Mango (*Mangifera indica* L.) Bagasse-Added Gum Confections Are a Source of Bioactive Compounds Exhibiting Prebiotic Effects In Vitro †

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Abstract: The high consumption of sugar-added food products by children has stimulated research on formulations using ingredients such as mango bagasse (MB), which deliver health-associated components. This research aimed to characterize, perform a sensory evaluation, and assess the probiotic effect in vitro of MB-added gum confections (1:4 and 1:5 water:MB). The 1:4 formulation displayed the highest acceptance by 51 children from a primary school in Ciudad Juárez (Mexico). This formulation contained a high fiber content (10.50%) and phenolic compounds (mainly mangiferin and (+)-catechin), and it allowed *L. plantarum*, *L. reuteri*, *L. helveticus*, and *L. rhamnosus GG* growth. The results suggest that MB-confections are fiber- and polyphenol-rich products with a sensory profile accepted by children and prebiotic effects.

Keywords: mango (*Mangifera indica* L.); dietary fiber; functional confectionery; phenolic compounds; texture profile; sensory study

1. Introduction

Obesity and chronic non-communicable diseases originate during childhood due to several risk factors, such as maternal physical inactivity and smoking during pregnancy, excessive gestational weight gain, and inadequate diet [1]. In Mexico, it has been reported that saturated fats, artificial sweeteners, and added sugars account for up to 30% of the daily caloric intake of children [2]. Most of these alterations end in gut microbiota dysbiosis, requiring prebiotics, probiotics, or both (symbiotics) to confer a health benefit.

In this sense, fiber-rich formulations could contain valuable bioactive compounds that could be used to manufacture highly acceptable and appropriate food products [3]. Since children liberally consume and greatly appreciate confections, functional confectioneries could deliver bioactive compounds, such as dietary fiber and phenolic compounds, to restore nutraceutical deficiencies in this population [3]. Mango (*Mangifera indica* L.) bagasse offers an opportunity as an ingredient in functional confections since previous reports have indicated its richness in dietary fiber and highly bioaccessible phenolic compounds [4], and it exhibits potential gut microbiota modulation through the production of beneficial
microbial metabolites, such as short-chain fatty acids [5]. Moreover, the mango byproducts have been extensively used as livestock feed due to the mango’s valuable content of digestible crude protein and total digestible nutrients [6]; in addition, mango peels and seed kernels are highly digestible and easily complement additional protein sources used for sheep feeding [7].

Therefore, this research aimed to formulate and characterize sensory-evaluated mango bagasse (MB)-added gum confections for children and assess their probiotic potential in vitro.

2. Materials and Methods

2.1. Biological Materials and Confection Manufacturing

Peel-free mango (Mangifera indica L.) bagasse (MB) from mango pulp processing was acquired from Frozen Pulps of Mexico S.A. de C.V. The product was frozen (−18 °C), freeze-dried (245 h), and ground (250 µm). To manufacture the gum confections, the reported procedure of Herrera-Cazares et al. [8] was followed with modifications. Gelatin was used instead of pre-gelatinized corn starch, and the resulting boiling mixture was placed in silicone molds until it reached room temperature (25 ± 1 °C), followed by storage at 4 °C for 3 h. A commercial bear-shaped gum confection (C1) was used for comparison purposes.

2.2. Texture Profile Analyses (TPA) and Sensory Study

Initially, several water-added formulations were assayed (1:3, 1:4, and 1:5 MB:water), but only the 1:4 and 1:5 formulations were used since 1:3 displayed the worst TPA outcomes (results not published). A texturometer (4411 Series Instron, Northwood, MA, USA) was used to determine the hardness (expressed in Newtons, N), cohesiveness (g), springiness (mm), and chewiness (N × cm) [9]. These formulations were subjected to a sensory evaluation involving 51 children (6–12 years) from a primary school in Ciudad Juárez (Mexico). A non-structured scale was used to test the confections (1: dislike very much; 2: dislike moderately; 3: dislike slightly; 4: neither like nor dislike; 5: like slightly; 6: like moderately; 7: like very much). Informed consent was previously signed by the children’s parents, and the procedure was approved by the Ethics Committee from the School of Chemistry of Universidad Autonoma de Queretaro.

2.3. Proximal and Nutraceutical Composition of 1:4 Formulation

Since the 1:4 formulation received the highest sensory acceptance (p < 0.05), the proximal and nutraceutical composition was conducted solely for this sample. The AOAC [10] methods were followed to determine the moisture (method 925.09), lipids (method 920.39), proteins (method 920.15), and ash (method 945.46). The total carbohydrates were determined by difference, and all results are expressed as a percentage on a dry basis. For the nutraceutical composition, the total fiber (TDF), soluble fiber (SDF), and insoluble fiber (IDF) were determined following the AOAC methods. The phenolic compounds from the confections were obtained by methanolic extraction, followed by high-performance liquid chromatography analysis (HPLC) coupled to diode-array detection (DAD) [11]. Samples were injected (20 µL) and separated in a Zorbax Eclipse XDB column (Agilent Technologies, Palo Alto, CA, USA) at 1 mL/min using two wavelengths (280 and 320 nm). The phenolic compounds were identified and quantified using standard curves of mangiferin, gallic acid, quercetin, and (+)-catechin. The results are expressed in µg equivalents of each phenolic compound/g dry sample.

2.4. Prebiotic Effect In Vitro

A qualitative prebiotic effect in vitro was determined considering the growth of specific strains from gut microbiota (Lactobacillus reuteri, NRRL B-14171; Lactobacillus plantarum, NRRL B-4496, Lactobacillus helveticus LH R0052, and L. rhamnosus GG LRH). All the strains were inoculated in a dextrose-added MRS medium at 37 °C for 48 h (5% CO₂)
until 108 colony-forming units (CFUs) were obtained [12]. The optical density (OD) of the bacterial growth was evaluated at 600 nm.

2.5. Statistical Analysis

All results are expressed as means ± SD. An ANOVA analysis was conducted, followed by Student’s t-test or a Tukey–Kramer test. Significance was established at p < 0.05. For the sensory analysis, a Chi-square analysis was carried out. All analyses were performed using JMP v. 14 software.

3. Results and Discussion

3.1. Texture Profile and Sensory Study for the 1:4 and 1:5 MB:Water Formulations

Textural evaluation (Table 1) of the formulations showed no differences with a commercial control (p > 0.05) for cohesiveness, while the MB-added gum confections were harder, less elastic, and chewier (p < 0.05). These results agree with reports suggesting less chewiness and similar hardness in low-sugar confections [13].

<table>
<thead>
<tr>
<th>Formulations</th>
<th>Hardness (N)</th>
<th>Cohesiveness (g)</th>
<th>Springiness (mm)</th>
<th>Chewiness (N × cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:4</td>
<td>14.57 ± 2.08 (^a)</td>
<td>0.74 ± 0.03 (^a)</td>
<td>3.60 ± 0.21 (^b)</td>
<td>11.14 ± 0.73 (^b)</td>
</tr>
<tr>
<td>1:5</td>
<td>11.13 ± 0.73 (^a)</td>
<td>0.80 ± 0.05 (^a)</td>
<td>3.48 ± 0.31 (^b)</td>
<td>11.14 ± 0.73 (^b)</td>
</tr>
<tr>
<td>C1</td>
<td>1.88 ± 0.28 (^b)</td>
<td>0.90 ± 0.04 (^a)</td>
<td>4.99 ± 0.23 (^a)</td>
<td>1.89 ± 0.28 (^c)</td>
</tr>
</tbody>
</table>

Results are the means ± SD of three independent experiments in triplicates. Different letters by column express significant differences between samples by Tukey–Kramer test (p < 0.05). C1: commercial control.

The absence of textural differences impacted the sensory analyses conducted by the children (Figure 1), which showed a similar trend for both formulations. However, the 1:4 formulation was judged as the best gum confection because of its lower chewiness (p > 0.05).

![Figure 1. Sensory scores between 1:4 and 1:5 MB-added gum confections. Results are expressed as the mean ± SD of 51 evaluations. The p-values are the result of a Chi-square evaluation between the formulations.](image)

3.2. Proximal and Nutraceutical Composition of MB-Added Formulations

Since the 1:4 formulation was the most sensory-accepted confection, proximal and nutraceutical composition was conducted for this confection (Table 2). Total dietary fiber (TDF) accounted for 10.50% of total carbohydrates, and high values of mangiferin and (+)-quercetin were found. The TDF and mangiferin contents were lower than those reported values for “Ataulfo” mango-based fruit bars [14], although no mango byproducts were
used. However, the reported contents in this study suggest the potential delivery of these phenolics, most of which are highly bioaccessible when they come from MB and exhibit antioxidant effects [4].

Table 2. Proximal and nutraceutical composition of the 1:4 formulation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal composition</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>25.60 ± 2.40</td>
</tr>
<tr>
<td>Protein</td>
<td>4.40 ± 1.10</td>
</tr>
<tr>
<td>Ash</td>
<td>0.50 ± 0.00</td>
</tr>
<tr>
<td>Lipids</td>
<td>0.20 ± 0.01</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>58.80 ± 4.20</td>
</tr>
<tr>
<td>TDF</td>
<td>10.50 ± 2.10</td>
</tr>
<tr>
<td>SDF</td>
<td>7.10 ± 1.50</td>
</tr>
<tr>
<td>IDF</td>
<td>3.40 ± 0.70</td>
</tr>
<tr>
<td>Gallic acid</td>
<td>716.11 ± 0.11</td>
</tr>
<tr>
<td>Mangiferin</td>
<td>1377.29 ± 0.10</td>
</tr>
<tr>
<td>Quercetin</td>
<td>n.d.</td>
</tr>
<tr>
<td>(+)-catechin</td>
<td>1093.01 ± 0.43</td>
</tr>
</tbody>
</table>

Results are the means ± SD of three independent experiments in triplicate. TDF: total dietary fiber; SDF: soluble dietary fiber; IDF: insoluble dietary fiber. 1 Expressed in percentage; 2 expressed in µg. Equivalents of each phenolic compound/g dry sample.

3.3. Prebiotic Effect In Vitro

Compared with the control (dextrose), MBC did not exhibit differences in *L. helveticus* growth, while all the other strains showed a significantly lower growing trend (Figure 2). MB fiber was also evaluated; the evaluation indicated that except for *L. plantarum*, the fiber and associated components could influence bacterial growth. It has been reported that DF and DF-associated phenolics are beneficial bacterial substrates that allow prebiotic bacteria growth [12], suggesting that their richness in MB could be useful in stimulating selective bacterial populations.

![Figure 2. Prebiotic bacterial strain growth after using several substrates. The results are the means ± SD of three independent experiments in triplicate. Different letters represent significant differences between strains for each sample by Tukey–Kramer test (p < 0.05). MBC: Mango (*Mangifera indica* L.) bagasse-added confection.](image-url)

4. Conclusions

The results obtained in this work suggest that mango bagasse is a suitable ingredient for manufacturing functional gum confections with high sensorial acceptance by children.
Since these confections contain dietary fiber and phenolic compounds, they could serve as beneficial substrates to allow prebiotic bacteria growth, resulting in potential health benefits.


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**Institutional Review Board Statement**: The study was approved by the Institutional Ethics Committee of Universidad Autónoma de Querétaro (CBQ17/070 from 9 June 2017).

**Informed Consent Statement**: Informed consent was obtained from the parents of the children involved in the study.

**Data Availability Statement**: Data are available upon reasonable request.

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**Conflicts of Interest**: The authors declare no conflict of interest.

**References**


