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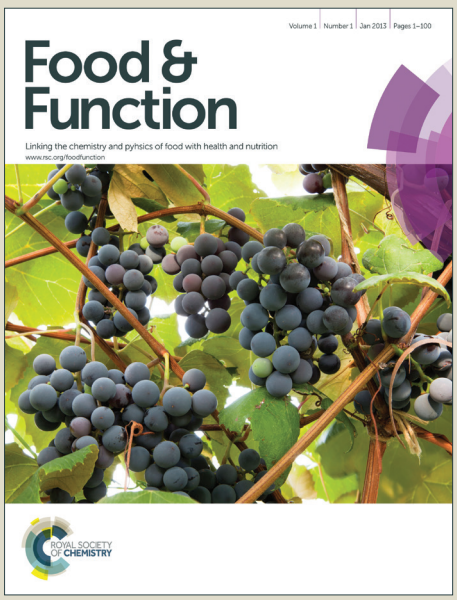

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High Hydrostatic Pressure Processing reduces the Glycemic Index of Fresh Mango Puree in Healthy Subjects

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ABSTRACT

Dietary guidelines recommend daily consumption of fruits; however, healthy and type 2 diabetes mellitus (T2DM) subjects receive conflicting messages regarding ingestion of fruits, such as mango, because of its sugar content. We investigated the effects of high hydrostatic pressure (HHP) processing of fresh mango puree (MP) on the glycemic indexes (GIs) and postprandial glycemic responses of 38 healthy Mexican subjects in a randomized cross-over clinical trial. Physicochemical characterization of MP included sugar profiles by HPLC-ELSD, starch, fibers, moisture, viscosity, swelling capacity and solubility properties of alcohol insoluble residue (AIR). The mean GI for HHP-MP was significantly lower (32.7±13.4) than that of unprocessed-MP (42.7±19.5). A significantly higher proportion of subjects showed a low GI following consumption of HHP-MP compared to unprocessed-MP and none of them showed a high GI for the HHP-MP compared to a significantly higher proportion for the unprocessed-MP. The viscosity and AIR solubility values of HPP-MP samples were significantly higher, which influenced glucose peaking later (Tmax) at 45 minutes and induced 20% lower AUC values than unprocessed-MP, corresponding to greater retardation indexes. The study findings support data stating that low GI fruits are appropriate for glycemic control and that mango may be part of healthy and possible T2DM subjects´ diets. Furthermore, HHP processing of mango may offer additional benefits for glycemic control, as its performance regarding GI, AUC and Tmax was significantly better than the unprocessed-MP. To our knowledge, this is the first report on the impact of this commercial non-thermal pasteurization technology on glucose metabolism.

Key words: glycemic index, type 2 diabetes mellitus, high hydrostatic pressure, mango, carbohydrate metabolism.

INTRODUCTION

Relevant diseases and their prevention have been linked to the postprandial glucose levels and the glycemic index (GI) of foods, especially those related to insulin resistance and diabetes mellitus. Intervention studies in healthy and type 2 diabetes mellitus (T2DM) subjects have shown that foods characterized by a low GI benefit risk markers for the metabolic syndrome[1] and lower the risk of coronary heart disease (CHD) in T2DM patients[2]. On the contrary, unstable hyperglycemic occurrences elicit the production of pro-inflammatory cytokines, which have been related with endothelial damage and risk of cardiovascular disease (CVD)[3, 4].

A food's GI is established by quantifying the increase in blood glucose after consumption by the same subject of an amount containing 50 g of carbohydrate equivalents, which is compared with the same quantity of a reference carbohydrate, such as glucose[5]. A food´s GI $\leq$ 55 is considered low, from 55 to 69 as medium, and $\geq$ 70 as high[6, 7]. The glycemic responses to starchy foods are primarily influenced by an individual´s fasting state and gastrointestinal tract status, as well as the presence of other foods that might be combined with them[8]. However, the GI of fruits may also be influenced by their carbohydrate composition (glucose, fructose, sucrose and starch)[4], structure, maturity degree, and food processing preservation technologies.

Controversy exists regarding consumption of fruits. On one hand, sugar and fructose intake have been associated with decreased insulin sensitivity[9], and increased risk of T2DM[10], CHD and the metabolic syndrome[11, 12]. On the other hand, national authority guidelines recommended for the general public include eating more fruit every day in order to maintain and improve health and to avoid cardio-metabolic diseases[13,14]. This may seem as a paradox. However, general advice regarding consumption of fruits does not consider their GI, nor the type of glycemic postprandial

response each fruit might generate. It has been demonstrated, for example, that a flatter glycemic response occurs after ingestion of whole fruit, in comparison with fruit puree, and fruit juice[15, 16]. The American Diabetes Association[17] guidelines recommend that patients with T2DM include lower GI foods in their diets. A low GI dietary intervention study showed that T2DM patients can improve glycemic control by reducing glycated hemoglobin (HbA1c)[18].

Nevertheless, general public, and especially diabetic patients are frequently misinformed by their relatives, other patients, health providers, and the media, about the pertinence of consuming some types of fruits, such as mango. Many people seem to think that mango has too much sugar content, and therefore suggest avoidance of its consumption in order to maintain or improve glycemic control.

For these reasons, the food industry is being challenged to develop high quality fruit products with a low GI that can be ingested by both, healthy and diabetic consumers. High Hydrostatic Pressure (HHP) processing has been proposed as a promising alternative, since it retains the flavor and the nutritional properties of fruits[19]. HHP treatments have resulted in minor losses of low molecular weight compounds in vegetables, such as pigments, vitamins, and flavor substances without affecting covalent bonds[20]. HHP processing of mango has been reported to result in moderate ascorbic acid losses, of about 15% of initial levels when pulps were treated at lower pressures (100-200MPa for 20 min)[21], whereas treatments at higher pressures (300-600 MPa) resulted in non-significant losses[21,22]. Mango carotenoids have been observed to be stable to HHP processing (non-significant treatment effects) and in some instances levels have even increased[22,23]. Similar observations have been reported for other fruits and vegetables[24-33]. However, HHP treatments have been reported to induce changes in macromolecular structures, for instance, proteins, starches, and cell wall polysaccharides[34]. Prior works have documented that HHP processing can

also result in changes in rheological properties, such as the viscosity[35] and the interconvertions in dietary fibers[34,36].

Therefore, the objective of this study was to assess the effects of HHP processing of mango puree, under common commercial conditions (592 MPa, 3min), compared to unprocessed mango puree (unprocessed-MP) on the GIs and postprandial glycemic responses of healthy subjects. The study also aimed to generate new knowledge for the food processing industry. Additionally, it intended to ascertain the consumption of mango, a well-liked and widely available fruit in Mexico and many tropical countries, as a fit fruit for healthy subjects, and potentially for insulin resistant and diabetic patients. To our knowledge, no meal studies have been published comparing the impact of emerging processing technologies such as HHP, on glycemic responses in humans.

MATERIALS AND METHODS

Subjects

Mexican healthy volunteers (n=38) aged 20-50 years, 19 female and 19 male, were recruited through e-mail or phone communications. All participants answered a questionnaire, administered by a trained person, which included age and gender, caffeine, alcohol and medications use, physical activity, present health status, and past medical history. Anthropometric measurements were performed for each subject: height, weight, BMI, waist circumference, and percentage body fat using a Tanita BF-350 Body Composition Analyzer (Tanita Corp., Tokyo, Japan). Inclusion criteria included a BMI $\leq$27.4, waist circumference $\leq$102 cm for men and $\leq$88 cm for women, and a laboratory fasting plasma glucose <100 mg/dl. Exclusion criteria included a BMI >27.5, the use of hypoglycemic agents, glucocorticoids, thyroid hormone, gastrointestinal motility enhancers or other drugs that interfere with intestinal absorption, as well as gastrointestinal or metabolic

diseases, pregnancy, surgical procedures in the past six months, allergy to mango, known diabetes mellitus, glucose intolerance or insulin resistance, and parents with diabetes mellitus. Subjects were required a 10 hour fast, no alcohol, caffeine, or vigorous exercise 24 h before each food test. To diminish within and inter-subject variability in GI measurements, the participants were requested to avoid modifying their usual diet (except for alcohol and caffeine the previous day of the test) during the length of the study. Written informed consent was obtained from each subject. The study was approved by the Research and Ethics Committee of the School of Medicine, Tecnológico de Monterrey, and was registered as a clinical trial in ClinicalTrials.gov – identifier NCT01929551.

Materials/processing

Fresh ripe mangos (*Mangifera indica L*. cv. Tommy Atkins) were obtained from a local market in Monterrey, NL, México in August, 2013. Fresh mangos (120 kg) were selected by size, shape, peel color, and maturity stage, and transported to the Biotechnology Center-FEMSA laboratories at Tecnológico de Monterrey, Campus Monterrey (Monterrey, NL, México).

Prior to processing, mangos were washed with sodium hypochlorite (12 ppm), manually peeled, and the pulp was homogenized in a commercial blender (Torrey LP12, San Nicolás de los Garza, NL, México). Mango puree was vacuum-packaged into plastic bags (20.3 cm width x 30.5 cm length) that contained 5 layers of polymers making them impermeable to oxygen (Filmpack, Guadalupe, NL, México). Half of the sealed bags were separated as unprocessed control, and the other half were processed by HHP at commonly used commercial processing parameters. The samples were placed in a high-pressure system Quintus (Avure Technologies, Kent, WA, USA) filled with water as the pressure-transmitting fluid, and subjected to pressures of 86,000 psi (592

MPa) for 3 minutes at room temperature (25°C). The samples were transported under refrigeration (4°C) and stored in a freezer at -80°C until their use for analytical determinations and the clinical trial. The samples were then thawed right before the subjects ate the meals each day.

Carbohydrate Standardization of Meals

Sugar profiles by HPLC-ELSD. The sample extraction and characterization was performed following the methodology described in Waters Application Method No. WA64101[37], with modifications. The solvent extraction was conducted with 100% water, similarly to previous authors[38]. The solvent substitution was evaluated and compared to the original methodology, indicating a non-significant ($P<0.05$) effect due the change in solvent (data not shown). The fresh mango puree samples (0.25 g) were weighed and diluted in ultra-pure water (1 mL). The samples were vortexed (30 s) and centrifuged (10,000 rpm over 10 minutes). The supernatants were collected and precipitates were subjected to additional extractions (3-times). The number of extractions required for a complete recovery, in the modified methodology used herein, was previously optimized using various fruit matrixes that included mango, strawberries, apples, and pears. The samples were adjusted to a final volume (5 mL) and filtered through polytetrafluoroethylene membranes (0.45 µm, Millex™, Millipore, Billerica, MA, USA) prior to HPLC analyses.

Chromatographic separation of sugars was performed in a 1200 Series HPLC system (Agilent Technologies, Santa Clara, CA, USA) equipped with an Evaporative Light Scattering Detector (ELSD) and a 4.6 x 250 mm, 3.5 µm, XBridge™ Amide column (Waters Corporation, Milford, MA, USA). Quantification was performed following Waters Application Method No. WA64101[24]. The elution conditions included two mobile phases. Phase A was composed of acetonitrile:water

(80:20 v/v) with 0.2% triethylamine and phase B of acetonitrile:water (30:70 v/v) with 0.2% triethylamine. The gradient elution consisted of 0/90, 16/30, 16.01/90, 30/90 (min/% phase A) at a flow rate of 1.0 mL/min, and an injection volume of 10 µL.

Starch determination. The starch contents of mango pulps were determined by the total starch AOAC method No. 996.11[39] using a commercial kit from Megazyme (Wicklow, Ireland).

Quantification of available carbohydrates. Calculations of available carbohydrates in both treatment meals were obtained using the formula described by Brouns and collaborators (2005)[40]. The quantifications were performed using three independent samples and carbohydrate contents were expressed as available carbohydrates (g of carbohydrates/100 g of mango puree). Each of the two test meals, unprocessed-MP and mango processed by HHP, were portioned to contain 50 g of carbohydrate equivalents.

Clinical study design

A randomized cross-over design was used for the study. Capillary blood was employed to measure glucose by means of Accu-Check Performa glucometers (Roche Diagnostics GmbH, Mannheim, Germany), which were tested twice before each test day for accuracy and precision with the provided kits. Oral glucose (50 g - 250 ml) was used twice as the reference food according to the established recommendations[41]. The tests were considered to have begun at the first oral contact with the index fruit, or the 50 g of oral glucose. All the meals were ingested completely within 15 minutes. Both mango puree meals were consumed with 250 ml of water. A fasting glucose was obtained before each meal. Blood samples to determine postprandial plasma glucose levels were

obtained at 15, 30, 45, 60, 75, 90, 105, and 120 min after consumption of the fruit or the glucose meal. The study took place at the same time in the morning of each test day.

The randomized cross-over design allowed the serving of unprocessed-MP, HHP processed mango puree (HHP-MP), as well as the two oral glucose references, each day of the study to different subjects. The washout period between each test meal was three days.

The GI was calculated as reported by Jenkins and collaborators (1981)[6]:

GI (%) = (Incremental area under the 2-h glucose response curve for a 50 g carbohydrate equivalent of the test fruit ×100)/Incremental area under the 2-h glucose response curve for a 50 g glucose load.

The incremental area under the glycemic response curves, AUC, for each test meal was expressed as a percentage of the mean area under the glucose curves for the same subject. The mean of the two AUCs for glucose was obtained for each subject. The resulting values for all the participants were averaged to calculate the GI for the unprocessed-MP and HHP-MP treatments[4]. Maximum increases in blood glucose (Cmax) values were determined as the maximum values in the postprandial glucose levels above the preprandial plasma glucose levels.

Dietary fiber determination

Total (TDF), soluble (SDF) and insoluble (IDF) dietary fibers were determined by AOAC 991.43[42] and AOAC 985.29[43] methods using the total dietary fiber assay kit from Megazyme (K-TDFR) (Wicklow, Ireland). Analyses were performed in duplicate and the results were expressed as grams (g) of dietary fiber per portion ingested by the study participants.

Hydration properties of mango puree

Swelling determination. Swelling capacity of lyophilized mango puree solids (dry weight) was determined for both, unprocessed and HHP processed treatments, as described by Robertson and others[44].

Characterization of the mango purees alcohol insoluble residues. The weights of alcohol insoluble residues (AIR) were obtained after the extraction of mango puree samples with alcohol (85%) at 78ºC for 5 min. The solubility properties of AIR obtained from both mango purees were determined according to Robertson and others[44].

Viscosity determination. The rheological measurements were carried out using a rheometer model MCR (Anton Paar, Austria). The mango puree samples (~3 g) were placed between parallel plates (model PP50) of 49.71 mm diameter. Measurements were performed at a shear rate of 100 s^{-1} at room temperature (25ºC), as previously described for mango products[22]. The apparent viscosity values were calculated as the average of values in the lineal part of the curve (from 48s to 120s).

Statistical Analyses

All statistical analyses were performed using MINITAB 16 Statistical Software (State College, PA, USA) and JMP s version 5.0 (SAS Institute Inc., Cary, NC, USA). The incremental AUC from 0 to 120 min was calculated by the trapezoidal rule with fasting concentrations as the baseline and truncated at zero[23]. Cmax and maximum concentration time (Tmax) values were obtained directly from the blood glucose concentration data. Values are expressed as mean ± SD for continuous variables and percentages for nominal variables. Comparisons and the difference between means were determined by the paired Student's t-test. Proportions differences were evaluated by the Chi-squared test. The level of statistical significance was set at $P< 0.05$.

RESULTS

Characteristics and anthropometric measurements of the population are shown in Table 1**.** Mean BMI was similar for both genders, 23.4 ± 2.98 for men and 22.7 ± 2.41 for women. Mean waist circumference in cm was higher for males (84.1 ± 7.67) compared to women (76.4 ± 5.63), while mean percentage body fat was higher for women (26.6 ± 5.71) than for men (18.5 ± 5.28).

The chemical composition of the mango puree portions ingested by the participants is presented in Table 2. In order to provide portions with equivalent available carbohydrate levels (50 g/portion), the portion weights were adjusted to 287.61 g for the unprocessed-MP and to 276.01 g for the HHP-MP treatments. Less HHP-MP weight was required per serving because HHP processing resulted in significant increases ($P<0.05$) in the concentrations of free glucose (3%), fructose (3%), and sucrose (4%) (Supplemental Table 1). However, as shown in Table 2, at equivalent carbohydrate levels, both mango puree portions contained non-significant different concentrations of simple sugars, starch, nor of dietary fiber.

The postprandial glucose responses after the consumption of the unprocessed-MP, the HHP-MP and glucose are shown in Figure 1. Glucose rose quickly to high levels above 160 mg/dL, peaked at 45 min and still remained above 100 mg/L at two hours. Both, unprocessed-MP and HHP-MP rose to lower levels and reached their preprandial levels, compared to glucose. It's noteworthy, that the HHP-MP treatment maintained lower levels at the beginning of the test and peaked later than the unprocessed-MP.

Table 3 presents the pharmacokinetics of the unprocessed-MP and HHP-MP meals. Although both fruit meals resulted in low GI values, the mean GI for the HHP-MP was significantly lower (32.7 ± 13.4) than that of unprocessed-MP (42.7 ± 19.5) ($P=0.003$). There was no significant difference

between genders. For the unprocessed-MP, men showed a mean GI of 40.2 ± 19.9 compared to that of women of 33.3 ± 9.2 (*P=0.44*); while for the HHP-MP treatments, men showed a mean GI of 33.3 ± 9.2 and women presented a mean of 33.2 ± 16.9 (*P=0.80*). The unprocessed-MP peaked (Cmax) to 129.7 mg/dL at 30 min (Tmax) while the HHP-MP presented a Cmax of 127.6 mg/dL but significantly afterwards, at 45 min. The average AUC value for glucose, unprocessed-MP and HHP-MP was 4890, 2011, and 1610 mg·min/dL, respectively. Therefore, AUC values of HHP-MP treatments were 20% smaller (*P<0.05*) than the unprocessed-MP values.

Figure 2 reveals that a significantly higher proportion of the subjects showed a low GI when they consumed the HHP-MP (92%), compared to the unprocessed-MP (72%). None of the participants showed a high GI for the HHP-MP, whereas a significantly higher proportion (13%) for the unprocessed-MP did (*P=0.009*).

The concentrations of simple sugars and fibers were the same in both mango puree meals, thus, other physicochemical properties of the food matrixes and their isolated cell wall materials were also studied (Table 4). The evaluated parameters were selected based on their prior associations with changes in glucose retardation indexes and possibly on GI responses[45]. Both mango puree samples presented similar alcohol insoluble residues (AIR) weights and swelling capacities. However, the solubility of the AIR material isolated from the HHP- MP was significantly higher (9%) than that isolated from the unprocessed-MP. The viscosity readings from the HPP-MP were also significantly higher (9%) than those from the unprocessed-MP.

DISCUSSION

Effects of high hydrostatic pressure processing on the composition of mango puree carbohydrates

The content of simple sugars was higher per gram of MP after HHP processing (Supplemental Table 1). Similar increases in concentrations of metabolites such as sugars, carotenoids and organic acids, among others, have been reported in fruits processed by HHP[46-48]. These observations have been attributed to losses of cell integrity, which induce the release of molecules from compartmentalized structures and non-covalent associations[20, 45]. The potential clinical impact of the release of molecules in HHP treated foods has not been evaluated previously. However, the results from the present work suggest that changes in the matrix as a whole, instead of individual components, and the interactions with human metabolism need to be considered to understand the clinical implications of this novel food processing alternative. For instance, while sugars increased by the HHP treatment, the contents of insoluble and soluble dietary fiber were not affected. These results were in agreement with prior publications[46, 49], but differ from those of other authors that have observed fiber inter-conversions in white cabbage and soybean okra[34, 36]. Differences in these observations can be attributed, perhaps, to dissimilarities in the food structures, their enzyme systems, and the HHP processing conditions used[36].

Effects of high hydrostatic pressure processing on the subject´s glucose absorption kinetics

The fact that both, unprocessed-MP and HHP-MP showed a low GI, and that specifically, the GI was significantly lower with the HHP-MP (Table 3) has important clinical implications for both, healthy subjects and potentially for T2DM patients. It has been demonstrated that a low GI diet may improve body weight and lipid profile, and decrease the risk of CHD[2, 50-52]. It has been shown as well, that low GI diets may improve glycemic control and HbA1c levels, [18, 53]. An improved glycemic control through diet can reduce the need for medication, expand quality of life, lessen the risk of diabetic complications and increase life expectancy[18]. A prior study reported a GI of

41 for raw mango[54], and one other study a low to medium GI ranging from 41-60[55]. Differences with these prior studies may be attributed to variations in the biological material used (e.g. cultivar, maturity) or to the preparation methods. Other reports also indicate that fruits in diverse conditions, such as whole fruit, puree, or juice could affect the glycemic response[15, 16].

Contrary to glucose, both mango meals demonstrated a slower rise and a faster decline in the postprandial glucose response. It is noteworthy that, compared to the unprocessed-MP, the HHP-MP showed lower levels at the beginning of the test, peaked significantly later (Tmax) (Figure 1) and the AUC value was significantly lower (Table 3). Furthermore, a significantly higher proportion of subjects showed a low GI, and none of them a high GI when they consumed the HHP-MP, compared to the unprocessed-MP (Figure 2). The clinical importance of these results could be that mango may be part of the diet of healthy subjects, and may perhaps be potentially useful as part of the diet of insulin resistant and T2DM subjects. The study findings may support the scientific data that low GI fruits can improve glycemic control. Moreover, the HHP technology could offer additional benefits in the postprandial glycemic control since its performance was better compared to the unprocessed-MP.

Very small amounts of fructose intake in the range of 7–10 g have shown an impact in priming glucose metabolism by improving glucose tolerance in subjects with uncontrolled T2DM[56]. Fructose pre-feeding also reduced the postprandial glucose concentrations of high GI foods[57]. Additionally, low-dose fructose had a favorable impact on hyperglycemia and reduced hepatic glucose production in T2DM[58]. In the present study, both, unprocessed-MP and HHP-MP, contained adequate fructose concentrations (12 g/portion) to prime glucose metabolism, according to these prior scientific works. Besides, HHP processing resulted in significant increases in the concentrations of free fructose (3%), compared to unprocessed-MP. The consumption of low GI

fruit could also reduce postprandial blood glucose excursions by releasing small amounts of fructose from the gastrointestinal tract into the blood stream over a longer period of time[2]. Thus, mango fruit, and especially HHP processing, may offer this additional benefit. This is a relevant observation that goes against the dietary perception that mango, because of its simple sugar content, should be excluded from the diet of diabetics and patients seeking control of their glycemic responses. Future recommendations on fruits should maybe include a focus on their GI as well as on their technological processing.

Effects of high hydrostatic pressure processing on other physicochemical properties of mango puree

Additional parameters that also affect the absorption of glucose and thus impact glycemic index are the viscosity of the fruit matrix and fiber properties, such as swelling and water retention capacities[45]. In the present study, since there were no significant inter-conversions of IDF into SDF as an effect of HHP processing, the results are mainly attributable to the significantly higher viscosity and higher solubility of AIR residues observed for the HHP-MP treatment (Table 4). Higher solubility of AIR is possibly due to structural and solubility modifications of macromolecules contained in it, particularly complex carbohydrates and proteins. Additionally, the HHP-MP samples presented significantly longer Tmax values (Table 3), which can also be attributable to a higher viscosity[45]. It has likewise been described that HHP treatments affected the glucose retardation index of tomatoes samples, and that tomato AIR presented a higher water holding capacity than the corresponding untreated samples[20]. Significant increases in viscosity values of HHP processed fruits and vegetables have also been observed by prior authors. Increases

in rheological parameters of HHP treated mango pulp[59] and guava juice samples[35] have been reported.

The present study has the limitation that the results cannot be extrapolated to patients with T2DM; however, its several strengths, including the cross-over design, the control of all variables, and the substantial number of participants, allowed statistical significance to be established.

In conclusion, our data indicate that mango has a low GI, and that treatment with HHP generated additional benefits, such as a significantly lower GI, a more favorable glycemic response, a longer Tmax, and a lower AUC than the unprocessed-MP. A higher proportion of the subjects presented a low GI and none of them a high GI for the HHP-MP. HHP treatment significantly increased the solubility of the AIR material, as well as the viscosity values. These results have important clinical implications for healthy subjects who may include mango as part of their diet, and perhaps for insulin resistant and T2DM subjects. There are further relevant implications for the food industry, since HHP processing of fruits could be potentially useful in the dietetic management of insulin resistance, diabetes mellitus and obesity. Prospective studies are needed to assess the effects of HHP processing of fruits on the glycemic control and postprandial glucose responses in patients with insulin resistance and T2DM.

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FIGURE CAPTIONS

Figure 1. Comparison of the area under the curve (AUC) values of blood glucose levels obtained from healthy patients after the ingestion of unprocessed mango puree (MP) and high hydrostatic pressure (HHP) processed MP.

Figure 2. Percentage values of study participants that presented glycemic indexes (GI) classified as low, intermediate and high, after the ingestion of unprocessed mango puree (MP) and high hydrostatic pressure (HHP) processed MP. Low GI: ≤ 55, Medium: 56-69, and High: ≥ 70.

Table 1 Characteristics and anthropometric measurements of the study participants[a]

Variable	Men (n=19)		Women (n=19)	
	Mean	Range	Mean	Range
Age (years)	29.1 ± 6.42	20 – 40	29.4 ± 7.09	20 – 50
Weight (kg)	68.1 ± 10.4	46 – 91	57.0 ± 6.43	49 – 67
Height (m)	1.7 ± 0.05	2 – 1.8	1.6 ± 0.04	2 – 1.7
Fat (%)	18.5 ± 5.28	11 – 27	26.6 ± 5.71	16 – 37
Waist circumference (cm)	84.1 ± 7.67	69 – 100	76.4 ± 5.63	67 – 86
BMI[b] (kg/m^2)	23.4 ± 2.98	19 – 29	22.7 ± 2.41	18 – 26

[a] Values are means ± SD. [b] BMI = Body mass index.

Table 2 Chemical characterization of the portions of unprocessed mango puree and high hydrostatic pressure processed mango puree ingested by the study participants and adjusted to 50 g of carbohydrate equivalents[a]

Parameters	Unprocessed-MP[b]	HHP-MP[c]
Weight (g/portion)	287.61	276.01
Soluble solid content (°Brix)	15.8 ± 0.12 a[d]	15.7 ± 0.10 a
Total sugars (g/portion)	48.5 ± 0.08 a	48.5 ± 0.37 a
Glucose (g/portion)	5.8 ± 0.10 a	5.8 ± 0.10 a
Fructose (g/portion)	12.8 ± 0.00 a	12.7 ± 0.20 a
Sucrose (g/portion)	29.9 ± 0.10 a	30.0 ± 0.20 a
Total starch	ND[d]	ND
Total dietary fiber (g/portion)	4.8 ± 0.17 a	4.7 ± 0.07 a
Insoluble fiber (g/portion)	2.4 ± 0.14 a	2.2 ± 0.01 a
Soluble fiber (g/portion)	2.4 ± 0.03 a	2.4 ± 0.08 a
Moisture content (%)	81.8 ± 0.04 b	82.2 ± 0.11 a

[a] Values are means ± SD (*n*=38). [b] Unprocessed-MP = unprocessed mango puree. [c] HHP-MP = High hydrostatic pressure mango pure, processed at 592 MPa/3 min. [d]ND = non-detectable levels.

Table 3 Pharmacokinetic parameters of glucose metabolism obtained from 38 healthy subjects following the ingestion of unprocessed mango puree and high hydrostatic pressure processed mango puree[a]

Kinetic Parameter	Unprocessed-MP[b]		HHP-MP[c]	
Cmax[d] (mg dL^{-1})	129.7 ± 15.2	a[e]	127.6 ± 14.0	a
Tmax[f] (min)	30	b	45	a
AUC[g] (0-120) (mg·min/dL)	2010.90 ± 921.1	a	1610.20 ± 780.6	b
Glycemic index (GI)	42.7 ± 19.5	a	32.7 ± 13.4	b
GI range	12 - 83		5 - 61	
GI classification[h]	Low		Low	

[a] Values are means ± SD (n=38). [b] Unprocessed-MP = unprocessed mango puree. [c] HHP-MP = High hydrostatic pressure mango pure, processed at 592 MPa/3 min. [d] Cmax = Maximum blood glucose concentration. [e] Means with different letters in the same row are significantly different (paired Student t-test, $P< 0.05$). [f] Tmax = Time at which maximum blood glucose concentration was reached. [g] AUC = Area under the curve. [h] Low glycemic index ≤ 55; Medium glycemic index 56-69; High glycemic index ≥ 70.

Table 4 Viscosity of mango puree samples and characterization of isolated alcohol residues from unprocessed mango puree and high hydrostatic pressure processed mango puree[a]

Parameters	Unprocessed-MP[b]		HHP-MP[c]	
Viscosity[d] (cps)	385.4 ± 5.30	b[e]	433.1 ± 13.22	a
Swelling capacity[f] (mL/g DW)	4.4 ± 0.18	a	4.7 ± 0.18	a
AIR weight[g] (g/100 g DW)	20.2 ± 0.07	a	20.5 ± 0.29	a
AIR solubility[h] (%)	31.1 ± 0.40	b	34.3 ± 0.50	a

[a] Values are means of three independent repetitions for all the parameters ± SD. [b] Unprocessed-MP = unprocessed mango puree. [c] HHP-MP = High hydrostatic pressure mango pure, processed at 592 MPa/3 min. [d] Viscosity determinations were performed in mango puree samples and expressed in centipoise (cps). [e] Means with different letters in the same row are significantly different (paired Student t-test, $P < 0.05$). [f] Evaluation was performed in lyophilized mango puree. [g,h] AIR = Alcohol insoluble residues, obtained after the extraction of mango puree with ethanol (85%) at 78°C.

Figure 1

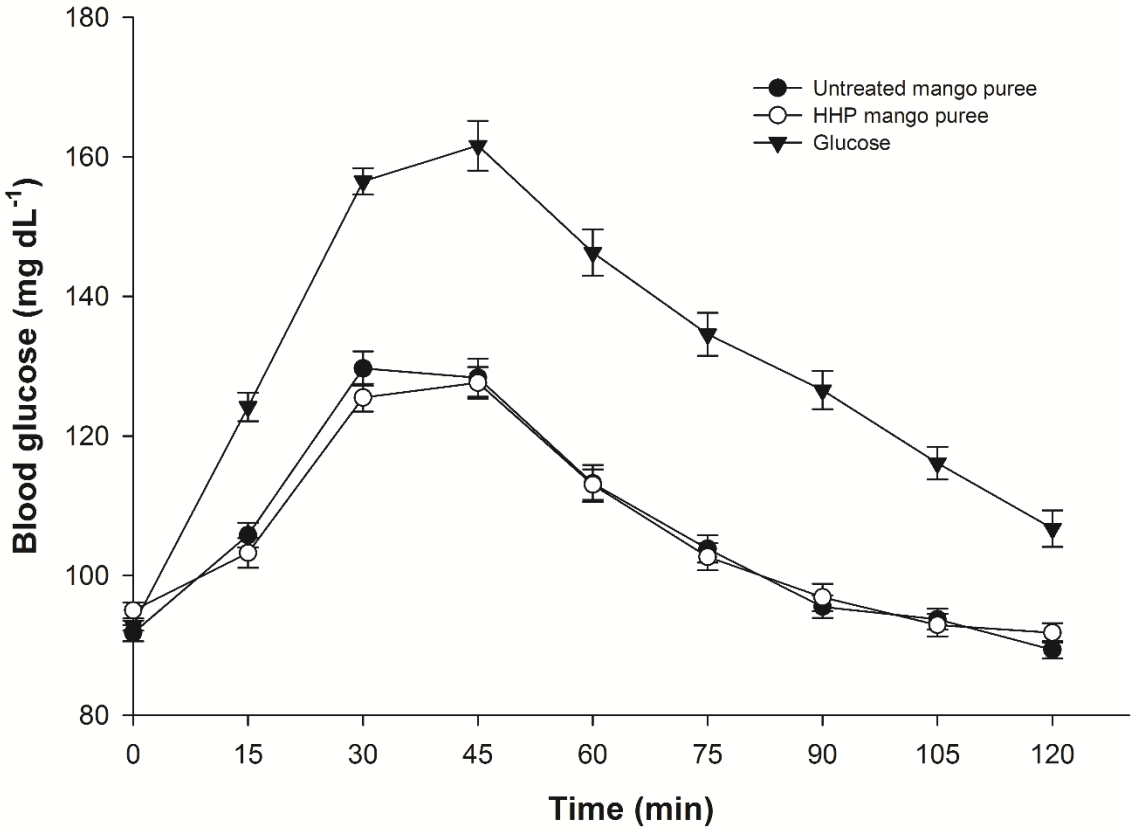
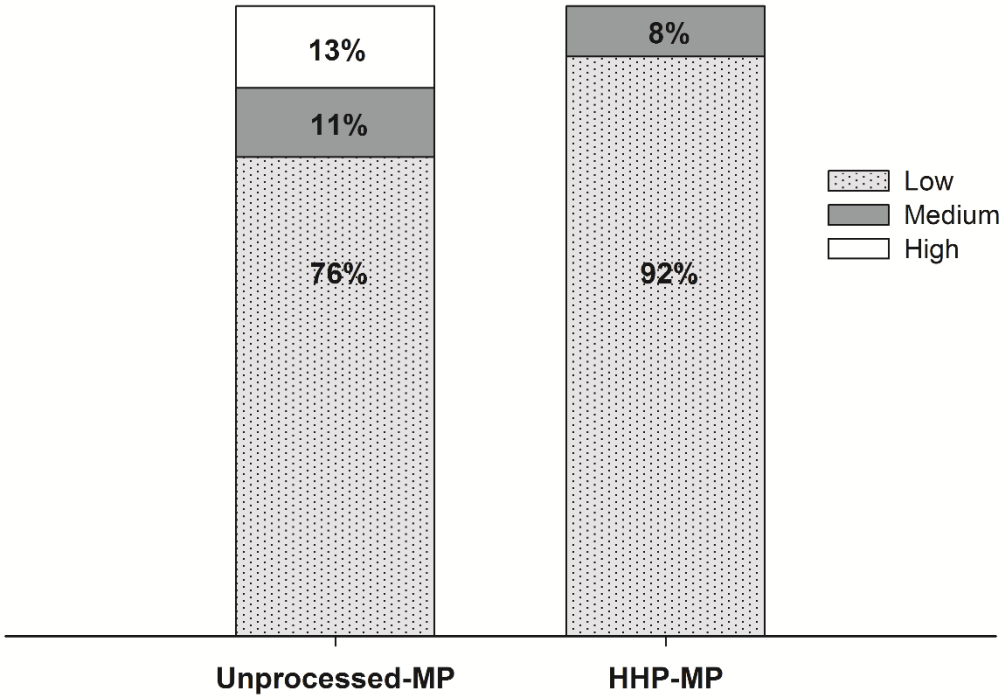


Figure 2



Portions differences were evaluated by the Chi-squared test (*P=0.009*).