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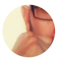

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Foods 2021

Proceeding Paper

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

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

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

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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 highly consume and appreciate confections, functional confectionery could deliver bioactive compounds such as dietary fiber and phenolic compounds to supply nutraceutical deficiencies in this population [3]. Mango (*Mangifera indica* L.) bagasse offers an opportunity as an ingredient for functional confections since previous reports have indicated its richness in dietary fiber and highly bioaccessible phenolic compounds [4], exhibiting potential gut microbiota modulation through the production of beneficial microbial metabolites such as short-chain fatty acids [5]. Therefore, this research aimed to formulate and characterize a children's sensory-evaluated mango bagasse (MB)-added confections and assess its 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 confections, the reported procedure of Herrera-Cazares et al. [6] was followed with modifications. Gelatin was used instead of pre-gelatinized corn starch, and the resulting boiling mixture was placed in silicone molds until room temperature (25 ± 1 °C), followed by storing at 4 °C for 3 h. A commercial bear-shaped gum confections (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 1:4 and 1:5 were used since 1:3 displayed the worst TPA outcomes (results not published). A texturometer (4411 Series, Instroom, USA) was used to conduct hardness (expressed in Newtons, N), cohesiveness (g), springiness (mm), and chewiness (N × cm) [7]. These formulations were subjected to a sensory evaluation participating 51 children (6–12 years) from a primary school of 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 or 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 1:4 formulation received the highest sensory acceptance ($p < 0.05$), the proximal and nutraceutical composition was conducted solely for this sample. The AOAC [8] methods were followed to determine 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 were expressed as a percentage in dry basis. For the nutraceutical composition, the total (TDF), soluble (SDF), and insoluble (IDF) were determined following the AOAC methods. Phenolic compounds from the confections were obtained after a methanolic extraction, followed by high-performance liquid chromatography analysis (HPLC) coupled to diode-array detection (DAD) [9]. Samples were injected (20 μL), 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 were 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 reutei*, NRRL B-14171; *Lactobacillus plantarum*, NRRL B-4496, *Lactobacillus helveticus* LH R0052, and *L. rhamnosus* GG LRH). All the strains were inoculated in dextrose-added MRS medium at 37 °C for 48 h (5% CO_2) until the obtention of 108 colony forming units (CFU) [10]. The optical density (OD) of the bacterial growth was evaluated at 600 nm.

2.5. Statistical Analysis

All results were expressed as mean ± SD. An ANOVA analysis was conducted, followed by Student's *t*-test or Tukey-Kramer's test. The significance was established at $p <$

0.05. For the sensory analysis, a Chi-square analysis was carried out. All analyses were performed on JMP v. 14 software.

3. Results and Discussion

3.1. Texture Profile and Sensory Study from 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 confections were harder, less elastics, and chewier ($p < 0.05$). These results agree with reports suggesting less chewiness and similar hardness in low-sugar confections [11].

Table 1. Texture profile analysis (TPA) from all the MB-added formulations and a commercial control.

Formulations	Hardness (N)	Cohesiveness (g)	Springiness (mm)	Chewiness (N*cm)
1:4	14.57 ± 2.08 [a]	0.74 ± 0.03 [a]	3.60 ± 0.21 [b]	14.57 ± 2.08 [a]
1:5	11.13 ± 0.73 [a]	0.80 ± 0.05 [a]	3.48 ± 0.31 [b]	11.14 ± 0.73 [b]
C1	1.88 ± 0.28 [b]	0.90 ± 0.04 [a]	4.99 ± 0.23 [a]	1.89 ± 0.28 [c]

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

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

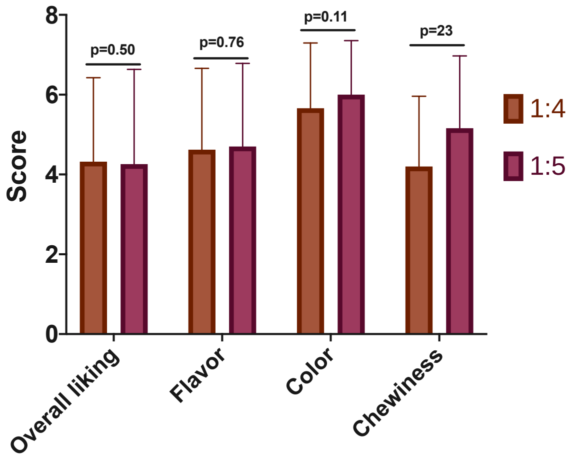

Figure 1. Sensory scores between 1:4 and 1:5 MB-added confections. Results are expressed as the mean ± SD from 51 evaluations. The *p*-values are the result of a Chi-Square evaluation between the formulations.

3.2. Proximal and Nutraceutical Composition of MB-Added Formulations

Since de 1:4 formulation was the best 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, whereas high values of mangiferin and (+)-quercetin were found. TDF and mangiferin contents were lower than those reported values for "Ataulfo" mango-based fruit bars [12], although no mango by-products were used. However, the reported contents in this study suggest the potential delivery of these phenolics, most of them highly bioaccessible when coming from MB, exhibiting antioxidant effects [4].

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

Parameter		Value
Proximal composition [1]	Moisture	25.60 ± 2.40
	Protein	4.40 ± 1.10
	Ash	0.50 ± 0.00
	Lipids	0.20 ± 0.01
	Carbohydrates	58.80 ± 4.20
Nutraceutical composition	TDF	10.50 ± 2.10
	SDF	7.10 ± 1.50
	IDF	3.40 ± 0.70
	Gallic acid [2]	716.11 ± 0.11
	Mangiferin [2]	1377.29 ± 0.10
	Quercetin [2]	n.d.
	(+)-catechin [2]	1093.01 ± 0.43

Results are the mean ± SD of three independent experiments in triplicates. 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 to 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, indicating that except for *L. plantarum,* fiber and associated components could influence the bacterial growth. It has been reported that DF and DF-associated phenolics are beneficial bacterial substrates to allow prebiotic bacteria growth [10], suggesting that their richness in MB would be useful to stimulate selective bacterial populations.

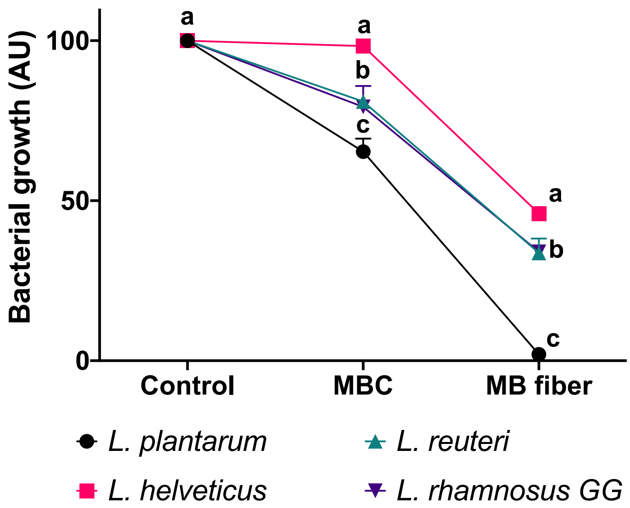

Figure 2. Prebiotic bacterial strains growth after using several substrates. The results are the means ± SD of three independent experiments in triplicates. Different letters express significant differences between strains, for each sample, by Tukey-Kramer's test ($p < 0.05$). MBC: Mango (*Mangifera indica* L.) bagasse-added confection.

4. Conclusions

The results obtained from this work suggest that mango bagasse is a suitable ingredient to manufacture functional 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.

Author Contributions: Conceptualization, A.W.-M. and M.G.-M.; methodology: D.F.-Z., F.J.O.-A., A.W.-M. and J.E.A.; software: I.L.-O., D.F.-Z., M.G.-M. and A.W.-M.; resources: A.W.-M., G.L.-P., J.E.A. and M.G.-M.; data curation: D.F.-Z., and F.J.O.-A.; writing—original draft and preparation: I.L.-O.; writing—review and editing: I.L.-O., M.G.-M., G.L.-P. and A.W.-M.; visualization: I.L.-O., D.F.-Z. and M.G.-M.; supervision: M.G.-M.; project administration: M.G.-M. and A.W.-M.; funding acquisition: M.G.-M., A.W.-M., J.E.A. and G.L.-P. All authors have read and agreed to the published version of the manuscript.

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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 June 09/2017).

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

Data Availability Statement: Data will be available upon reasonable request.

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

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