J Food Sci Technol (February 2022) 59(2):606–614
https://doi.org/10.1007/s13197-021-05048-x

ORIGINAL ARTICLE

Sensory and process optimization of a mango bagasse-based beverage with high fiber content and low glycemic index

Alma Karen Burgos-Araiza[1] · Marcela Gaytán-Martínez[2] · Aurea Karina Ramírez-Jiménez[3] · María de la Luz Reyes-Vega[4]

Revised: 15 February 2021 / Accepted: 23 February 2021 / Published online: 14 March 2021

Abstract This research aimed to develop and optimize a mango bagasse (MB) powdered beverage with high fiber content and low glycemic index, acceptable by their potential consumers. The powdered beverage contained 40 g of mango bagasse (*Manguifera indica* L., var. Manila), xanthan gum (XG), carboxymethyl cellulose (CMC), and silicon dioxide (SDO). The amount of MB remained constant and, 0.5.%, 1.0%, and 2.0% of CMC, XG and SDO were added according to a factorial design 3^3. The independent variables evaluated were relative viscosity, sedimentation index, solids (°Bx), and color. Statistical optimization was carried out, looking for low values of viscosity and sedimentation index, obtaining the formulation, 0.5% XG, 0.5% CMC, and 0.5% SDO. A preference test was performed with this formulation using a commercial powdered beverage as a reference, 60 consumers participated. Data showed a preference similar to that of the commercial powered beverage, moreover, the MB beverage had a content of 40.90% of total fiber, from which 15.03% was soluble fiber. The beverage had a low glycemic index (45.99) and its postprandial glycemic curve was stable for 120 min, indicating that the beverage shows potential as a functional food.

Keywords Beverage · Fiber · Mango bagasse · Sensory analysis · Glycemic index

✉ Marcela Gaytán-Martínez
marcelagaytanm@yahoo.com.mx

[1] Posgrado en Diseño e Innovación de Producto, Facultad de Ingeniería, Universidad Autónoma de Querétaro, Cerro de Las Campanas S/N Col. Cerro de Las Campanas, C.P. 76010 Santiago de Querétaro, Mexico

[2] Posgrado en Ciencia y Tecnología de Los Alimentos, Research and Graduate Studies in Food Science, School of Chemistry, Universidad Autónoma de Querétaro, Cerro de Las Campanas S/N Col. Cerro de Las Campanas, C.P. 76010 Santiago de Querétaro, Mexico

[3] Tecnologico de Monterrey, School of Engineering and Science, Av. Eugenio Garza Sada 2501 Sur, Monterrey C.P. 64849, N.L., Mexico

[4] Universidad Autónoma de Querétaro, Departamento de Investigación y Posgrados, C.P. 76010 Santiago de Querétaro, Mexico

Introduction

Mango (*Manguifera indica* L.) is considered the tropical fruit most cultivated around the world. Mexico is the fifth producer country (SAGARPA 2017) averaging 1.88 million tons per year. One of the most cultivated mango varieties is Manila (Krieger et al. 2017) which is further processed to obtain a great variety of products, such as pulp, juice or nectar, confectionery, jellies, sauces, pickles, ice cream and dehydrated mango. After mango processing, skin (15–20%), seeds (20–60%) and bagasse are the main by-products (40–60%) of the mango industry, which represent economic losses and ecological contamination if they are not properly discarded (Serna-Cock et al. 2016).

Mango bagasse (MB) comprises the fibers attached to the seeds and distributed in the pulp. It has a remarkable potential in the development of food products due to its abundance of bioactive compounds, such as dietary fiber (33.12%), insoluble fiber (19.43%) and soluble fiber (13.68%) (Herrera-Cazares et al. 2017). MB is also an important source of mangiferin and phenolic compounds such as quercetin, gallic acid (Herrera-Cazares et al. 2017), anthocyanins, yellow flavonoids, β-carotene and fiber (Ribeiro da Silva et al. 2014), that have important health benefits.

Currently, the role of dietary fiber as functional ingredient is well known. Fiber is negatively correlated with low glycemic index (Vargas-Aguilar and Hernández-Villalobos 2013) and prevents obesity, overweight and type II diabetes (Øverby et al. 2013), among other effects. Unfortunately, the consumption of foods with high glycemic index (GI), with high calorie content is popular among the population. In this category, sugary beverages contribute to the prevalence of metabolic disorders due to the high calorie load contains in a single portion (Singh et al. 2015). To prevent this situation, the intake of functional foods and beverages are recommended, especially those with low to moderate GI and high fiber content (Freidin 2016).

Functional beverages represent an emergent market that is beginning to be explored. According to Corbo et al. (2014), beverages are considered active functional products that can be used as vehicles of bioactive compounds. A number of studies had evaluated the glycemic index of beverages that contain dietary fiber from different sources. For example, Chen et al. (2017) found a 23% reduction in the post-prandial metabolic curve's area of a beverage containing 77% of orange sub-products. Vuksan et al. (2017) evaluated post-prandial glycemia of two beverages, added with 8.8 g of either linen or chia. The authors reported that the beverage with chia reduced ($-$ 0.64 $\pm$ 0.24 mmol/L) and retarded (11.3 $\pm$ 3.8 min) the maximum peak of the post-prandial curve compared with the linen beverage.

Since MB is a mango by-product that is commonly discarded despite its important content of dietary fiber, antioxidants, and phenolic compounds, in this research we have developed a beverage that contains MB as the main ingredient. Our objective was to develop a functional beverage with low glycemic index added with MB as source of dietary fiber. The main technological challenge was the optimization of the beverage´s formulation, in order to obtain a product with sensory and physicochemical characteristics close to the beverages that already exist in the market, especially viscosity and sedimentation index. In summary, this research contributes to ameliorate the ecological impact of the mango industry and to provide a functional beverage that contributes to consumers health.

Materials and methods

Mango bagasse

MB from commercial mango (*Manguifera indica* L. Var. Manila) was provided by an enterprise located in San Juan del Río, Querétaro, México. MB was collected in plastic bags and stored at – 18 °C.

Beverage development

The development of powdered beverage was carried out in four stages: (1) Powder preparation, (2) Evaluation of additives on the beverages physical properties, (3) Statistical optimization and (4) Sensory evaluation.

Powder preparation

MB was dehydrated at 57 °C (Dehydrator Excalibur 9-try Delux, model #39,000, USA) and pulverized in a grinder (Krups GX4100, México) until its average particle size was 128 µm. For the development of the powdered beverage, a factorial experiment design 3^3 was carried out. The independent variables were carboxymethylcellulose (CMC), xanthan gum (XG) and silicon dioxide (SDO) level. These ingredients were added to MB in different amounts (Table 1) and mixed until a homogeneous powder was obtained. The response variables evaluated were viscosity, sedimentation index, soluble solids and color. The level of additives were established based on the Codex Alimentarius 192–1995 (FAO/OMS 1995). A commercial powdered beverage was used as control.

Effect of additives on physical characteristics

Viscosity

Twenty-one mL of beverage was prepared by mixing the MB powder with water in a 1:25 ratio during 2 min to obtain a homogeneous solution. A rheometer (Anton Paar, Physica MCR101 model, Graz, Switzerland) with geometry ST24-2D/2 V/2 V-30 was used. The evaluation was performed for 2 min at 25 °C and at a constant speed (160 min).

Sedimentation index

The methodology proposed by Matalanis and McClements (2013) was used with some modifications. Fifty mL of the beverage were measured in a 100 mL graduated cylinder and let stand during 2 h. After this time, the sediment volume was recorded. Sedimentation index was reported as the relation between initial (0%) and final sedimentation level (after 2 h).

Soluble solids

This analysis was performed according to the methodology proposed by Ozarda et al. (2015), using a digital refractometer (Hanna Instruments Inc., HANNA HI-96801, Rhode Island, USA).

Table 1 Effect of independent variables on soluble solids and color of the beverage

Formulation	CMC (%*)	XG (%*))	SD (%*))	Soluble solids (°Bx)	Color		
					L	C	H
1	0.5	0.5	0.5	2.93 ± 0.06	46.63 ± 0.49	22.74 ± 0.77	58.42 ± 0.06
2	0.5	0.5	1	2.97 ± 0.06	46.85 ± 0.79	23.64 ± 0.34	59.02 ± 0.68
3	0.5	0.5	2	3.00 ± 0.00	45.71 ± 0.27	22.05 ± 0.45	59.51 ± 0.15
4	0.5	1	0.5	2.97 ± 0.06	47.21 ± 0.04	23.49 ± 0.99	57.50 ± 0.29
5	0.5	1	1	2.40 ± 0.10	47.56 ± 1.12	23.64 ± 0.42	57.52 ± 0.72
6	0.5	1	2	2.97 ± 0.06	47.27 ± 0.23	23.51 ± 0.08	57.08 ± 0.20
7	0.5	2	0.5	3.03 ± 0.06	46.99 ± 0.84	23.49 ± 0.55	57.36 ± 0.44
8	0.5	2	1	3.00 ± 0.00	46.94 ± 0.84	22.55 ± 0.63	58.80 ± 0.51
9	0.5	2	2	3.00 ± 0.00	45.72 ± 0.13	21.39 ± 0.12	58.85 ± 0.12
10	1	0.5	0.5	3.03 ± 0.06	45.10 ± 0.54	22.08 ± 0.41	59.83 ± 0.46
11	1	0.5	1	3.00 ± 0.00	45.65 ± 0.30	22.01 ± 0.68	58.93 ± 0.08
12	1	0.5	2	3.00 ± 0.00	46.26 ± 0.37	22.14 ± 0.67	58.22 ± 1.16
13	1	1	0.5	3.00 ± 0.00	48.19 ± 0.33	21.21 ± 0.04	56.06 ± 0.26
14	1	1	1	3.03 ± 0.06	45.96 ± 0.02	21.88 ± 0.65	59.28 ± 0.26
15	1	1	2	3.00 ± 0.00	45.64 ± 1.54	21.62 ± 0.12	58.91 ± 1.33
16	1	2	0.5	2.93 ± 0.06	47.07 ± 0.46	22.68 ± 0.84	57.84 ± 0.74
17	1	2	1	3.00 ± 0.00	47.69 ± 0.50	23.49 ± 0.08	57.20 ± 0.46
18	1	2	2	2.93 ± 0.06	46.49 ± 0.50	22.79 ± 0.23	57.56 ± 0.41
19	2	0.5	0.5	2.90 ± 0.1	45.15 ± 4.69	22.73 ± 2.31	57.41 ± 0.87
20	2	0.5	1	3.00 ± 0.00	47.26 ± 1.18	23.28 ± 1.08	57.62 ± 0.67
21	2	0.5	2	2.97 ± 0.06	46.44 ± 0.20	22.86 ± 0.07	58.43 ± 0.18
22	2	1	0.5	3.00 ± 0.00	46.80 ± 0.66	23.20 ± 0.27	58.02 ± 0.48
23	2	1	1	2.97 ± 0.06	47.13 ± 1.11	22.98 ± 0.81	57.20 ± 0.68
24	2	1	2	2.93 ± 0.06	46.31 ± 0.55	22.12 ± 0.46	58.69 ± 0.59
25	2	2	0.5	3.00 ± 0.00	45.72 ± 1.26	21.12 ± 0.33	58.66 ± 1.12
26	2	2	1	2.97 ± 0.06	46.77 ± 1.07	23.38 ± 0.50	57.17 ± 0.73
27	2	2	2	2.97 ± 0.06	46.41 ± 0.76	22.38 ± 0.26	58.12 ± 0.54

The concentration used of the powder to prepare the beverage was 0.04 g/mL

CMC carboxymethylcellulose, *XG* xanthan gum y, *SD* silicon dioxide, *L* lightness, *C* chroma y, *H* hue

*Percentage calculated based on the content of mango bagasse, taking this as 100%

Color

Color parameters were measured using a NH310 high-quality portable colorimeter (8 mm). Before each measurement, the instrument was calibrated with a white tile provided by the fabricant. To perform the test, 20 mL of the beverage were poured in a transparent container. The colorimeter was placed at 0.5 cm from the sample to acquire the image. The Commission Internationale de L'éclairage (CIE) coordinates Lightness (L), chroma (C), and hue (H) values were obtained directly from the instrument. Each measurement was made in triplicate. Differences in color were calculated with Eq. 1, according to Guimarães et al. (2018), where delta represents the difference between the MB beverage and the control beverage.

$$\Delta E*_{LCH} = \left(\Delta L^2 + \Delta C^2 + \Delta H^2\right)^{1/2} \tag{1}$$

where ΔE: global color variation, L: lightness, C: chroma, H: hue.

Statistical optimization

From the results obtained with the 3^3-factorial design, only viscosity and sedimentation had a significant effect on the model. A response surface model was used for optimization of the beverage formulation. Based on data obtained from the preliminary sensory evaluation (data not shown), the optimal response should minimize viscosity and the sedimentation index. For both variables, desirability was higher than 85%. The theoretical values obtained with the regression analysis were contrasted with the experimental values obtained from the optimized formulation.

Sensory evaluation

A ranking test was performed with the optimized beverage (OB) to evaluate its preference according to the previous reported method (Ramírez-Jiménez et al. 2018). Sixty consumers participated in this evaluation, 34 women and 26 men whose average ages were 24.4 ± 5.62 years for women and 22.8 ± 3.39 for men. Each participant evaluated two beverages (OB and a commercial beverage (CB)) in a single session. The sensory tests were performed at 11:00 am. in the sensory evaluation laboratory of Universidad Autónoma de Querétaro. Each panelist was provided with 20 mL of each beverage, which was labeled with 3-digit random numbers. The panelists were asked to rinse their mouths with water for 1 min and then spit it out in a special container. Then, they evaluated the samples, performing a wash between each one. Samples were randomly presented to the panelists who were asked to assign number 1 to the most preferred sample and number 2 to the least preferred sample. Preference was expressed as the rank sum of scores given to each formulation. The most preferred formulation was selected for further analyses. The sum of the ranks of each formulation was plotted to observe differences between formulations. This protocol was approved by the Ethics Committee of the Universidad Autónoma de Querétaro (registry number: 9366).

Proximate analysis

The AOAC (2002) methods were used: moisture (925.10), protein (920.15), lipid (920.39), dietary fiber (941.43), ash (942.05), and total carbohydrate (by difference method). Reducing sugars were determined by the DNS method (Başkan et al. 2016).

Glycemic index

Eighteen young adults (22–30 years-old, 11 women and 7 men) with 20–24.9 kg/m^2 body mass index participated voluntarily. The study was carried out in accordance with the ethical guidelines of the Helsinki Code and was approved by the Ethics Committee (file 9366) of the Faculty of Engineering of the Universidad Autónoma de Querétaro. Each participant explicitly expressed their informed consent to participate in the study. The medical history, weight, height, body mass index (BMI) and abdominal circumference were registered for each participant who signed the informed consent form. The inclusion criteria were: absence of chronic diseases, especially Diabetes Mellitus, absence of medical prescription, and normal blood biochemical values. The exclusion criteria were smoking, lipid-lowering medication, use of steroids and other agents that may influence the metabolism of lipids, thyroid disease, recent eating disorders and cardiovascular events suffered in the last semester.

A randomized-cross-over test was used to evaluate blood glucose levels of the participants at baseline and after the consumption of the optimized beverage (OB), a commercial beverage (CB) or an anhydrous glucose solution (GS) used as reference solution (50 g dissolved in 335 mL of water). Each product was evaluated in duplicate (two sessions). The study was conducted after a 12 h fasting, in each session, participants consumed 335 mL of the assigned beverage (50 g of carbohydrates) after a 12 h fasting (time 0). Capillary finger-prick blood samples were taken from subjects at 0, 15, 30, 45, 60, 75, 90, 105, and 120 min. Glucose concentrations were measured with a glucometer (Accu-check, ROCHE, Reg. No. 0681E2017 SSA) and plotted against time. The area under the curve (AUC) of blood glucose was calculated with GraphPad Prism 5 software (GraphPad, La Jolla, CA, USA.) and the baseline was taken at the average fasting glucose values for each sample: 84.98 mg/dL for GS, 87.81 mg/dL for CB and 87.66 mg/dL for OB. GI was calculated as the ratio between the mean AUC of OB or CB and the mean AUC of the reference beverage (glucose solution).

Statistical analysis

In the first stage, a randomized 3^3 factorial test was used. Concentration of CMC, XG and SDO (0.5, 1, 2%) were the independent variables. All measurements were made in triplicate; data were evaluated using an ANOVA test ($p < 0.05$), Minitab 17 software. Sensory evaluation data were evaluated using a Kruskall-Wallis test ($p < 0.05$). Data from the evaluation of the glycemic index were expressed as mean ± standard deviation.

Results and discussion

Beverage development

The powder developed to prepare the beverage was a homogeneous yellow ocher powder and the beverage showed the same color with some visible suspended particles in it.

Viscosity

Viscosity was influenced by CMC and XG, whereas SDO did not have any effect on this variable. The interaction between CMC and XG ($p < 0.01$) also had a significant effect on viscosity. Figure 1 shows the effect of CMC and XG concentrations on viscosity at 1% SDO. Viscosity values were in the range of 32.84–157.50 cP; viscosity was dependent of the CMC and XG concentration, the least viscous formulations were observed with the lowest addition of these two ingredients. Vickers et al. (2015) reported that beverages with viscosities between 51–350 cP are considered nectar (syrup like) beverage, for this reason, the samples with more than 51 cP were discarded from this study.

Similarly, Abedi et al. (2014) reported that the addition of CMC to a dairy beverage with raspberry flavor increased its viscosity in a concentration-dependent manner. This increment in viscosity occurs because of the chemical structure of CMC; its particles get adsorbed on the particles of the powdered concentrate during mechanical agitation, forming a protective coating that avoids aggregation or flocculation (Ibrahim et al. 2011). Cho and Yoo (2015) reported a similar case in fruit juices and milk beverages using XG, an effect explained by the high molecular weight of XG and the electrostatic repulsion forces between the particles that maintain the viscosity and stability of the product (Brandenstein et al. 2014).

Sedimentation index

The sedimentation index of samples was found between 0.33 and 27.67%. Higher concentrations of CMC and XG, caused lower sedimentation index. The interaction between both gums was also significant ($p < 0.01$), whereas SDO did not affect on this characteristic. Data from this study showed that the lowest sedimentation index value corresponded to samples with 1–2% CMC and 2% XG; however, the viscosity of those samples was > 51 cP and were discarded from the study.

The sedimentation index is an important characteristic for consumer's acceptance (Saxena et al. 2015). Hajmohammadi et al. (2016) reported desirable sedimentation rates (5–10%) using 0.25–0.5% CMC in a beverage with basil seeds, whereas Aghajanzadeh et al. (2017) used 0.1–0.2 g/100 g XG in a watermelon juice without sedimentation. It is well known that CMC and XG are carbohydrates that stabilize and emulsify different beverages providing an homogeneous appearance (Hajmohammadi et al. 2016; Cardozo et al. 2017); however, concentration must be regulated because the excess of gums may cause flocculation (Xu et al. 2013).

Soluble solids and color

Soluble solids of the OB were significantly lower (2.40–3.03 °Bx) than those of the CB, a commercial juice

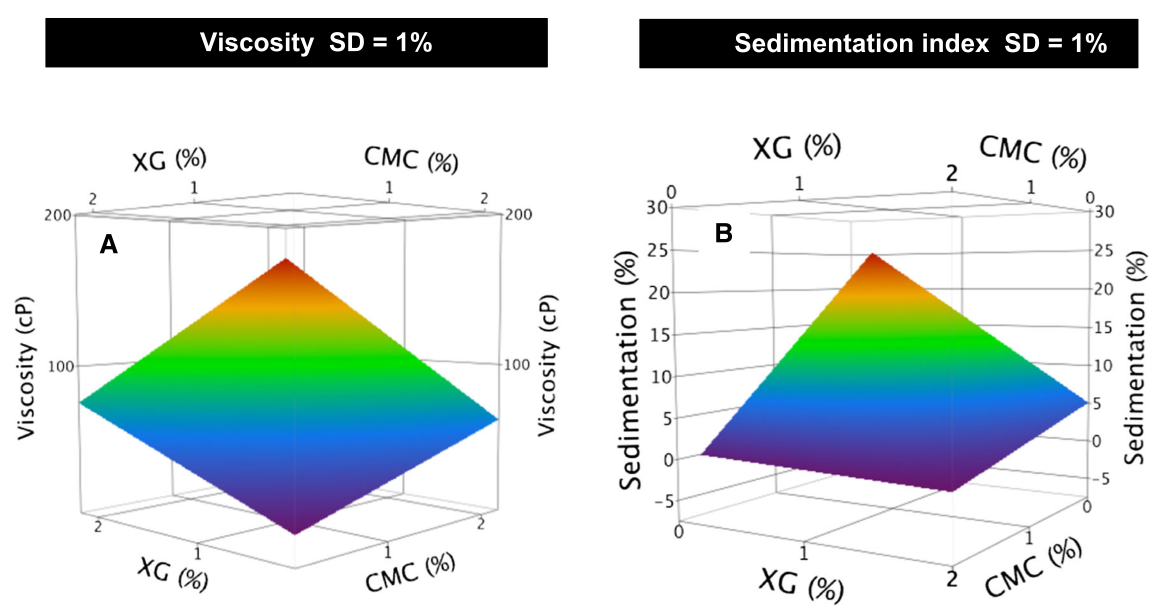

Fig. 1 Surface response plots showing the interaction between carboxymethyl cellulose and xanthan gum at 1% of silicon dioxide, for viscosity (**a**) and sedimentation index (**b**). Only the graph for 1% silicon dioxide (SD) is included as a representation of the behavior, since the variation of % SD did not have a significant effect on the viscosity and sedimentation index

and a commercial nectar (10.6 and 12.17 °Bx, respectively). This value is related to the sugar concentration of the beverage (Maireva et al. 2013).

Data from color evaluation (Table 1) indicated that average L (lightness) was 46.55 ± 0.78, C (chroma) 22.61 ± 0.77 and H (hue) 58.12 ± 0.89. No significant differences were detected between samples for these values. Color is an important quality characteristic for consumers. For this reason, the color differences between samples and a CB (L = 46.28 ± 2.94, C = 26.74 ± 0.76, H = 62.08 ± 0.91) were calculated. The global differences between the mango beverage an CB were $\Delta L = +0.27$, $\Delta C = -4.13$ and $\Delta H = -3.96$ indicating that the samples of the mango beverage were more luminous, with lower color saturation (chroma) and a less intensive yellow tone (hue) than the commercial one.

Optimization

After the factorial regression analysis, the formulation containing 100 g MB, 0.5 g CMC, 0.5 g XG and 0.5 g SDO was selected. These values met the criteria for the minimum viscosity and sedimentation index previously stablished in the regression model. Table 2 compares the predicted and experimental values of viscosity and sedimentation index without a significant difference between them.

Sensory analysis

Figure 2 shows the rank sum obtained from the sensory analysis for the OB and the CB. A similar preference between these samples was observed. This data is especially important, since it indicates that the OB can be positioned in a market with similar preference than the existing products, a market where high-fiber beverages have low acceptance by consumers (Yang et al. 2017).

Chemical composition

The proximate composition of the optimized mango bagasse powder is shown in Table 3. The optimized mango bagasse powder contained 2.71 ± 0.08% ash, 1.55 ± 0.07% lipids and 4.74 ± 0.04% proteins. Herrera-Cazares et al. (2017) reported 6.9 ± 0.03%, 3.0 ± 0.04%, 2.5 ± 0.5%, for ashes, lipids and proteins respectively, in mango bagasse obtained from Ataulfo mango. Differences may be due to different mango varieties.

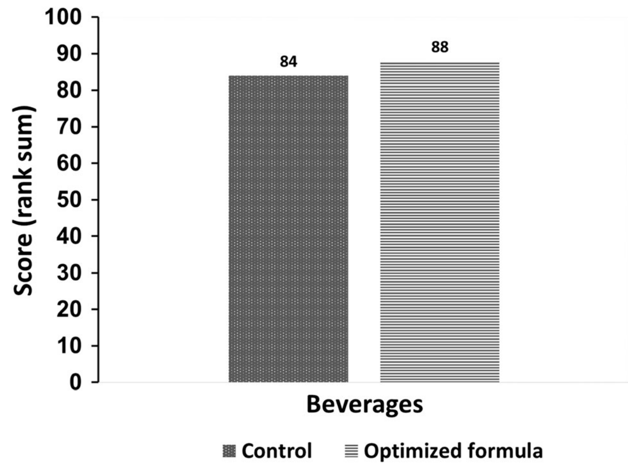

Fig. 2 Ranking test of the optimized formulation versus control. *Control* commercial beverage, *Optimized formula* MB beverage with 0.5% CMC, 0.5% XG and 0.5% SD. There's no significant difference between the beverages in the Kruskal–Wallis test ($p < 0.05$)

Table 3 shows that the dietary fiber content (40.19 ± 0.19%) of the OB is enough to be considered a high-fiber beverage. According to FAO (1997) standards, a high-fiber beverage must contain at least 6 g of total dietary fiber per serving. As expected, the amount of total dietary fiber was lower in the CB than in the OB, and although the sugars content was higher in the OB, these are natural sugars from the MB. The proportion of soluble:insoluble fiber was 1:1.72 showing a lower proportion of insoluble fiber than most fiber-rich foods such as oats and legumes (Ramírez-Jiménez et al. 2014, 2018), but similar to other fruit by-products (Amaya-Cruz et al. 2015).

Some other researchers reported the development of different fiber-added beverages, such as Saxena et al. (2015) that developed a watermelon beverage with 5% of guar fiber. In another study, Lyly et al. (2009) developed beverages with 2.5–5 g of β-glucan fiber. In these investigations, a sensory evaluation was not carried out in order to determine the preference of the beverages by the consumers. And neither did the researchers who used some agroindustry waste for the development of their beverages,

Table 2 Parameters by statistical optimization for viscosity and sedimentation index

Parameter	Predicted value	Experimental value	p value*
Viscosity	34.64 ± 2.08 cP	32.84 ± 0.49 cP	0.4053
Sedimentation index	23.75 ± 1.83%	23.67 ± 0.58%	0.9459

The predicted and experimental values correspond to the optimized 0.5% CMC, 0.5% XG and 0.5% SD. The R^2 value of the statistical optimization equation for the parameters was 0.85

*Obtained from the Student's t test

Table 3 Proximal analysis and glycemic index of the final optimized beverage and commercial control

Compound	Final Optimized Beverage (OB)	Commercial Beverage (CB)	Glucose solution
Moisture (%)	8.04 ± 0.34	–	
Ashes (%)	2.71 ± 0.08	–	
Lipids (%)	1.55 ± 0.07	0*	
Proteins (%)	4.74 ± 0.04	6.6*	
Carbohydrates (%)	82.94 ± 0.32	60*	
Sugars (%)	16.64 ± 1.61	8.39 ± 1.05	
Total fiber (%)	40.90 ± 0.19	6.6*	
Soluble fiber (%)	15.03 ± 1.12	–	
Insoluble fiber (%)	25.87 ± 0.54	–	
Incremental glucose peak (mg/dL)	110.4 ± 3.39[b]	138.6 ± 4.67[a]	133.95 ± 4.17[a]
Area under the curve	85.56 ± 5.36[c]	144.1 ± 1.55[b]	186.6 ± 9.89[a]
Glycemic index	45.99 ± 5.55[c]	77.35 ± 4.94[b]	100[a]

The formulation corresponding to the final optimized beverage was: 0.5% CMC, 0.5% XG and 0.5% SD. *Values in the nutritional table of the commercial beverage. Different letters indicate significant difference between values of the columns

such as beet (Sharma et al. 2016) or linen and chia (Vuksan et al. 2017).

Glycemic index

The amount of MB used to prepare the beverage assured the inclusion of 8 g of dietary fiber per serving (500 mL). The goal was to formulate the beverage as a source of dietary fiber for an adult from 19 to 50 years-old, providing at least 20% of the recommended daily intake (USDA 2015).

Figure 3 shows the curves of postprandial glycemia of each solution: glucose (GS), optimized beverage (OB) and commercial beverage (CB). Glucose absorption was similar for GS and CB with a maximum peak at 30 min, whereas OB followed a different glucose absorption patter. The CB showed a pronounced decrease of blood glucose, typical of simple sugars. The blood levels of glucose for OB were stable over time, showing no significant differences with basal values, this behavior is typical of low glycemic index foods. Similar values were reported for some pasta, such as noodles with millet flour (Shukla and Srivastava 2014) and a cookie with whole wheat, spelled and oats (Schuchardt et al. 2016).

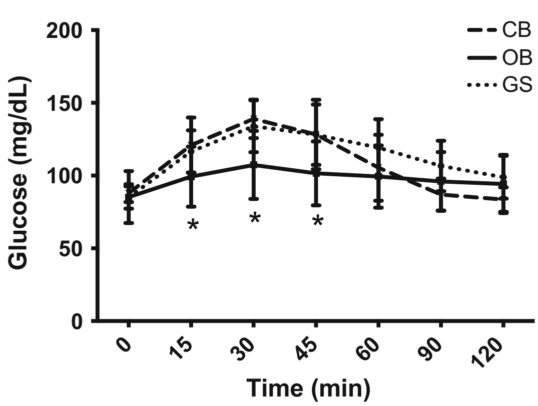

Fig. 3 Postprandial blood glucose curves after control and optimized beverage consumption. *CB* Commercial beverage, *OB* Optimized beverage, *GS* Glucose control solution. *Statistical differences within samples

From Table 3 it can be observed the peak values of blood glucose and the area under the curve (AUC) for the beverages. The GS and the CB did not differ statistically, but OB had a lower AUC value, which indicates a slow release of glucose, typical of products with a low glycemic index. This behavior has been reported for products with a relative high proportion of soluble fiber (Chen et al. 2017), and for low AUC values (Vuksan et al. 2017). Moreover, Cree-Green et al. (2018) reported that the shape of the glucose curve is related to the secretion and action of insulin, which is related to diabetes II.

The glycemic index of OB was 45.99 ± 5.55, value that fits in the low GI category (GI $<$ 55), which means a low increase of blood glucose over time. In contrast, CB had a GI of 77.35 ± 4.94, which is considered high (GI $\geq$ 70). GI is lower when the absorption of digestible carbohydrates is slow; in this sense, the soluble fiber contained in MB as well as the additives used (CMC and XG), decreased the absorption rate of carbohydrates (Vuksan et al. 2017). This phenomenon is possibly related to the viscosity, which has been associated with slow digestion and absorption of carbohydrates and satiety regulation (Lyly et al. 2009).

Conclusion

The powdered mango bagasse beverage designed in this study, was optimized to fulfilled the FAO requirements for being considered a high-fiber beverage (> 6 g of total dietary fiber per serving). Despite the added value of its dietary fiber content, the soluble to insoluble fiber ratio is an important feature since soluble fiber is closely related to the prevention and amelioration of certain metabolic disorders, such as colitis, obesity and cardiovascular disease. Given the rise of these metabolic diseases, consumers are demanding low-calorie and healthier products, but with the same sensory value as the traditional ones. In this line, the optimized beverage formulation (100 g MB, 0.5% XG, 0.5% CMC, and 0.5% SDO) minimizes undesirable features such as sedimentation and viscosity. These results might have positively influenced the beverage acceptance by consumers, since no significant differences were found for consumers preference between the OB beverage and the commercial powered beverage.

According to our results, the OB (GI = 45.99 ± 5.55) can be considered as a low glycemic index beverage, that keeps stable the post-prandial blood glucose levels, due to its high- dietary fiber content. This feature is an advantage to position our product in the high- dietary fiber beverage market. Moreover, we favor the industrial use of a by-product (mango bagasse), which has proven to be a functional ingredient with potential use in the beverage market.

Acknowledgements Author Alma Karen Burgos Araiza was supported by a scholarship from the Consejo Nacional de Ciencia y Tecnología (CONACYT-Mexico). This research was supported by the FOFI-UAQ Universidad Autónoma de Querétaro.

Author contributions GM participated with the design of work and supervision of results. BA carried out the experimental part of this work. RJ gave support to interpret the results and to write the article. RV participate in the interpretation of results and statistical analysis.

Declarations

Conflict of Interest Authors have nothing to disclose.

References

Abedi F, Sani AM, Karazhiyan H (2014) Effect of some hydrocolloids blend on viscosity and sensory properties of raspberry juice-milk. J Food Sci Technol 51:2246–2250. https://doi.org/10.1007/s13197-012-0705-0

Aghajanzadeh S, Ziaiifar AM, Kashaninejad M (2017) Influence of thermal treatment, homogenization and xanthan gum on physicochemical properties of watermelon juice: a response surface approach. LWT Food Sci Technol 85:66–74. https://doi.org/10.1016/j.lwt.2017.07.007

Amaya-Cruz DM, Rodríguez-González S, Pérez-Ramírez IF et al (2015) Juice by-products as a source of dietary fibre and antioxidants and their effect on hepatic steatosis. J Funct Foods 17:93–102. https://doi.org/10.1016/j.jff.2015.04.051

AOAC (2002) Official methods of analysis of AOAC International, 16a edición. Asociación de analíticos oficiales, Washington, DC

Başkan KS, Tütem E, Akyüz E et al (2016) Spectrophotometric total reducing sugars assay based on cupric reduction. Talanta 147:162–168. https://doi.org/10.1016/j.talanta.2015.09.049

Brandenstein CV, Busch-Stockfisch M, Fischer M (2014) Sweetness and other sensory properties of model fruit drinks: does viscosity have an impact? J Sci Food Agric 95:809–818. https://doi.org/10.1002/jsfa.6907

Cardozo CJM, Castañeda CAJ, Ripoll CSS (2017) Development of mango (Mangifera indica L.) energy drinks. Rev Fac Nac Agron Medellín 70:8115–8121. https://doi.org/10.15446/rfna.v70n1.61770

Chen C-YO, Rasmussen H, Kamil A et al (2017) Orange pomace improves postprandial glycemic responses: an acute, randomized, placebo-controlled, double-blind, Crossover Trial in Overweight Men. Nutrients 9:130. https://doi.org/10.3390/nu9020130

Cho HM, Yoo B (2015) Rheological characteristics of cold thickened beverages containing xanthan gum-based food thickeners used for dysphagia diets. J Acad Nutr Diet 115:106–111. https://doi.org/10.1016/j.jand.2014.08.028

Corbo MR, Bevilacqua A, Petruzzi L et al (2014) Functional beverages: the emerging side of functional foods: commercial trends, research, and health implications. Compr Rev Food Sci Food Saf 13:1192–1206. https://doi.org/10.1111/1541-4337.12109

Cree-Green M, Xie D, Rahat H et al (2018) Oral glucose tolerance test glucose peak time is most predictive of prediabetes and hepatic steatosis in obese girls. J Endocr Soc 2:547–562. https://doi.org/10.1210/js.2018-00041

FAO (1997) Declaraciones Nutricionales y Saludables (CAC/GL 23-1997). http://www.fao.org/ag/humannutrition/33313-033ebb12db9b719ac1c14f821f5ac8e36.pdf

FAO/WHO (1995) Codex Alimentarius Commission, Codex Committee on Pesticide Residues, Rome, Supplement 1, vol 2

Freidin B (2016) Alimentación y riesgos para la salud: visiones sobre la alimentación saludable y prácticas alimentarias de mujeres y varones de clase media en el Área Metropolitana de Buenos Aires. Salud colectiva 12:519–536. https://doi.org/10.18294/sc.2016.913

Guimarães JT, Silva EK, Alvarenga VO et al (2018) Physicochemical changes and microbial inactivation after high-intensity ultrasound processing of prebiotic whey beverage applying different ultrasonic power levels. Ultrason Sonochem 44:251–260. https://doi.org/10.1016/j.ultsonch.2018.02.012

Hajmohammadi A, Pirouzifard M, Shahedi M, Alizadeh M (2016) Enrichment of a fruit-based beverage in dietary fiber using basil seed: effect of Carboxymethyl cellulose and Gum Tragacanth on stability. LWT Food Sci Technol 74:84–91. https://doi.org/10.1016/j.lwt.2016.07.033

Herrera-Cazares LA, Hernández-Navarro F, Ramírez-Jiménez AK et al (2017) Mango-bagasse functional-confectionery: vehicle for enhancing bioaccessibility and permeability of phenolic compounds. Food Funct 8:3906–3916. https://doi.org/10.1039/c7fo00873b

Ibrahim GE, Hassan IM, Abd-Elrashid AM et al (2011) Effect of clouding agents on the quality of apple juice during storage. Food Hydrocoll 25:91–97. https://doi.org/10.1016/j.foodhyd.2010.05.009

Krieger HM, Soria EG, de la Carranza MTG, Farías JPG (2017) Análisis econométrico de las ventas de pulpa de mango de frozen pulps de méxico sa de cv. Pist Educ 38:124

Lyly M, Liukkonen K-H, Salmenkallio-Marttila M et al (2009) Fibre in beverages can enhance perceived satiety. Eur J Nutr 48:251–258. https://doi.org/10.1007/s00394-009-0009-y

Maireva S, Usai T, Manhokwe S (2013) The determination of adulteration in orange based fruit juices. Midl State Univ Dep Food Sci Nutr 2:365

Matalanis A, McClements DJ (2013) Hydrogel microspheres for encapsulation of lipophilic components: optimization of fabrication & performance. Food Hydrocoll 31:15–25. https://doi.org/10.1016/j.foodhyd.2012.09.012

Øverby NC, Sonestedt E, Laaksonen DE, Birgisdottir BE (2013) Dietary fiber and the glycemic index: a background paper for the nordic nutrition recommendations 2012. Food Nutr Res 57:20709. https://doi.org/10.3402/fnr.v57i0.20709

Ozarda O, Demirkoz AB, Özdemir M (2015) Sensory characteristics and antioxidant capacity of red raspberry extract as a preservative in fruity flavoured beverages. J Food Sci Technol 52:6687–6694. https://doi.org/10.1007/s13197-015-1763-x

Philipp Schuchardt J, Wonik J, Bindrich U et al (2016) Glycemic index and microstructure analysis of a newly developed fiber enriched cookie. Food Funct 7:464–474. https://doi.org/10.1039/C5FO01137J

Ramírez-Jiménez AK, Reynoso-Camacho R, Mendoza-Díaz S, Loarca-Piña G (2014) Functional and technological potential of dehydrated Phaseolus vulgaris L. flours. Food Chem 161:254–260

Ramírez-Jiménez AK, Gaytán-Martínez M, Morales-Sánchez E, Loarca-Piña G (2018) Functional properties and sensory value of snack bars added with common bean flour as a source of bioactive compounds. LWT Food Sci Technol 89:674–680

Ribeiro da Silva LM, Teixeira de Figueiredo EA, Pontes Silva Ricardo NM et al (2014) Quantification of bioactive compounds in pulps and by-products of tropical fruits from Brazil. Food Chem 143:398–404

SAGARPA (2017) Potencial del mango mexicano. SAGARPA

Saxena D, Chakraborty SK, Sabikhi L, Singh D (2015) Process optimization for a nutritious low-calorie high-fiber whey-based ready-to-serve watermelon beverage. J Food Sci Technol 52:960–967. https://doi.org/10.1007/s13197-013-1066-z

Serna-Cock L, García-Gonzales E, Torres-León C (2016) Agro-industrial potential of the mango peel based on its nutritional and functional properties. Food Rev Int 32:364–376. https://doi.org/10.1080/87559129.2015.1094815

Sharma SK, Bansal S, Mangal M et al (2016) Utilization of food processing by-products as dietary, functional, and novel fiber: a review. Crit Rev Food Sci Nutr 56:1647–1661. https://doi.org/10.1080/10408398.2013.794327

Shukla K, Srivastava S (2014) Evaluation of finger millet incorporated noodles for nutritive value and glycemic index. J Food Sci Technol 51:527–534. https://doi.org/10.1007/s13197-011-0530-x

Singh GM, Micha R, Khatibzadeh S et al (2015) Global, regional, and national consumption of sugar-sweetened beverages, fruit juices, and milk: a systematic assessment of beverage intake in 187 countries. PLoS ONE 10:e0124845. https://doi.org/10.1371/journal.pone.0124845

USDA (2015) Dietary Guidelines for Americans 2015–2020, 8th edition

Vargas-Aguilar P, Hernández-Villalobos D (2013) Harinas y almidones de yuca, ñame, camote y ñampí: propiedades funcionales y posibles aplicaciones en la industria alimentaria. Rev Tecnol En Marcha 26:37–45. https://doi.org/10.18845/tm.v26i1.1120

Vickers Z, Damodhar H, Grummer C et al (2015) Relationships among rheological, sensory texture, and swallowing pressure measurements of hydrocolloid-thickened fluids. Dysphagia 30:702–713. https://doi.org/10.1007/s00455-015-9647-9

Vuksan V, Choleva L, Jovanovski E et al (2017) Comparison of flax (*Linum usitatissimum*) and Salba-chia (*Salvia hispanica* L.) seeds on postprandial glycemia and satiety in healthy individuals: a randomized, controlled, crossover study. Eur J Clin Nutr 71:234–238. https://doi.org/10.1038/ejcn.2016.148

Xu L, Xu G, Liu T et al (2013) The comparison of rheological properties of aqueous welan gum and xanthan gum solutions. Carbohydr Polym 92:516–522. https://doi.org/10.1016/j.carbpol.2012.09.082

Yang Y, Ma S, Wang X, Zheng X (2017) Modification and application of dietary fiber in foods. J Chem 2017:1