's in-house methods based on Methods of Analysis for Nutrition Labeling (Sullivan & Carpenter, 1993).

2.4 Statistical analysis

Physicochemical and chemical data are presented as mean ± standard deviation (SD) of triplicate analyses. Statistical analyses were performed using IBM SPSS Statistics version 23 (IBM Corp., Armonk, NY, USA). Differences among formulations were analyzed using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test. Statistical significance was considered at $p < 0.05$.

Sensory evaluation was conducted using a randomized complete block design (RCBD), with formulations as treatments and consumers as blocks. Sensory liking scores from 50 untrained consumers using a 9-point hedonic scale were analyzed by ANOVA according to the RCBD. Duncan's multiple range test was used for mean comparison when significant differences were detected ($p < 0.05$).

3. Results

The physicochemical properties, bioactive compounds, antioxidant activity, and product development of the reduced-energy Aloe vera jelly beverage containing fruit juice are presented in this section.

3.1 Chemical composition, bioactive compounds, and antioxidant activity of *Aloe vera* gel

The chemical composition, bioactive compounds, and antioxidant activity of fresh *Aloe vera* gel are summarized in Table 1. Moisture was the predominant component of *Aloe vera* gel, accounting for 99.26%, followed by carbohydrate (0.47%), dietary fiber (0.46%), and ash (0.27%). Protein and fat contents were less than 0.10% and 0.01%, respectively. These findings confirm that *Aloe vera* gel is a high-moisture raw material with low levels of macronutrients, consistent with previous reports.

Regarding bioactive compounds, fresh *Aloe vera* gel contained a total phenolic content of 2.9 ± 0.4 mg GAE/100 g fresh weight and a total flavonoid content of 2.24 ± 0.30 mg QE/100 g fresh weight. Because fresh *Aloe vera* gel had a very high moisture content (99.26%), the relatively low values observed on a fresh-weight basis may partly reflect the high proportion of water in the sample. Therefore, comparison with previous studies reporting phenolic or flavonoid contents on a dry-weight basis should be interpreted with caution. Although the measured total flavonoid content appeared numerically similar to the total phenolic content, these values should not be directly compared quantitatively because the Folin–Ciocalteu and aluminium chloride assays are based on different analytical principles and use different calibration standards, namely gallic acid and quercetin, respectively. Thus, the reported values represent method-dependent estimates of phenolic- and flavonoid-related compounds rather than directly comparable absolute concentrations.

Fresh *Aloe vera* gel exhibited an ABTS•+ radical scavenging activity of 46.57 ± 3.62% at a sample concentration of 200 mg/mL and a FRAP value of 23.37 ± 0.81 mg TE/100 g fresh weight. These results indicate that the fresh gel exhibited measurable antioxidant activity under the assay conditions used. The aloin content of the fresh *Aloe vera* gel was 2.50 mg/kg sample.

Table 1. Chemical composition, bioactive compounds, and antioxidant activity of fresh *Aloe vera* gel

Parameter	Content
Carbohydrate (%)	0.47
Protein (%)	<0.10
Fat (%)	<0.01
Ash (%)	0.27
Dietary fiber (%)	0.46
Moisture (%)	99.26
Total phenolic content (mg GAE/100 g fresh weight)	2.90±0.40
Total flavonoid content (mg QE/100 g fresh weight)	2.24±0.30
ABTS radical scavenging activity (%) at 200 mg/mL	46.57±3.62
Ferric reducing antioxidant power (FRAP) (mg TE/100 g fresh weight)	23.37±0.81
Aloin (mg/kg sample)	2.50

Note: The symbol "<" indicates that the value was below the reporting limit of the analytical method

3.2 Development of *Aloe vera* jelly beverage containing fruit juice

3.2.1 Effect of gelling agent ratio on sensory liking of *Aloe vera* jelly beverage containing fruit juice

Gelling agents play an important role in determining the texture and sensory characteristics of jelly beverages. Table 2 summarizes the sensory evaluation scores of *Aloe vera* jelly beverages prepared with different carrageenan and konjac glucomannan ratios.

Table 2. Sensory evaluation scores of *Aloe vera* jelly beverages with different gelling agent ratios

Attribute	Carrageenan 0.6% + Konjac powder 0.07%	Carrageenan 0.6% + Konjac powder 0.10%	Carrageenan 0.8% + Konjac powder 0.07%	Carrageenan 0.8% + Konjac powder 0.10%
Color ^{ns}	7.22 ± 0.61	7.16 ± 0.62	7.01 ± 0.60	7.00 ± 0.45
Aroma ^{ns}	7.26 ± 0.82	7.02 ± 0.86	7.10 ± 0.91	7.00 ± 0.90
Taste	7.36 ± 0.89^{a}	6.97 ± 0.82^{b}	6.84 ± 0.74^{b}	6.77 ± 0.74^{b}
Texture	7.42 ± 0.83^{a}	6.94 ± 0.74^{b}	6.78 ± 0.68^{b}	6.72 ± 0.67^{b}
Overall liking	7.39 ± 0.86^{a}	7.00 ± 0.69^{b}	6.68 ± 0.69^{c}	6.67 ± 0.59^{c}

Note: Different superscript letters within the same row indicate significant differences ($p < 0.05$); ns indicates no significant difference ($p > 0.05$).

The sensory evaluation scores of *Aloe vera* jelly beverages formulated with different concentrations of carrageenan and konjac glucomannan are shown in Table 2. The results showed that the color and aroma liking scores of the four formulations were not significantly different ($p > 0.05$). The color scores ranged from 7.00 to 7.22, while the aroma scores ranged from 7.00 to 7.26. These findings indicate that variations in carrageenan and konjac glucomannan concentrations did not significantly influence sensory liking of color and aroma ($p > 0.05$).

For taste, texture, and overall liking, the formulation containing 0.6% carrageenan and 0.07% konjac glucomannan received the highest scores, with values of 7.36 ± 0.89, 7.42 ± 0.83, and 7.39 ±

0.86, respectively. These scores were significantly higher ($p < 0.05$) than those of the other formulations. Increasing the concentrations of carrageenan and/or konjac glucomannan generally reduced the liking scores for taste, texture, and overall liking. Therefore, the formulation containing 0.6% carrageenan and 0.07% konjac glucomannan was selected as the optimal gelling agent formulation for further development of the *Aloe vera* jelly beverage.

3.2.2 Effect of carrageenan and konjac glucomannan ratios on the physicochemical properties of *Aloe vera* jelly beverage

Table 3 summarizes the physicochemical properties of *Aloe vera* jelly beverages prepared with different carrageenan and konjac glucomannan ratios. No significant differences ($p > 0.05$) were observed in L* and b* values among the four formulations, with values ranging from 31.07 to 31.57 and from 24.16 to 24.32, respectively. These results suggest that the tested gelling agent concentrations had little influence on the lightness and yellowness of the products. This observation is likely attributable to the identical concentrations of *Aloe vera* juice and white grape juice concentrate, which were the primary contributors to product color.

Table 3. Physicochemical properties of *Aloe vera* jelly beverage with different ratios of gelling agents

Attribute	Carrageenan 0.6% + Konjac powder 0.07%	Carrageenan 0.6% + Konjac powder 0.10%	Carrageenan 0.8% + Konjac powder 0.07%	Carrageenan 0.8% + Konjac powder 0.10%
Color value L* ^{ns}	31.57± 0.42	31.45 ±0.23	31.07± 0.65	31.52 ±0.17
a*	4.14 ±0.06^{a}	4.04 ±0.07^{b}	4.07 ±0.07^{ab}	4.01 ±0.08^{b}
b* ^{ns}	24.16± 0.33	24.25 ±0.37	24.32 ±0.27	24.30 ±0.15
pH	3.43 ±0.06^{b}	3.46 ±0.01^{b}	3.51 ±0.01^{a}	3.53± 0.02^{a}
Titratable acidity (%)	0.70 ±0.01^{a}	0.68 ±0.01^{ab}	0.66 ±0.01^{b}	0.66 ±0.01^{b}
Total soluble solids ns (°Brix) ^{ns}	17.05±0.13	16.67±0.45	16.85±0.12	16.72±0.22

Note: Different superscript letters within the same row indicate significant differences ($p \leq 0.05$); ns indicates no significant difference ($p > 0.05$).

The *a** values differed significantly among formulations ($p < 0.05$). However, the magnitude of the difference was small (4.01–4.14), suggesting only a minor effect of gelling agent ratio on product redness. Therefore, the gelling agent ratio exerted only a minor influence on product redness.

The pH values ranged from 3.43 to 3.53, while titratable acidity ranged from 0.66% to 0.70%. As expected, formulations with lower pH exhibited higher titratable acidity because pH and titratable acidity are inversely related. Total soluble solids (TSS) did not differ significantly ($p > 0.05$) among formulations, with values ranging from 16.67 to 17.05 °Brix. This finding is likely attributable to the constant levels of sucrose and white grape juice concentrate across formulations, whereas only the hydrocolloid concentrations were varied.

3.2.3 Effect of sucrose replacement with sucralose on sensory liking of *Aloe vera* jelly beverage containing fruit juice

The sensory liking scores of *Aloe vera* jelly beverages prepared with different levels of sucrose replacement by sucralose are presented in Table 4. The results showed that the color, aroma, and texture liking scores of the three formulations were not significantly different ($p > 0.05$). The color scores ranged from 7.10 to 7.16, aroma scores ranged from 6.92 to 7.08, and texture scores ranged from 7.24 to

7.36. These findings indicate that sucrose replacement with sucralose at levels of 50% and 100% did not significantly affect sensory liking of color, aroma, and texture.

Table 4. Sensory quality of *Aloe vera* jelly beverages with different levels of sucrose replacement with sucralose

Attribute	Control formulation (0% sucrose replacement)	50% sucrose replacement with sucralose	100% sucrose replacement with sucralose
Color ^{ns}	7.16±0.93	7.10±0.86	7.12±0.75
Aroma ^{ns}	7.08±0.60	7.06±0.71	6.92±0.83
Taste	7.28±0.75^{a}	7.14±0.81^{a}	6.76±0.98^{b}
Texture ^{ns}	7.36±1.01	7.32±0.84	7.24±0.94
Overall liking	7.28±0.83^{a}	7.22±0.81^{ab}	6.90±0.84^{b}

Note: Values are expressed as mean ± SD. Different superscript letters within the same row indicate significant differences ($p \leq 0.05$); ns indicates no significant difference ($p > 0.05$).

For taste, no significant difference ($p > 0.05$) was observed between the control formulation and the formulation with 50% sucrose replacement with sucralose, with mean scores of 7.28 ± 0.75 and 7.14 ± 0.81, respectively. However, complete replacement of sucrose with sucralose significantly reduced the taste score to 6.76 ± 0.98 compared with the other two formulations ($p \leq 0.05$). A similar trend was observed for overall liking, with the formulation containing 100% sucrose replacement receiving the lowest score (6.90 ± 0.84). The overall liking score of the control formulation (7.28 ± 0.83) was significantly higher than that of the 100% replacement formulation, whereas the formulation with 50% sucrose replacement (7.22 ± 0.81) did not differ significantly from either formulation ($p > 0.05$).

Therefore, replacing 50% of sucrose with sucralose was considered the most appropriate level among the formulations tested for developing a reduced-energy *Aloe vera* jelly beverage containing fruit juice, as this formulation maintained taste liking and overall liking comparable to those of the control formulation while allowing a substantial reduction in sucrose content.

3.2.4 Effect of sucrose replacement with sucralose on the physicochemical properties and energy content of Aloe vera jelly beverage

Table 5 summarizes the physicochemical properties and energy content of *Aloe vera* jelly beverages formulated with 0%, 50%, and 100% sucrose replacement with sucralose. No significant differences were observed in L* values among the three formulations ($p > 0.05$), with values ranging from 31.23 to 31.78. These findings indicate that sucrose replacement with sucralose did not markedly affect the lightness of the product. In contrast, significant differences were observed in the a* and b* values among the formulations ($p \leq 0.05$). The formulation with 50% sucrose replacement with sucralose exhibited lower a* and b* values than the control and the formulation with 100% sucrose replacement. These differences may be associated with variations in sucrose concentration and soluble solids within the gel system.

Table 5. Physicochemical properties and nutritional composition of *Aloe vera* jelly beverages with different levels of sucrose replacement with sucralose

Parameter	Control formulation (0% sucrose replacement)	50% sucrose replacement with sucralose	100% sucrose replacement with sucralose
Color (L*) ^{ns}	31.23 ± 0.15	31.28 ± 0.49	31.78 ±0.46
a*	4.28 ±0.16^{a}	4.02 ±0.17^{b}	4.33 ±0.09^{a}
b*	24.26± 0.29^{a}	21.65 ±1.06^{b}	24.28 ±0.45^{a}
pH	3.41 ±0.01^{a}	3.39± 0.01^{b}	3.39 ±0.01^{ab}
Titratable acidity ^{ns} (% citric acid)	0.80 ±0.03	0.86± 0.04	0.89 ±0.08
Total soluble solids (°Brix)	15.9± 0.10^{a}	12.5± 0.10^{b}	8.50± 0.10^{c}
Energy (kcal/100 g)	94.52	59.72	26.00
Energy from fat (kcal/100 g)	0	0	0
Carbohydrate (%)	23.47	14.74	6.28
Total fat (%)	<0.01	<0.01	<0.01
Moisture (%)	76.03	84.75	93.13
Protein (%)	0.17	0.19	0.22
Ash (%)	0.34	0.32	0.37

The pH values ranged from 3.39 to 3.41, indicating only minor variation among the formulations. Although statistically significant differences were detected ($p < 0.05$), the magnitude of these differences was very small. Titratable acidity ranged from 0.80% to 0.89% and did not differ significantly among the formulations ($p > 0.05$). This is likely because identical amounts of citric acid and malic acid were added to all formulations, resulting in comparable acidity.

Total soluble solids (TSS) decreased significantly ($p < 0.05$) as the level of sucrose replacement increased. TSS decreased from 15.90 ± 0.10 °Brix in the control formulation to 12.50 ± 0.10 and 8.50 ± 0.10 °Brix in the formulations with 50% and 100% sucrose replacement with sucralose, respectively. The reduction in TSS was expected because sucrose is a major contributor to soluble solids, whereas sucralose is a high-intensity sweetener used in much smaller quantities. In addition to providing sweetness, sucrose contributes to the flavor, texture, and mouthfeel of food products; therefore, its reduction or complete replacement may alter the overall sensory characteristics of the product (Di Monaco et al., 2018). High-intensity sweeteners may also differ from sucrose in sweetness quality and temporal sensory characteristics, which can influence consumer perception and acceptance (Di Monaco et al., 2014). Consequently, the lower TSS together with the complete removal of sucrose may have contributed to the lower taste and overall liking scores observed for the formulation with 100% sucrose replacement.

Regarding energy content, replacing sucrose with sucralose markedly reduced the energy content of the product. The energy content decreased from 94.52 kcal/100 g in the control formulation to 59.72 and 26.00 kcal/100 g in the formulations containing 50% and 100% sucrose replacement, respectively. This reduction was primarily attributable to the decrease in carbohydrate content because sucrose was progressively replaced with the high-intensity sweetener sucralose.

Carbohydrate content decreased from 23.47% in the control formulation to 14.74% and 6.28% in the formulations with 50% and 100% sucrose replacement, respectively. Energy from fat was 0 kcal/100 g, while total fat remained below 0.01% in all formulations.

Moisture content increased progressively with increasing levels of sucrose replacement, from 76.03% in the control formulation to 84.75% and 93.13% in the formulations with 50% and 100% sucrose replacement, respectively. The increase in moisture content corresponded to the reductions in carbohydrate content and total soluble solids, reflecting the replacement of sucrose with a high-intensity sweetener used at substantially lower concentrations. Considering both sensory liking and energy reduction, the formulation with 50% sucrose replacement with sucralose was selected as the most appropriate reduced-energy *Aloe vera* jelly beverage formulation among those tested for further quality evaluation.

3.3 Quality changes during storage

3.3.1 Changes in physicochemical properties and bioactive compounds during storage

The quality changes of the selected reduced-energy *Aloe vera* jelly beverage during refrigerated storage (4 ± 2 °C) are summarized in Table 6.

Table 6. Changes in physicochemical properties and bioactive compounds of *Aloe vera* jelly beverage during refrigerated storage

Parameter	Week 0	Week 4
Color (L*) ^{ns}	31.55±0.27	31.37±0.23
a* ^{ns}	4.02±0.16	4.03±0.12
b* ^{ns}	22.57±0.20	22.81±0.40
pH ^{ns}	3.42±0.03	3.46±0.02
Titratable acidity ^{ns}	0.77±0.03	0.74±0.04
Total soluble solids (°Brix) ^{ns}	16.8±0.10	16.63±0.15
Total phenolic content (mg GAE/g sample) ^{ns}	7.18±1.63	6.86±0.73
Total flavonoid content (mg QE/g sample) ^{ns}	5.88±1.41	5.04±0.99
DPPH radical scavenging activity (%) at 1,000 mg/mL	34.81±0.60^{a}	32.01±0.07^{b}

Note: Values are expressed as mean ± SD. Different superscript letters within the same row indicate significant differences ($p \leq 0.05$); ns indicates no significant difference ($p > 0.05$).

The absence of significant changes in L*, a*, b*, pH, titratable acidity, and total soluble solids suggests that the selected *Aloe vera* jelly beverage maintained relatively stable physicochemical properties during 4 weeks of refrigerated storage. Although total phenolic and total flavonoid contents showed slight decreases during storage, these changes were not statistically significant, indicating that these bioactive components remained relatively stable over the storage period. In contrast, DPPH radical scavenging activity decreased significantly from 34.81 ± 0.60% to 32.01 ± 0.07% ($p < 0.05$). This reduction may be associated with oxidation or reduced activity of antioxidant constituents during storage, even though the measured total phenolic and flavonoid contents remained relatively stable.

3.3.2 Changes in microbiological quality of *Aloe vera* jelly beverage during storage

The microbiological quality of the selected *Aloe vera* jelly beverage during refrigerated storage is summarized in Table 7. Total viable counts and yeast and mold counts remained below 10 CFU/g throughout storage. Coliforms and *Escherichia coli* remained < 3 MPN/g, while *Staphylococcus aureus* remained <10 CFU/g throughout the storage period.

Table 7. Microbiological quality of *Aloe vera* jelly beverage during refrigerated storage

Microbiological parameter	Week 0	Week 4
Total viable count (CFU/g)	<10	<10
Yeast and mold count (CFU/g)	<10	<10
Coliforms (MPN/g)	<3	<3
Escherichia coli (MPN/g)	<3	<3
Staphylococcus aureus (CFU/g)	<10	<10

These findings indicate that the measured microbiological counts remained low throughout refrigerated storage. The observed microbiological stability may be associated with the low pH of the product (approximately 3.4), together with refrigerated storage and the use of screw-cap aluminum foil pouches, which may have helped minimize external contamination and restrict microbial growth. Overall, the selected *Aloe vera* jelly beverage remained microbiologically stable throughout 4 weeks of refrigerated storage at 4 ± 2 °C.

3.4 Quality characteristics of the final *Aloe vera* jelly beverage formulation

The selected reduced-energy *Aloe vera* jelly beverage containing fruit juice was analyzed for its physicochemical, nutritional, and bioactive characteristics. Table 8 summarizes the physicochemical, nutritional, and bioactive characteristics of the selected formulation. The product contained an energy content of 59.72 kcal/100 g. Carbohydrate was the major macronutrient contributing to the energy content, with a content of 14.74 g/100 g, of which sugars accounted for 12.63 g/100 g. Protein was present at a relatively low level of 0.19 g/100 g, while the moisture content was 84.75 g/100 g, consistent with the high water content characteristic of jelly beverages. The product also contained sodium, calcium, and iron at 75.12, 71.23, and 0.39 mg/100 g, respectively.

Regarding bioactive compounds, the final product contained a total phenolic content of 7.18 mg GAE/g sample and a total flavonoid content of 5.88 mg QE/g sample. DPPH radical scavenging activity was 34.81% at a sample concentration of 1000 mg/mL. These findings indicate that the final product contained measurable levels of phenolic- and flavonoid-related compounds and exhibited DPPH radical scavenging activity under the assay conditions used. The total phenolic content of the final formulation was higher than that measured in fresh *Aloe vera* gel. This difference may be attributed, at least in part, to the contribution of other ingredients in the formulation, particularly white grape juice concentrate, which may provide additional phenolic compounds. However, the individual contribution of each ingredient to the total phenolic content was not determined in the present study; therefore, this interpretation should be considered cautiously.

The aloin content determined by high-performance liquid chromatography (HPLC) was 1.25 mg/kg sample, which was lower than that measured in fresh *Aloe vera* gel. The lower aloin content may be associated with several factors, including removal of the outer leaf tissues, washing and separation of the *Aloe vera* gel from latex-containing tissues, and dilution with other ingredients during product formulation. Because these factors were not evaluated independently, their individual contributions to the reduction in aloin content cannot be determined from the present study.

Overall, the selected formulation had a reduced energy content and contained measurable levels of bioactive compounds and antioxidant activity. These findings describe the nutritional and bioactive characteristics of the selected reduced-energy *Aloe vera* jelly beverage formulation under the conditions evaluated in this study.

Table 8. Nutritional composition, bioactive compounds, antioxidant activity, and aloin content of the selected *Aloe vera* jelly beverage formulation

Parameter	Content
Energy (kcal/100 g)	59.72
Energy from fat (kcal/100 g)	0
Total fat (g/100 g)	<0.01
Saturated fat (g/100 g)	Not detected
Cholesterol (mg/100 g)	Not detected
Protein (g/100 g)	0.19
Carbohydrate (g/100 g)	14.74
Dietary fiber (g/100 g)	0.99
Sugars (g/100 g)	12.63
Sodium (mg/100 g)	75.12
Calcium (mg/100 g)	71.23
Iron (mg/100 g)	0.39
Ash (g/100 g)	0.32
Moisture (g/100 g)	84.75
Total phenolic content (mg GAE/g sample)	7.18
Total flavonoid content (mg QE/g sample)	5.88
DPPH radical scavenging activity (%)at 1000 mg/mL	34.81
Aloin (mg/kg sample)	1.25

Note: "Not detected" indicates that the value was below the detection limit of the analytical method.

4. Discussion

The analysis of fresh *Aloe vera* gel showed that moisture was the predominant component, accounting for 99.26%, whereas protein, fat, carbohydrate, ash, and dietary fiber were present at relatively low levels. This finding is consistent with previous reports indicating that *Aloe vera* gel consists primarily of water, accounting for approximately 99% of its composition, while the remaining solids include polysaccharides, vitamins, minerals, organic acids, enzymes, and phenolic compounds (Hamman, 2008; Maan et al., 2018).

The TPC and TFC values were expressed on a fresh-weight basis because fresh *Aloe vera* gel was used for analysis. Given the very high moisture content of the gel (99.26%), direct comparison with studies reporting results on a dry-weight basis should be interpreted with caution. Although the total phenolic content of fresh *Aloe vera* gel was relatively low, the gel exhibited antioxidant activity as determined by the ABTS and FRAP assays, with an ABTS•+ radical scavenging activity of 46.57 ± 3.62% at a sample concentration of 200 mg/mL and a FRAP value of 23.37 ± 0.81 mg TE/100 g fresh weight. These findings suggest that the observed antioxidant activity may not be associated solely with total phenolic compounds but may also reflect contributions from other bioactive constituents, including flavonoids, polysaccharides, vitamins, and other phytochemicals that may act individually or synergistically. Several flavonoids have been reported in *Aloe vera* and related *Aloe* species, including genistein, isovitexin, isorhamnetin, daidzein, vicenin-2, lucenin-2, and orientin, some of which have been associated with antioxidant and anti-

inflammatory activities (Tizazu & Bekele, 2024). This interpretation is consistent with previous reports indicating that *Aloe vera* contains multiple classes of bioactive compounds with potential antioxidant and anti-inflammatory activities (Sánchez et al., 2020). However, because no correlation analysis between individual bioactive compounds and antioxidant activity was performed in the present study, a direct causal relationship cannot be established.

Aloin was detected in fresh *Aloe vera* gel at 2.50 mg/kg sample, indicating the presence of a low measurable level of latex-derived constituents after gel preparation. Aloin is an anthraquinone glycoside associated with the laxative activity of aloe latex and is predominantly located in the yellow latex layer beneath the leaf rind (Boudreau et al., 2017). Its concentration in *Aloe vera* products can be influenced by raw material preparation and processing, particularly the extent of rind removal, separation of the inner gel from latex-containing tissues, and washing. Therefore, careful removal of the outer leaf tissues, separation of the gel from the yellow latex, and thorough washing are important processing steps for minimizing residual aloin in *Aloe vera*-based food products. From a safety perspective, the European Food Safety Authority has raised concerns regarding hydroxyanthracene derivatives, particularly in relation to prolonged or high-level exposure (EFSA Panel on Food Additives and Nutrient Sources Added to Food, 2018). The aloin concentration observed in the present study should therefore be interpreted in the context of differences in raw material preparation and latex-removal procedures among studies. Direct comparison with regulatory limits should also be made cautiously because applicable criteria may vary according to product category and jurisdiction.

The present study demonstrated that the ratio of carrageenan to konjac glucomannan significantly influenced taste, texture, and overall liking of the *Aloe vera* jelly beverage. The formulation containing 0.6% carrageenan and 0.07% konjac glucomannan received the highest liking scores among the formulations tested. This finding may be explained by the complementary functional properties of the two hydrocolloids, whereby carrageenan contributes to gel formation while konjac glucomannan enhances water binding and modifies gel texture. This observation agrees with previous studies reporting that hydrocolloids can improve the rheological and textural properties of food systems and that interactions between konjac glucomannan and **K**-carrageenan can influence gel strength, elasticity, and overall structural characteristics (Saha & Bhattacharya, 2010; Li et al., 2024). The lower texture and overall liking scores observed at higher hydrocolloid concentrations suggest that excessive gel strength may have negatively affected sensory perception, possibly by producing a firmer, denser, or more adhesive gel structure.

The physicochemical analyses of the jelly beverages formulated with different gelling-agent ratios showed no significant differences in L*, b*, or total soluble solids among the formulations. These findings indicate that variation in the levels of carrageenan and konjac glucomannan within the studied range had little effect on product lightness, yellowness, or soluble solids content. These findings are likely attributable to the relatively small quantities of hydrocolloids used and to the fact that the major ingredients contributing to product color and soluble solids were maintained at constant levels across the formulations.

When sucrose was replaced with sucralose, the formulation with 50% sucrose replacement showed taste and overall liking scores comparable to the control formulation. In contrast, complete replacement of sucrose with sucralose significantly reduced the taste score compared with both the control and 50% replacement formulations, while the overall liking score was significantly lower than that of the control formulation. These findings confirm that sucrose contributes not only sweetness but also flavor balance, mouthfeel, and overall sensory quality. This interpretation is consistent with Di Monaco et al. (2018), who reported that sugar contributes to flavor, texture, and several other quality attributes of food products. Sucralose is a high-intensity sweetener with a sweetness approximately 600 times greater than that of

sucrose and is used at very low concentrations because of its high sweetening potency, thereby reducing sugar and energy contents. However, it cannot fully replace the bulking and sensory functions of sucrose in food systems (U.S. Food and Drug Administration [FDA], n.d.).

The results of the present study are consistent with those of Kanpairo (2018), who reported that 50% sucrose replacement with sucralose in torch ginger gummy jelly resulted in an overall liking score that was not significantly different from that of the control formulation. This suggests that partial sucrose replacement may maintain sensory liking more effectively than complete replacement. Therefore, replacing 50% of sucrose with sucralose may represent an effective strategy for reducing the energy content of jelly products while maintaining liking comparable to that of the control formulation.

Regarding the physicochemical properties and energy content, replacing sucrose with sucralose markedly reduced total soluble solids from 15.90 °Brix in the control formulation to 12.50 and 8.50 °Brix in the formulations with 50% and 100% sucrose replacement, respectively. This reduction was primarily associated with the progressive decrease in sucrose and carbohydrate contents, as sucralose provides sweetness at substantially lower concentrations than sucrose. Consequently, the energy content decreased from 94.52 kcal/100 g in the control formulation to 59.72 and 26.00 kcal/100 g in the formulations with 50% and 100% sucrose replacement, respectively. When overall liking was considered together with energy reduction, the formulation with 50% sucrose replacement was considered the most appropriate among the formulations tested, as it achieved a substantial reduction in energy content while maintaining taste and overall liking comparable to the control formulation.

The final product contained an energy content of 59.72 kcal/100 g and measurable levels of bioactive compounds and antioxidant activity, including a total phenolic content of 7.18 mg GAE/g sample, a total flavonoid content of 5.88 mg QE/g sample, DPPH radical scavenging activity of 34.81% at a sample concentration of 1000 mg/mL, and an aloin content of 1.25 mg/kg sample. The higher total phenolic content of the final product compared with fresh *Aloe vera* gel may be attributed, at least in part, to the contribution of other ingredients in the formulation, particularly white grape juice concentrate, which may provide additional phenolic compounds and other antioxidant-related constituents. However, the present study did not determine the individual contribution of each ingredient to the total phenolic content; therefore, this interpretation should be considered cautiously. The lower aloin content of the final product compared with fresh *Aloe vera* gel may be associated with several factors, including removal of the outer leaf tissues, washing and separation of the *Aloe vera* gel from latex-containing tissues, and dilution with other ingredients during product formulation. Because these factors were not evaluated independently, their individual contributions to the reduction in aloin content cannot be determined from the present study.

DPPH radical scavenging activity was also examined during the preliminary evaluation of fresh *Aloe vera* gel; however, the observed activity was very low, and some calculated inhibition values were negative under the tested conditions. Therefore, antioxidant activity of the fresh gel was primarily interpreted using the ABTS and FRAP assays. In contrast, the final jelly beverage and changes in its antioxidant activity during storage were evaluated using the DPPH assay. Differences in assay mechanisms and sample preparation conditions may have influenced the observed responses. Consequently, antioxidant values obtained from the fresh gel and the final product were interpreted separately and were not directly compared quantitatively. Future studies should apply the same antioxidant assay across experimental stages to improve comparability.

During storage, the selected *Aloe vera* jelly beverage formulation maintained relatively stable physicochemical properties under refrigerated conditions at 4 ± 2 °C for 4 weeks. Color values, pH, titratable acidity, and total soluble solids did not change significantly during storage. The observed stability may be

associated with the combined effects of the acidic pH of the product and refrigerated storage. Although the screw-cap aluminum foil pouch may also have helped limit exposure to light, oxygen, and external contamination, its specific protective effect was not independently evaluated in the present study. Total phenolic and total flavonoid contents showed slight decreases after 4 weeks of storage, although these changes were not statistically significant. In contrast, DPPH radical scavenging activity decreased significantly during storage. This finding suggests that changes in antioxidant activity may have occurred even though the measured total phenolic and flavonoid contents remained statistically unchanged. Such differences may reflect changes in specific antioxidant constituents or their reactivity during storage; however, individual antioxidant compounds were not determined in the present study. The product nevertheless retained measurable levels of bioactive compounds and DPPH radical scavenging activity after 4 weeks of refrigerated storage.

Overall, the results demonstrated that the *Aloe vera* jelly beverage containing fruit juice formulated with 0.6% carrageenan, 0.07% konjac powder, and 50% sucrose replacement with sucralose was the most appropriate formulation among those tested. This formulation reduced energy content while maintaining overall liking comparable to the control and showed relatively stable physicochemical properties and low microbiological counts during 4 weeks of refrigerated storage. The product also contained measurable levels of bioactive compounds and antioxidant activity. However, the present study evaluated storage stability for only 4 weeks and employed untrained consumers for sensory evaluation. Further studies should investigate longer storage periods, consumer liking among target populations, changes in individual bioactive compounds and antioxidant stability during storage, and product performance under conditions relevant to industrial-scale production.

5. Conclusions and recommendations

This study developed a reduced-energy *Aloe vera* jelly beverage containing fruit juice. Fresh *Aloe vera* gel contained 99.26% moisture and relatively low levels of energy-providing nutrients. The gel also contained measurable levels of phenolic compounds, flavonoids, and aloin and exhibited antioxidant activity as determined by the ABTS and FRAP assays.

Among the gelling-agent formulations tested, the formulation containing 0.6% carrageenan and 0.07% konjac powder received the highest liking scores for taste, texture, and overall liking and was therefore selected as the base formulation for further development. When sucrose replacement with sucralose was investigated, replacing 50% of sucrose with sucralose was identified as the most appropriate level among those tested because it maintained taste and overall liking comparable to the control formulation while reducing the energy content from 94.52 to 59.72 kcal/100 g.

The final product contained a total phenolic content of 7.18 mg GAE/g sample, a total flavonoid content of 5.88 mg QE/g sample, DPPH radical scavenging activity of 34.81% at a sample concentration of 1000 mg/mL, and an aloin content of 1.25 mg/kg sample. After 4 weeks of refrigerated storage at 4 ± 2 °C, no significant changes were observed in color values, pH, titratable acidity, or total soluble solids. Total phenolic and total flavonoid contents also remained relatively stable, although DPPH radical scavenging activity decreased significantly during storage. Total viable counts and yeast and mold counts remained below 10 CFU/g, coliforms and *Escherichia coli* remained <3 MPN/g, and *Staphylococcus aureus* remained <10 CFU/g throughout the storage period.

Overall, the formulation containing 0.6% carrageenan, 0.07% konjac powder, and 50% sucrose replacement with sucralose was the most appropriate among those tested. It reduced energy content while

maintaining overall liking comparable to the control and showed relatively stable physicochemical properties and low microbiological counts during 4 weeks of refrigerated storage. Further studies should investigate longer storage periods, changes in individual bioactive compounds and antioxidant stability, consumer liking among target populations, and product performance under conditions relevant to commercial-scale production.

6. Acknowledgement

This research was financially supported by the Fundamental Fund of Suan Dusit University, funded by the Science, Research and Innovation Promotion Fund (TSRI).

7. References

AOAC International. (2019). Official methods of analysis of AOAC International (21st ed.). AOAC International.

Boudreau, M. D., Olson, G. R., Tryndyak, V. P., Bryant, M. S., Felton, R. P., & Beland, F. A. (2017). From the cover: Aloin, a component of the *Aloe vera* plant leaf, induces pathological changes and modulates the composition of microbiota in the large intestines of F344/N male rats. Toxicological Sciences, 158(2), 302–318. https://doi.org/10.1093/toxsci/kfx105

Di Monaco, R., Miele, N. A., Cabisidan, E. K., & Cavella, S. (2018). Strategies to reduce sugars in food. Current Opinion in Food Science, 19, 92–97. https://doi.org/10.1016/j.cofs.2018.03.008

Di Monaco, R., Miele, N. A., Volpe, S., Picone, D., & Cavella, S. (2014). Temporal sweetness profile of MNEI and comparison with commercial sweeteners. Journal of Sensory Studies, 29(6), 385–394. https://doi.org/10.1111/joss.12119

EFSA Panel on Food Additives and Nutrient Sources Added to Food (ANS). (2018). Safety of hydroxyanthracene derivatives for use in food. *EFSA* Journal, 16(1), Article e05090. https://doi.org/10.2903/j.efsa.2018.5090

Hamman, J. H. (2008). Composition and applications of *Aloe vera* leaf gel. Molecules, 13(8), 1599–1616. https://doi.org/10.3390/molecules13081599

Itsarasook, K., Prompamorn, P., Tanghiranrat, J., & Panichakul, T. (2021). Investigation of in vitro antioxidant activity and cytotoxicity on human skin fibroblasts of *Pluchea indica* (L.) Less. leaves extract and development to microemulsion for skin cosmetic product. Asian Journal of Pharmaceutical and Clinical Research, 14(6), 86–93. https://doi.org/10.22159/ajpcr.2021.v14i6.39880

Kanpairo, K. (2018). Effect of different sweeteners on the quality of torch ginger (*Etlingera elatior* (Jack) R.M. Smith) gummy jelly. Burapha Science Journal, 23(2), 944–958. https://scijournal.buu.ac.th/index.php/sci/article/view/1992

Li, Y., Li, K., Guo, Y., Liu, Y., Zhao, G., Qiao, D., Jiang, F., & Zhang, B. (2024). Mechanism for the synergistic gelation of konjac glucomannan and **K**-carrageenan. International Journal of Biological Macromolecules, 277, Article 134423. https://doi.org/10.1016/j.ijbiomac.2024.134423

Maan, A. A., Nazir, A., Khan, M. K. I., Ahmad, T., Zia, R., Murid, M., & Abrar, M. (2018). The therapeutic properties and applications of *Aloe vera*: A review. Journal of Herbal Medicine, 12, 1–10. https://doi.org/10.1016/j.hermed.2018.01.002

Maizura, M., Aminah, A., & Wan Aida, W. M. (2011). Total phenolic content and antioxidant activity of kesum (*Polygonum minus*), ginger (*Zingiber officinale*), and turmeric (*Curcuma longa*) extract. International Food Research Journal, 18(2), 529–534.

Mishra, L. K., & Sangma, D. (2017). Quality attributes, phytochemical profile and storage stability studies of functional ready to serve (RTS) drink made from blend of *Aloe vera*, sweet lime, amla and ginger. Journal of Food Science and Technology, 54(3), 761–769. https://doi.org/10.1007/s13197-017-2516-9

Martinez, J. O., Solano, M. G., Barbas, R. A., & Paternina, G. A. (2026). Healthy drink mixtures with tropical fruits, cashew (*Anacardium occidentale*), acerola (*Malpighia emarginata*), and *Aloe vera* (*Aloe barbadensis* Miller). International Journal of Food Science, 2026, Article 2602574. https://doi.org/10.1155/ijfo/2602574

Saha, D., & Bhattacharya, S. (2010). Hydrocolloids as thickening and gelling agents in food: A critical review. Journal of Food Science and Technology, 47(6), 587–597. https://doi.org/10.1007/s13197-010-0162-6

Sánchez, M., González-Burgos, E., Iglesias, I., & Gómez-Serranillos, M. P. (2020). Pharmacological update properties of *Aloe vera* and its major active constituents. Molecules, 25(6), Article 1324. https://doi.org/10.3390/molecules25061324

Sharma, R., Burang, G., Kumar, S., Sharma, Y. P., & Kumar, V. (2022). Optimization of apricot (*Prunus armeniaca* L.) blended *Aloe vera* (*Aloe barbadensis* M.) based low-calorie beverage functionally enriched with aonla juice (*Phyllanthus emblica* L.). Journal of Food Science and Technology, 59(5), 2013–2024. https://doi.org/10.1007/s13197-021-05216-z

Sullivan, D. M., & Carpenter, D. E. (Eds.). (1993). Methods of analysis for nutrition labeling. AOAC International.

Tananuwong, K., & Tewaruth, W. (2010). Extraction and application of antioxidants from black glutinous rice. LWT - Food Science and Technology, 43(3), 476–481. https://doi.org/10.1016/j.lwt.2009.09.014

Tizazu, A., & Bekele, T. (2024). A review on the medicinal applications of flavonoids from aloe species. European Journal of Medicinal Chemistry Reports, 10, Article 100135. https://doi.org/10.1016/j.ejmcr.2024.100135

U.S. Food and Drug Administration. (n.d.). Aspartame and other sweeteners in food. Retrieved September 21, 2026, from https://www.fda.gov/food/food-additives-petitions/aspartame-and-other-sweeteners-food

Vongsak, B., Kongkiatpaiboon, S., Jaisamut, S., & Konsap, K. (2018). Comparison of active constituents, antioxidant capacity, and α-glucosidase inhibition in *Pluchea indica* leaf extracts at different maturity stages. Food Bioscience, 25, 68–73. https://doi.org/10.1016/j.fbio.2018.08.006

Yamamoto, M., Ishikawa, M., Masui, T., Nakazawa, H., & Kabasawa, Y. (1985). Liquid chromatographic determination of barbaloin (aloin) in foods. Journal of the Association of Official Analytical Chemists, 68(3), 493–494. https://doi.org/10.1093/jaoac/68.3.493