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The Effect of Nopal (*Opuntia Ficus Indica*) on Postprandial Blood Glucose, Incretins, and Antioxidant Activity in Mexican Patients with Type 2 Diabetes after Consumption of Two Different Composition Breakfasts

Patricia López-Romero; Edgar Pichardo-Ontiveros; Azalia Avila-Nava, MSc; Natalia Vázquez-Manjarrez; Armando R. Tovar, PhD; José Pedraza-Chaverri, PhD; Nimbe Torres, PhD

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ABSTRACT

Nopal is a plant used in traditional Mexican medicine to treat diabetes. However, there is insufficient scientific evidence to demonstrate whether nopal can regulate postprandial glucose. The purpose for conducting this study was to evaluate the glycemic index, insulinemic index, glucose-dependent insulinotropic peptide (GIP) index, and the glucagon-like peptide 1 (GLP-1) index, and the effect of nopal on patients with type 2 diabetes after consumption of a high-carbohydrate breakfast (HCB) or high-soy-protein breakfast (HSPB) on the postprandial response of glucose, insulin, GIP, GLP-1, and antioxidant activity. In study 1, the glycemic index, insulinemic index, GIP index, and GLP-1 index were calculated for seven healthy participants who consumed 50 g of available carbohydrates from glucose or dehydrated nopal. In study 2, 14 patients with type 2 diabetes consumed nopal in HCB or HSPB with or without 300 g steamed nopal. The glycemic index of nopal was 32.5±4, insulinemic index was 36.1±6, GIP index was 6.5±3.0, and GLP-1 index was 25.9±18. For those patients with type 2 diabetes who consumed the HCB+nopal, there was significantly lower area under the curve for glucose (287±30) than for those who consumed the HCB only (443±49), and lower incremental area under the curve for insulin (5,952±833 vs 7,313±1,090), and those patients with type 2 diabetes who consumed the HSPB avoided postprandial blood glucose peaks. Consumption of the HSPB+nopal significantly reduced the postprandial peaks of GIP concentration at 30 and 45 minutes and increased the antioxidant activity after 2 hours measured by the 2,2-diphenyl-1-picrilhidracyl method. These findings suggest that nopal could reduce postprandial blood glucose, serum insulin, and plasma GIP peaks, as well as increase antioxidant activity in healthy people and patients with type 2 diabetes.
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THE CACTUS *OPUNTIA*, WHICH IS ALSO KNOWN AS nopal, is native to central Mexico[1] and the pads are eaten as a vegetable. Cactus plants have long served as a source of food for people, and they have long been used in traditional Mexican medicine for treating diabetes. Nopal is considered a functional food because it is a proven source of dietary fiber[2] and bioactive compounds with antioxidant activity, such as flavonoids, flavonols, carotenes, and ascorbic acid,[3] in addition to being low in calories (27 kcal/100 g). The current epidemic of obesity and diabetes has led to a search for functional foods that could aid in ameliorating these pathologies. In the case of diabetes, consuming high-calorie meals can lead to exaggerated postprandial peaks in blood glucose and in lipids that generate reactive oxygen species,[4,5] which results in inflammation[5] and endothelial dysfunction.[6] In addition, postprandial glucose homeostasis is controlled not only by direct stimulation of insulin release by absorbed nutrients, but also through secretion of incretin hormones, that is, glucagon-like peptide-1 (GLP-1) and glucose-dependent insulinotropic peptide (GIP).[7] These incretins are released from enteroendocrine cells and are responsible for at least 50% of the total insulin[8] secreted after the ingestion of food.[9] Therefore, the purpose of conducting this study was first to evaluate the glycemic index, insulinemic index, GIP index, and GLP-1 index, and second, to evaluate the metabolic effect of steamed nopal on postprandial peaks of glucose, insulin, GIP, and antioxidant activity after the

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consumption of a high-carbohydrate breakfast (HCB) or high-soy-protein breakfast (HSPB).

MATERIALS AND METHODS

Ethics Statement

All of the procedures were conducted with an adequate understanding by, and the written consent of, the participants. The study was approved by the Ethics Committee of Humans by the Instituto Nacional de Ciencias Médicas y Nutrición and was in compliance with the Declaration of Helsinki. The study was registered in the Institutional Committee for Human Biomedical Research (no. 118).

Participants

Two separate studies were performed using two separate groups of participants. Study 1 was performed to determine the glycemic index of nopal. This study included seven healthy, nonsmoking, nonmedicated, normal-weight volunteers (three men and four women, mean±standard error of mean [SEM]=26.3±1.2 years of age), with a mean±SEM body mass index (calculated as kg/m^2) of 23.5±0.8, according to the recommendations of the Joint Food and Agricultural Organization of the United Nations/World Health Organization Expert Consultation.[10]

Study 2 was performed to evaluate the effect of nopal on postprandial blood glucose after the consumption of two different types of breakfasts. This study included 14 outpatients (four men and 10 women) who were diagnosed with type 2 diabetes with durations of <8 years. Patients with type 2 diabetes were treated with metformin only and were between 40 and 60 years old (mean±SEM=48±2.1 years of age), with a body mass index <30 (mean±SEM=28.9±1). They did not have dyslipidemia, hypertension, or severe hypoglycemic episodes during the past year. Their glycosylated hemoglobin levels were <8% (mean±SEM=6.5%±0.2%), and their fasting serum glucose concentration was 100 to 120 mg/dL (6.7 mmol/L). Patients with type 2 diabetes were studied on four separate occasions. The day of the study, patients with type 2 diabetes were instructed not to take their morning doses of metformin. In this study, we included seven adults without diabetes who were recruited through fliers as a control group, including four men and three women within the age range of 25 to 54 years old (mean±SEM=24.1±1.2 years) with a BMI ≤25 (mean±SEM=22.2±0.6) for the past 6 months. No participant received any compensation for participation in the study. Exclusion criteria included current cigarette smoker, presence of known medical problem, or currently being on any medication.

Test Meals: Study 1

The test meal was composed of a portion of nopal containing 50 g of available carbohydrates, which is defined as total carbohydrates minus dietary fiber, according to the recommendation of the Joint Food and Agricultural Organization of the United Nations/World Health Organization Expert Consultation.[10] Because raw nopal contains a significant amount of water, dehydrated nopal was utilized to determine the glycemic index. Fresh nopal was obtained from Milpa Alta, México City, and dried for 48 hours at 55°C. The chemical composition in the dry basis was as follows: carbohydrates, 24.8%; insoluble fiber, 32.2%; soluble fiber, 4.8%; fat, <1.9%; and protein, 15.4%.

Test Meals: Study 2

The HCB contained 300 kcal and comprised 89% carbohydrates, 6% protein, and 5% fat, in the form of apple juice (240 mL), white bread (55.6 g), and strawberry jam (21 g).

The HSPB contained 344 kcal and comprised 42.4% carbohydrates, 40.7% protein, and 16.9% fat, in the form of soy hamburger (61.5 g) and soymilk beverage (230 mL). The HSPB was designed based on previous studies that have demonstrated that soy protein reduces the postprandial peaks of insulin and increases insulin sensitivity.[11,12]

The HCB+nopal or the HSPB+nopal contained the foods described here, with the addition of 300 g steamed nopal cut into small pieces (2.0- to 2.5-cm cubes), the traditional form consumed in Mexican cuisine. Raw nopal was cooked in a steamer for 11 minutes over a medium heat, and final cooked weight was approximately 250 g. It was then served as side dish. The chemical composition in fresh weight basis was determined according to Association of Analytic Communities methods: carbohydrates, 1.4%; insoluble fiber, 1.7%; soluble fiber, 0.17%; fat, negligible; and protein, 1.1%. Nopal was always obtained from the same location during the same season and harvested at the same time of day to minimize chemical variability.

Protocol

Each participant arrived in the morning after a 12-hour overnight fast and consumed the test meal as described here for either study 1 or study 2. All participants consumed the meal in the same order, and the washout period between test meals was 1 week. All participants completed the study. The test meals were consumed within 10 minutes and only within each selected study. Capillary blood samples for glucose determination in healthy participants were obtained intermittently using a finger-stick before and at 15, 30, 45, 60, 90, and 120 minutes after commencing the test meals. Whole blood glucose was measured using an automatic analyzer (Model 2700, YSI Inc.). An additional sample in patients with type 2 diabetes was collected at 150 minutes. Venous blood samples were also obtained at the same time as capillary blood to measure serum insulin, plasma GIP, GLP-1, and antioxidant activity. The insulin concentration was measured using a human radioimmunoassay kit (Linco Research Inc.). GIP and GLP-1 were determined in blood samples that were collected in tubes containing ethylenediamine tetraacetic acid. Immediately after the blood collection, 30 μL of the dipeptidyl peptidase 4 inhibitor for the GLP-1 measurement (Linco's DPP IV inhibitor) was added. Plasma was removed after centrifugation and stored at −20°C. The incretins were analyzed using the Human Gut Hormone Panel (LINCOplex Kit, Linco Research, Inc). The antioxidant capacity was determined by the method of 2,2-diphenyl-1-picrilhidracyl, which has been described previously.[13]

Statistical Analysis

Calculation of the glycemic index and incremental area under the curve (IAUC), excluding the area below fasting, were calculated using the trapezoid rule.[14]

Data are expressed as mean±SEM. Analysis of repeated measures was used to determine the diet and timing effects

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