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Sucrose reduction and addition of agave syrup and inulin in gummies with strawberry and blackberry pulp: Impact on physicochemical, antioxidant, and sensory characteristics

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Abstract

The current trend in the food industry involves the search for new formulations and processes to produce processed foods with enhanced nutritional value and improved functional properties that promote consumer health. Therefore, the present work aimed to investigate the physicochemical, antioxidant, and sensory properties of gummies made from strawberry and blackberry pulp. These gummies were formulated with reduced sucrose content and supplemented with agave syrup and inulin. Six formulations were developed using three levels of sucrose reduction (SR) namely 0, 40, and 50%, combined with two types of natural fruit pulp: strawberry (S) and blackberry (B). For the formulations with 40 and 50% SR, agave syrup and inulin were incorporated at a 1:1 ratio. The evaluation encompassed nutritional content, antioxidant activity, textural properties, and the overall acceptability of the various gummy products. Results demonstrated that SR led to a decrease in the caloric content of the gummies, from 279.38 to 178.69 kcal per 100 g. Gummies containing a blend of inulin and agave syrup exhibited an average of 3.69 times higher dietary fibre content. Moreover, the antioxidant compounds inherent in strawberry and blackberry pulp were effectively preserved during processing. Samples with 50% SR displayed an increase of up to 24.80 and 34.89% in phenolic and flavonoid contents, respectively, as compared to those with 0% SR. These samples also demonstrated elevated antioxidant activity as assessed by the ABTS and DPPH assays, reaching up to 109.4 µM Trolox per 100 g, and an inhibition rate of 77.9%, respectively. However, the incorporation of SR in the formulations had a noticeable impact on the textural properties of the gummies, particularly in terms of gumminess and chewiness. In terms of sensory analysis, it was observed that gummies labelled as S-SR-50 and B-SR-50 exhibited higher levels of acceptability, primarily attributed to their enhanced aroma, colour, and taste qualities. The findings of the present work propose a promising avenue for gummy candy reformulation involving reduced sucrose content and the reintroduction of inulin, agave syrup, and the inherent natural antioxidants from strawberry and blackberry. This approach could be a feasible strategy to produce gummy confections with improved nutritional values and antioxidant properties.

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Introduction

The confectionery industry is one of the most lucrative segments in the global agribusiness landscape. Among these confections, gelled products like gummies reign supreme, especially among children and adolescents (Spanemberg *et al*., 2019; Cano-Lamadrid *et al*., 2020). Central to these treats is a substantial presence of sucrose and/or glucose syrup, gelling agents, and minor additives such as

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artificial colours and flavours. These additives enhance sensory attributes like texture and flavour, increasing acceptance and market popularity (Cano-Lamadrid *et al.*, 2020; Gan *et al.*, 2022). However, recent years have unveiled the adverse impacts of excessive sucrose consumption, particularly in youngsters, linking it to concerns like obesity, hyperactivity, anxiety, and toxicity (Aranda-González *et al.*, 2015).

Furthermore, artificial colourings and flavours, when consumed excessively, have been associated with potential carcinogenic and neurotoxic risks, prompting a shift toward cleaner ingredient labels (Cano-Lamadrid *et al.*, 2020). Amidst escalating demands for healthier fare, characterised by reduced sugars, fats, and salts, as well as augmented dietary fibre and natural antioxidants sourced from fruits, the food industry confronts the challenge of reformulating numerous products. This shift aims to avert warning labels due to excessive ingredient content (as observed in México, Bolivia, Colombia, Ecuador, and Brazil), and to attain designations like "Heart Label" or "A Better Choice" in EU countries like Finland (Kaufer-Horwitz *et al.*, 2018; Šeremet *et al.*, 2020). In contrast to confectionery products incorporating natural ingredients and endowed with functional and biological activities (Otálora *et al.*, 2019), the reformulation of confectioneries is intricate due to their prevailing perception as unhealthy indulgences. However, evolving eating habits open a new era of confectionery offerings (Šeremet *et al.*, 2020).

In this context, agave syrup extracted from *Agave tequilana* and *A. salmiana* emerges as a natural, high potency sweetener with reduced caloric impact, attributed to its low glycaemic index (GI) (range of 17 to 27). This contrasts with sucrose's GI of 68 (Willems and Low, 2012; Nounmusig *et al.*, 2018). Concurrently, inulin is a functional confectionery ingredient, particularly as a gelling agent in soft candies. It synergises with gelatine while contributing dietary fibre (Shoaib *et al.*, 2016). Fruits and their by-products offer a viable avenue, infusing gummies with flavour, colour, texture, dietary fibre, and antioxidant compounds. Among these compounds, anthocyanins red, purple, or blue pigments found in soft fruits like strawberries and blackberries offer notable potential (Tena *et al.*, 2020). Natural pigments, revered for their functional properties, contribute to the prevention of chronic non-communicable ailments such as cancer and cardiovascular diseases (Otálora *et al.*, 2019). Encouragingly, some studies have showcased successful gummy reformulations. For instance, Rivero *et al.* (2021) introduced orange and raspberry juice into diverse gummy formulations, enriching the samples with functional compounds and antioxidants.

Similarly, Otálora *et al.* (2019) enhanced colour and stability in gummy candies by incorporating betalains from *Opuntia ficus-indica*. However, the amalgamation of agave syrup, inulin, blackberry, and strawberry pulp to develop gummies catering to contemporary needs and consumer preferences remains an untrodden path. Consequently, the present work aimed to assess the physicochemical, antioxidant, and sensory attributes of gummies crafted from strawberry and blackberry pulp, featuring reduced sucrose content while integrating agave syrup and inulin.

Materials and methods

Reagents

Inulin was obtained from Enature (Enature, S. de R. L. DE C.V., Zapopan, Jalisco, Mexico); agave syrup was obtained from Kirkland Signature (Costco de Mexico, S.A. de C.V., San Fernando la Herradura Huixquilucan, Estado de Mexico, Mexico); sugar was obtained from Zucarmex (Zucarmex S.A. de C.V, Culiacán, Sinaloa, Mexico); grenetina was obtained from Coloidales Duché (Coloidales Duché, S.A. de C.V., Juárez, Mexico City, Mexico); while boric acid, sulphuric acid, hydrochloric acid, sodium hydroxide, potassium sulphate, copper sulphate, anhydrous sodium sulphate, hydrogen peroxide, and zinc were obtained from Meyer (Química Suastes S.A. de C.V., Tláhuac, Mexico City, Mexico). 2,2'-diphenyl-1 picrylhydrazyl (DPPH), Trolox (6-hydroxy-2,5,8-tetramethylchroman-2-carboxylic acid), 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), and potassium persulphate were obtained from Sigma-Aldrich (Sigma Aldrich Química S.A. de C.V, Toluca, Estado de Mexico, Mexico). Hexane, ethanol, and acetone were obtained from J.T. Baker S.A. of C.V. (Avantor Performance Materials, Ecatepec, State of Mexico, Mexico), and anhydrous sodium sulphate was obtained from Karal S.A. of C.V.

Raw materials

Camino Real variety strawberries (6.98 ± 0.2 °Brix; pH of 3.37 ± 0.3) and Tupy variety blackberries (11.03 ± 0.41 °Brix; pH of 3.66 ± 0.073) were harvested at their maturity stage for consumption. The strawberries had an average weight of 16 g, while the blackberries weighed approximately 12 g. These fruits were collected from plots located in the municipality of Zitácuaro in the state of Michoacán (19° 26’ 2” N, 100° 21’ 7” W).

After harvesting, the fruits underwent a thorough washing process using water and sodium hypochlorite at a concentration of 150 ppm. Subsequently, they were stored under refrigeration until they were used to prepare the gummies.

Preparation of gummies

The formulations for gummy preparation are outlined in Table 1. Initially, gelatine was dissolved in water at room temperature and 1:2 ratio until achieving a consistent mixture. Subsequently, the temperature was increased to 70°C, and the remaining water, sucrose, and agave syrup were introduced. While maintaining the specified temperature, the mixture saw the addition of citric acid, pectin, and inulin, following the indications provided in Table 1 for respective formulations.

After this, the temperature was decreased to 35°C, and fruit pulp was incorporated with thorough mixing to ensure complete ingredient dissolution. The final formulations were then gently filtered and poured into silicone moulds, resulting in individual samples weighing 8 g each. These samples were stored at 4°C for a duration of 12 h to facilitate subsequent removal from the moulds. Finally, the gummies were transferred to commercial packaging, and stored at room temperature.

Table 1. Composition of gummies made from strawberry (S) and blackberry (B) pulp, with sucrose reduction (SR) of 0, 40, and 50%, and addition of agave syrup and inulin.

Composition	**Strawberry pulp (S)**			**Blackberry pulp (B)**		
(g)	**SR-0**	**SR-40**	**SR-50**	**BR-0**	**BR-40**	**BR-50**
Sugar	48	23.8	19	48	23.8	19
Agave nectar	0	5	5	0	5	5
Agave inulin	0	5	5	0	5	5
Fruit pulp	55	55	55	55	55	55
Gelatine	12	12	12	12	12	12
Oil	2	2	2	2	2	2
Pectin	1	1	1	1	1	1
Citric acid	0.3	0.3	0.3	0.3	0.3	0.3
Water	30	30	30	30	30	30

SR-0: sucrose reduction 0%; SR-40: sucrose reduction 40%; and SR-50: sucrose reduction 50%.

Chemical analysis of gummies

Chemical analysis of the samples was conducted following AOAC (2003) guidelines; moisture (method 934.01), lipid (method 920.39), crude protein (method 955.04), ash (method 923.03), and total dietary fibre (method 962.09). Carbohydrate content was determined by difference.

Functional analyses

Total phenolics and flavonoids

A gram of each sample was precisely weighed and mixed with 80% methanol. Subsequently, the mixture underwent ultrasonic treatment (Ultrasonic Cleaner, Mod. 32V118A, Illinois, United States of America) for 15 min at 30°C, operating at 40 kHz. After the ultrasonic treatment, the samples were centrifuged at 10,000 *g* for 10 min at 4°C. The quantification of total phenolics and flavonoids followed the method outlined by Rosales *et al.* (2011). Results were expressed as milligrams of gallic acid equivalents (GAE) per 100 g of sample for total phenolics, and milligrams of quercetin equivalents (QE) per 100 g for total flavonoids.

Antioxidant activity

The *in vitro* antioxidant activity was assessed through DPPH$^\bullet$ radical scavenging capacity and Trolox equivalent antioxidant capacity (TEAC) assays. The phenolics and flavonoids supernatant served as the basis for determining the DPPH$^\bullet$ radical scavenging activity, as outlined by Brand-Williams *et al.* (1995). This approach combined 0.3 mL of the supernatant with DPPH$^\bullet$ radical (6×10^{-5} M). Following a 60 min reaction period, the absorbance (A) at 517 nm was measured. The reduction of the DPPH$^\bullet$ radical was determined using Eq. 1:

$$DPPH^{\bullet}\text{ Detoxifying effect (\%)} = \left(1 - \frac{A_{517nm}\ of\ the\ sample}{A_{517nm}\ Control}\right) \times 100 \qquad \text{(Eq. 1)}$$

The TEAC assay was conducted following a modified approach based on the method developed by Re *et al.* (1999). For generating the ABTS$^{\bullet+}$ radical, ABTS was employed at a concentration of 7.0 mM, mixed with potassium persulphate at 2.45 mM. A total of 100 µL of the supernatant was blended with the diluted ABTS$^{\bullet+}$ radical, and after a 6 min reaction at 30°C, the absorbance at 734 nm was recorded. The outcomes were quantified regarding µM Trolox equivalents per gram of sample weight.

Textural analysis

Textural analysis of the samples was conducted using a TA-XTPlus analyser (Stable Micro Systems, Godalming, England). Following the methodology outlined by Marfil *et al*. (2012), the 15 mm gummies were tested using a TA-25 stainless steel cylindrical accessory measuring 20 mm in height and 0.05 m in diameter. The samples were positioned on the TA-90 aluminium platform. The tests were carried out with the subsequent parameters: a pre test speed of 1.00 mm/s; a post test speed of 5.00 mm/s; and a test speed of 5 mm/s; all with a deformation of 75%, lasting 5 s, and a force of 0.0050 kg.

These analyses were conducted at a room temperature of 25 ± 1°C and 55% humidity. Each formulation was analysed in five replicates for this examination. Data were analysed using Exponent Version 7.0 texture software (Stat-Easy Inc., Minneapolis, MN, USA).

Sensory evaluation

Sensory evaluations of the gummies were conducted by a panel comprising 50 consumers (25 women and 25 men) aged 18 to 59 years. These individuals were regular consumers of gummy type confectionery products. For the evaluation, 10 g of the samples were placed in plastic cups designated as number 0, maintained at 24 ± 0.5°C. The cups were coded with three digit random numbers, and then presented randomly to the panellists. The participants were instructed to rate their preferences for various attributes, including colour, aroma, flavour, texture, and overall acceptability. A nine point hedonic scale was employed for scoring, with values ranging from 1 (dislike extremely) to 9 (like extremely), as defined by Meilgaard *et al.* (2007).

Experimental design

The experimental design followed a 2 factorial approach: the level of sucrose reduction (SR) (0, 40, and 50%) and the type of fruit pulp utilised (strawberry and blackberry). This setup facilitated an analysis of variance, and subsequently, a Tukey mean comparison test was executed at a significance level of $p \leq 0.05$.

Regarding the sensory analysis, a randomised block experimental design was employed. This included a comparison test of LSD means, maintaining a significance level of $p \leq 0.05$. The Statistical Analysis System (SAS) program for Windows, version 9.4, was utilised for all statistical evaluations.

Results and discussion

Table 2 displays the proximate analysis of the gummies with reduced sucrose content, containing strawberry and blackberry pulp. Concerning moisture, higher values were observed in cases where SR was higher. This increase in moisture could be attributed to the partial substitution of sucrose with agave syrup and inulin (1:1 ratio). This effect was consistent regardless of the type of pulp used in the formulation. This phenomenon can be explained by the branched structure of agave and inulin syrup molecules, facilitating interactions with other components, such as proteins, and forming stable gels with immobilised water molecules (Santiago-García *et al.*, 2021).

Significant decreases in carbohydrate content and caloric intake were also noted in the gummies due to the reduction of sucrose. Furthermore, the choice of pulp impacted the carbohydrate content in the formulations. Gummies containing strawberry pulp exhibited lower carbohydrate and caloric contents than those with blackberry pulp. This discrepancy could be due to the higher solid concentration in blackberries as a raw material, leading to greater carbohydrate values up to 61% more than strawberries and, consequently, higher caloric intake (Ríos de Souza *et al.*, 2014).

Table 2. Impact on proximal chemical analysis (%) and energy content (kcal) due to sucrose reduction, and addition of agave syrup and inulin in gummies formulated with strawberry (S) and blackberry (B) pulp.

Treatment	Humidity	Lipid	Protein	Ash	Carbohydrate	Dietary fibre	Energy content
S-SR-0	39.37^{ed}	4.72^{a}	2.21^{a}	0.10^{a}	52.65^{b}	0.63^{b}	261.92^{ab}
B-SR-0	34.21^{e}	4.82^{a}	2.30^{a}	0.22^{a}	56.7^{a}	0.87^{b}	279.38^{a}
S-SR-40	46.23^{bc}	4.82^{a}	2.30^{a}	0.10^{a}	41.7^{d}	4.29^{a}	219.38^{c}
B-SR-40	42.48^{cd}	4.67^{a}	2.20^{a}	0.21^{a}	45.75^{c}	4.32^{a}	233.83^{bc}
S-SR-50	56.42^{a}	4.81^{a}	2.19^{a}	0.12^{a}	31.66^{f}	4.52^{a}	178.69^{d}
B-SR-50	51.87^{a}	4.70^{a}	2.19^{a}	0.24^{a}	36.27^{e}	4.64^{a}	196.14^{cd}

Values are mean of three replicates. Means followed by different lowercase superscripts in the same column are significantly different by Tukey's test at $p \leq 0.05$. SR-0: sucrose reduction 0%; SR-40: sucrose reduction 40%; and SR-50: sucrose reduction 50%.

In line with this, the caloric content of blackberry-based gummies was approximately 6% higher on average than their strawberry-based counterparts. Incorporating inulin into the gummy formulation reduces caloric intake because it provides only 25 - 35% of the energy relative to digestible carbohydrates (Shoaib *et al.*, 2016). Additionally, agave syrup, with its low GI and sweeter taste than honey, sucrose, and glucose, can be employed in various foods to achieve the desired sweetness level, effectively lowering calorie intake (Willems and Low, 2012).

No significant differences were observed across the analysed formulations regarding lipid, protein, and ash contents. Notably, fibre content was higher in samples with lower sugar content, irrespective of the fruit variant used. This phenomenon could be attributed to agave syrup and inulin, which contribute dietary fibre to the sugar-reduced gummies. This infusion of dietary fibre confers prebiotic effects, stimulating the growth of beneficial bacteria like *Lactobacillus* and *Bifidobacterium* in the human intestine. These effects, in turn, offer various health benefits, such as weight management, improved mineral absorption, and the prevention of gastrointestinal issues and colon cancer, among others (Espinosa-Andrews *et al.*, 2021).

The contents of total phenolics and flavonoids are presented in Table 3. It was observed that gummies based on blackberry pulp (B) exhibited higher levels of these compounds than those based on strawberries. Notably, gummies subjected to the B-SR-50 treatment contained up to 2.70 and 8.08 times more total phenolics and flavonoids, respectively, as compared to those from the S-SR-0 treatment. This disparity could be attributed to the inclusion of blackberry in the reformulated gummies. Fresh blackberry fruits have been reported to contain a total phenolic compound content ranging from 114 to 1,056 mg/100 g fresh weight (Kaume *et al.*, 2012), whereas strawberry cultivars exhibit values between 145 and 262 mg GAE/100 g fresh weight (Noriega *et al.*, 2021).

A similar trend emerged in the results of antioxidant activity assessed through ABTS and DPPH radical inhibition assays. This trend could be explained by the positive correlation between phenolic compound content and antioxidant activity (Pinedo-Espinoza *et al.*, 2020). Furthermore, inulin contributed to the antioxidant activity of the samples. Previous reports have indicated that inulin possesses antioxidant activity against DPPH and ABTS radicals (Shang *et al.*, 2018).

Additionally, agave syrup played a role in safeguarding the phenolic compounds present in the pulp of soft fruits during thermal processing. Moreover, the antioxidant capacity of inulin remained consistent across various thermal treatments. This preservation of bioactive compounds within the samples was facilitated by agave syrup and the stability of inulin's antioxidant capabilities (Garcia-López *et al.*, 2017).

Regarding the textural properties of gummies formulated with strawberry and blackberry pulp, the outcomes are outlined in Table 4. Notably, the concentration of sucrose in the various formulations substantially impacted the hardness parameter. As the

Table 3. Impact on the contents of total phenolics, flavonoids, and antioxidant activity due to sucrose reduction, and addition of agave syrup and inulin in gummies formulated with strawberry (S) and blackberry (B) pulp.

Treatment	Total phenolics (mg EAG/100 g)	Flavonoids (mg EQ/100 g)	ABTS (µM Trolox/100 g)	DPPH (Inhibition %)
S-SR-0	9.30[e]	4.96[e]	39.61[f]	27.57[f]
B-SR-0	20.12[c]	34.16[c]	92.31[c]	65.52[c]
S-SR-40	9.97[d]	4.66[e]	46.88[e]	32.62[e]
B-SR-40	22.11[b]	40.69[b]	98.09[b]	69.71[b]
S-SR-50	10.27[d]	10.51[d]	50.96[d]	35.57[d]
B-SR-50	25.11[a]	46.08[a]	109.4[a]	77.9[a]

Values are mean of three replicates. Means followed by different lowercase superscripts in the same column are significantly different by Tukey's test at $p \leq 0.05$. SR-0: sucrose reduction 0%; SR-40: sucrose reduction 40%; and SR-50: sucrose reduction 50%.

Table 4. Impact on textural properties due to reduction of sucrose, and addition of agave syrup and inulin in gummies formulated with strawberry (S) and blackberry (B) pulp.

Treatment	Hardness	Adhesiveness	Elasticity	Cohesiveness	Gumminess	Chewability	Resilience
	N	N•s × 10^{-3}	%	s	N	N	%
S-SR-0	231.33[a]	4.41[a]	0.93[a]	0.79[a]	182.26[a]	169.68[a]	0.50[a]
B-SR-0	218.65[a]	5.39[a]	0.91[a]	0.76[a]	166.74[a]	146.24[a]	0.49[a]
S-SR-40	191.06[b]	10.00[ab]	0.86[a]	0.63[b]	120.43[b]	104.12[b]	0.43[b]
B-SR-40	181.88[b]	7.55[ab]	0.86[a]	0.66[bc]	119.51[b]	102.65[b]	0.425[b]
S-SR-50	174.69[b]	13.73[b]	0.85[a]	0.65[bc]	113.17[b]	95.91[b]	0.40[b]
B-SR-50	171.50[b]	18.24[b]	0.88[a]	0.61[c]	105.21[b]	92.50[b]	0.427[b]

Values are mean of three replicates. Means followed by different lowercase superscripts in the same column are significantly different by Tukey's test at $p \leq 0.05$. SR-0: sucrose reduction 0%; SR-40: sucrose reduction 40%; and SR-50: sucrose reduction 50%.

sucrose concentration decreased, the hardness also decreased by up to 17.40 and 25.86%. This phenomenon could be attributed to sucrose's ability to enhance the stability of gelatine gels' bonds (Lorén *et al.*, 2001). The presence of agave syrup also contributed to a reduction in gummy hardness. This is due to agave syrup's predominant sugar component – fructose, which accounts for up to 86% of its composition. Fructose, as a sweetener, is linked to diminished textural properties, resulting in less stable gels (Willems and Low, 2012).

Conversely, the adhesiveness profile demonstrated an increase in formulations with greater SR, coupled with the inclusion of agave syrup and inulin (Table 4). However, it is noteworthy that elevated adhesiveness in gummies is not preferred, as it can lead to adherence on teeth, palate, and tongue during consumption, as noted by Sumonsiri *et al.* (2021). Nevertheless, the values documented in the present work were relatively low as compared to gummies from other fruit sources, such as palmyra palm (Sumonsiri *et al.*, 2021).

For elasticity, no significant discrepancies emerged among the samples. For cohesiveness, it was determined that gummies not subjected to SR in their formulation exhibited greater cohesiveness. Essentially, they formed a more uniform network with stronger internal bonds capable of enduring secondary deformations (Tireki *et al.*, 2021). Like the other textural parameters, gumminess, chewiness, and resilience are more influenced by the quantity of sucrose utilised in the formulation rather than the specific type of fruit pulp (Delgado *et al.*, 2021). A parallel observation was made by Delgado and Bañón (2018) in gummies incorporating inulin, glucose syrup, and sucrose. In a broader context, the use of inulin as a sucrose substitute in gummy formulations has been reported to weaken gel strength, leading to gummies that are softer and more prone to deformation (Glibowski and Wasko, 2008), a trend consistent with the findings of the present work.

The sensory evaluation results for the gummies, as assessed by volunteer panellists, are outlined in Table 5. Participants exhibited greater approval of aroma and flavour attributes in samples from treatments with a 50% reduction in sugar (S-SR-50 and B-SR-50). This preference might stem from the elevated concentration of compounds such as 2-heptanol, *p*-cymen-8-ol, 2-heptanone, 1-hexanol, α-terpineol, pulegone, 1-octanol, isoborneol, myrtenol, 4-terpineol, carvone, elemicine, and nonanal, which contribute to the aroma and flavour of blackberry fruits. Similarly, methyl butanoate, ethyl butanoate, ethyl hexanoate, ethyl 3-methyl butanoate, hexyl acetate, linalool, furaneol, mesifurane, and γ-dodecalactone are responsible for the aroma and flavour attributes in strawberry fruits (Du *et al.*, 2011).

Additionally, including inulin as a sucrose substitute in the various treatments, enhanced the attributes above. Inulin, a polysaccharide with a neutral and smooth flavour devoid of unpleasant tastes or aftertastes, has been demonstrated to blend seamlessly with other food components without altering delicate flavours. It can even enhance the natural flavour of certain products, including desserts and confectionery, while intensifying sweetness (Tárrega and Costell, 2006; Villegas *et al.*, 2010).

For colour, the gummies across the different treatments garnered high acceptability among the panellists. This favourable response is attributed to the presence of anthocyanins in both strawberry and blackberry pulp, natural pigments known for enhancing consumer acceptability in such products (Cuevas-Rodríguez *et al.*, 2010; Khoo *et al.*, 2017). The deeper hues generated by these berry pigments in various food gels tend to yield higher consumer preferences (Torres *et al.*, 2015). However, gummies from the S-SR-40 treatment and those with higher sucrose concentrations exhibited relatively lower colour acceptability. For S-SR-40 gummies, this can be explained by strawberries having fewer anthocyanins as compared to blackberries (Ma *et al.*, 2018). On the other hand, higher sucrose content could lead to a lacklustre and less vibrant appearance in the gummies. Hull (2010) observed similar trends in confectionery products, where samples with higher sucrose content received lower colour acceptance scores than samples with high agave syrup content.

For texture, diminished acceptance was noted for gummies subjected to greater SR, a characteristic that could substantially impact the overall product acceptance, as texture plays a crucial role in identifying a gummy (Aranda-González *et al.*, 2015). Conversely, gummies with higher sucrose content displayed improved texture attributes, as sugar contributes to gels enhanced development and stability (Kuan *et al.*, 2016; Gunes *et al.*, 2022).

In general, the gummies were well-received by the panellists. However, gummies from the S-SR-50 and B-SR-50 treatments stood out due to their aroma attributes, colour, and flavour, which garnered high levels of approval.

Table 5. Impact on sensory properties due to reduction of sucrose, and addition of agave syrup and inulin in gummies formulated with strawberry (S) and blackberry (B) pulp.

Treatment	Smell	Colour	Flavour	Texture	Overall acceptability
S-SR-0	6.58^{b}	7.71^{b}	7.91^{b}	6.95^{ab}	7.40^{b}
B-SR-0	6.95^{b}	7.61^{b}	8.00^{b}	7.01^{ab}	7.56^{b}
S-SR-40	6.60^{b}	7.60^{b}	7.98^{b}	7.11^{a}	7.46^{b}
B-SR-40	7.05^{b}	7.83^{ab}	7.91^{b}	6.89^{b}	7.58^{b}
S-SR-50	7.08^{a}	7.85^{ab}	8.30^{a}	6.51^{c}	7.75^{ab}
B-SR-50	7.57^{a}	8.15^{a}	8.48^{a}	6.49^{c}	7.90^{a}

Values are mean of three replicates. Means followed by different lowercase superscripts in the same column are significantly different by Tukey's test at $p \leq 0.05$. SR-0: sucrose reduction 0%; SR-40: sucrose reduction 40%; and SR-50: sucrose reduction 50%.

Conclusion

Confirmed improvements in physicochemical, sensory, and antioxidant properties were observed in the reformulated gummies incorporating strawberry and blackberry pulp alongside SR to 40 and 50%. Particularly noteworthy were the gummies featuring 50% decrease in sucrose content combined with strawberry pulp, thus demonstrating the lowest energy intake. Furthermore, the strategic substitution of sucrose with a blend of inulin and agave syrup introduced soluble fibre to the samples. Notably, including blackberry pulp as a natural ingredient had the most pronounced impact on bolstering the antioxidant properties of the gummies. Conversely, the utilisation of inulin and agave syrup as replacements for sucrose led to significant decrease in the textural attributes of the gummies. Nonetheless, the sensory quality of these alternatives surpassed that of the traditional gummy formulation. The present work demonstrated the feasibility of producing gummies with decreased sucrose content while increasing their nutritional and functional contributions.

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