Glycemic index and glycemic load in the *Opuntia ficus-indica* fruit

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Abstract

There is evidence that supports the clinical usage of glycemic index (GI) and glycemic load (GL) in the prevention of chronic disease. **Objective:** *The objective of the study was to determine the GI and GL of the Opuntia ficus-indica fruit.* **Methods:** *An analytic, transversal study was made involving 25 healthy volunteers accepted by an informed consent with a normal body mass index, glucose, glycoside hemoglobin, cholesterol, and serum triglycerides. The homogeneity of the population was evaluated with anthropometrical and biochemical data using principal component analysis (PCA). The equivalent of 50 g of carbohydrates test food (tuna) and 50 g of dextrose as food standard was provided for the measure of the glucose curve. The GI was determined by calculating the area under the curve by the triangulation method. The CG was reported as the product of GI by carbohydrate loading provided.* **Results and Conclusions:** *The GI of the tuna was 48.01 ± 17.4, classified as low, while the CG was 24.0 ± 8.7 rated as high. The chemometric analysis by PCA showed that the selection of the normal population for determining the IG, it is important to consider the values of cholesterol and triglycerides.*

KEY WORDS: *Glycemic index. Glycemic load. Opuntia ficus-indica.*

Introduction

The glycemic index (GI) concept was developed in 1981 by Dr. David Jenkins based on Burkitt and Trowell 1977 theory, who claimed that foods that are absorbed more slowly had metabolic benefits on patients with diabetes, cardiovascular problems and conditions with central adiposity excess with insulin resistance[1,2].

GI is the glycemic response of a certain amount of carbohydrates available in a test food as compared with the glycemic response to the same amount of carbohydrates in a standard food[3], such as anhydrous glucose or white bread consumed by the same person. Foods with low GI are those with a GI < 55, those with moderate GI have 55–70, and with high GI, they have > 70[1,3]. At present, using the GI as a sole indicator is not recommended, since it does not count the amount of carbohydrates, but only the response after ingestion[1,2]. The process to determine the GI and the glycemic load (GL) is a method standardized by Dr. Wolever[4,5].

GL represents the general glycemic effect of the diet since it accounts both for GI and the grams of carbohydrates consumed in a meal. It is calculated by multiplying the GI of the food by the grams of consumed carbohydrates of such food and dividing the result by 100. GL is classified as low if it is < 10, moderate if it is 11–20 and high when it is > 20[1,2].

Diets with high-GI foods are known to promote hyperglycemia and hyperinsulinemia, which in turn increase peripheral tissues insulin resistance and gradually damage pancreatic beta cells, thus promoting type 2 diabetes mellitus[6]. Furthermore, they affect

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Date of modified version reception: 06-06-2016
Date of acceptance: 08-06-2016
DOI: 10.24875/GMM.M17000026

Gac Med Mex. 2017;153:433-438
Contents available at PubMed
www.gacetamedicademexico.com

cardiac tissue due to an increase in protein glycation, oxidative stress, and hemostatic variables; in turn, this reduces low-density lipoprotein (LDL) cholesterol, thus affecting endothelial function[7]. These diets have also been associated with certain types of cancer, with most studied being colon and breast cancer[8,9]. In contrast, a diet with low GI has been shown to induce several favorable effects, such as rapid weight loss and glucose and insulin, as well as triglyceride decrease[7]. The most recommended nutritional therapy for the patient with diabetes mellitus is the use of GI and GL for better control of blood sugar and lower comorbidity[1,3].

Recent studies explain that when low-GI foods are consumed as breakfast, less hunger sensation is produced in the course of the day; conversely, if breakfast has a high GI, the same subjects experience more appetite in the course of day. On the other hand, the effect on children has been studied, with those who consume low GI breakfasts being found to be associated with better spatial memory and higher attention during the morning[10].

The consumption of prickly pear (*Opuntia ficus-indica*) can help as part of the diet therapy of the diabetic patient. The benefits are correlated with the frequency and quantity of consumed prickly pear[11,12].

According to Touil et al.[13] 2010 study, prickly pear is composed of 89% water and 10.37% of dry mass, with 18% of carbohydrates, and 0.17% of protein. Many beneficial properties have been associated to the prickly pears due to its high antioxidants content. Several authors conclude that the antioxidant capacity is determine by the amount of Vitamin C, flavonoids and carotenoids[14-16].

Prickly pear juice has a hypoglycemic and anti-hyperglycemic effect in experimental animals with pharmacologically-induced diabetes, but it does not act on non-diabetic rats. This might be due because it stimulates pancreatic beta cells; in addition, it increases blood hemoglobin and high-density lipoprotein cholesterol in diabetic rats. It also decreases LDL-cholesterol, triglycerides, and urea. One discovery in these investigations was that prickly pear juice improved pancreatic damage caused by diabetes-inducing drugs in rats[11,17,18].

The 2012 National Health and Nutrition Survey revealed a combined prevalence of overweight or obesity in adults of 73% for women and 69.4% for men[19]. The overweight tendency decreased by 5.1% between the years 2006 and 2012, while the obesity trend increased by 2.9%[19].

More than 371 million people have diabetes and, by the year 2030, this figure will have improved until reaching 552 million. Mexico is at sixth place worldwide in the number of people with diabetes[20]; the states with the highest prevalence of diabetes are Mexico City, Nuevo León, Veracruz, Tamaulipas, Durango and San Luis Potosí[20].

In two studies conducted in Mexico, the GI of several foods that are commonly consumed in Mexico was evaluated, including the pads of the *O. ficus-indica* species (*nopal*), and it is reported that when ingested alone or with other food it maintains a low GI, whereas other foods such as rice, potato, beans, and corn tortillas report a very similar GI to that of white bread (standard food). However, no report on the *O. ficus-indica* fruit (prickly pear) GI has been found in the literature[21,22].

GI and GL are important data as an alternative in diabetes mellitus and obesity complementary treatment. This is why we decided to determine the GI and GL of the *Opuntia ficus-indica* fruit, since it belongs to a species that has demonstrated multiple benefits for health, in addition to being endemic and abundant in our country.

Methods

A cross-sectional, analytic study was conducted, which was carried out at the Center of Research in Nutrition and Public Health of the Faculty of Public Health and Nutrition of the Nuevo León Autonomous University, at Monterrey, N.L., with adult residents of the same state. Volunteers aged 18–40 years who accepted to participate in the study by means of informed consent, with a body mass index (BMI) classified as normal (18–24.9 kg/m^2) according to the World Health Organization[23], and who denied non-transmittable chronic diseases, which was corroborated by means of biochemical tests that included complete blood count, blood chemistry, and glycosylated hemoglobin (HbA1c), were included. Only those subjects whose laboratory reports were found within normal parameters did participate[24]. All subjects at special physiological states, such as pregnancy and breastfeeding, and people with any impaired physical ability that would preclude for anthropometric parameters to be obtained, were excluded.

To analyze the sample characteristics and show the homogeneity of the participant individuals, a principal component analysis (PCA) was performed with the study subjects biochemical and anthropometric data using the Unscrambler program, version 9.7[25].

In the bromatological analysis, dry matter and moisture were determined; protein was determined with the Kjeldahl method modified by Winkler, fats, with the goldfish method and, crude fiber, according to the procedures established by the Association of Official Analytical Chemists[26]. With the obtained results, carbohydrates in the test food were calculated.

For the *O. ficus-indica* fruit GI and GL determination, the subjects underwent a standardized diet during the study days; the diet was prescribed according to the requirements for age and gender, adequate in terms of calories, carbohydrates, protein, and lipids. On the third day, the participants were asked to attend with a nocturnal fasting of at least 8 h and were administered 50 g of anhydrous dextrose, with a glucose curve being plotted based on capillary blood glucose at 0, 15, 30, 60, 90, and 120 min; minute 0 was considered as the moment the subject had the first bite of food or the first sip of beverage. This procedure was repeated on the 5th day with the equivalent of 50 g of carbohydrates available in the test food (*O. ficus-indica*). The procedure was repeated twice.

The GI determination was performed by applying the polynomial integration technique, with the method developed by Dr. Wolever, from the Toronto University, Canada[5]. The GL was obtained as the product of the test food GI and the carbohydrate grams of the portion divided by 100 (Fig. 1).

Results

The study was completed by 22 subjects, out of which 86% were females and 13% were males. Mean age was 24.3 ± 4.29 years. Average weight was 58.2 ± 8.5 kg, and average height was 1.63 ± 0.06 m, with a BMI average of 21.7 ± 1.9 kg/m^2 being obtained. These data are presented in table 1.

Serum glucose, HbA1c, cholesterol, and triglycerides biochemical data were determined and are shown in table 2. Mean serum glucose was 84.14 ± 5.47 mg/dL, HbA1c average value was 5.07 ± 0.253%, cholesterol was at 173.2 ± 29 mg/dL, and triglycerides showed an average value of 77.43 ± 40 mg/dL.

The PCA with the participant subjects' biochemical and anthropometric data explained 97% of the variance with two main components, and all the subjects included in the study were observed to be distributed in a single group (Fig. 2).

Fig. 3 depicts the variables' (loadings) behaviors, where all biochemical parameters were within normal values and in the same way they all contribute to the sample homogeneity. Of note, the cholesterol and triglycerides variables were the biochemical parameters that more influence showed in the sample dispersion; however, they were within acceptable values (Figs. 2 and 3).

Table 3 summarizes the results obtained for the *O. ficus-indica* vegetable species' fruit (prickly pear) nutrimental composition (macronutrients are expressed per 100 g of food).

The amount of food that provides 50 g of carbohydrates was 387 g of the fruit; an amount that was consumed by the study subjects. The values for the area under the curve, GI, and GL of the tested food (prickly pear) are shown in table 4.

The GI of the *O. ficus-indica* fruit was 48.01 ± 17.4, which was classified as low, whereas the GL was 24 ± 8.7, which was classified as high.

Capillary blood glucose maximum peak for the standard food can be observed to be at minute 30, with an average of 169 mg/dL, whereas with the tested food this maximum peak occurs at minute 15, with a mean of 159 mg/dL. With the tested food, capillary blood glucose reaches baseline values at minute 90;

$$GL = \frac{(\text{food GI})\,\text{g of food CH}}{100}$$

Figure 1. *Formula to calculate the glycemic load of a food.*

Table 1. Study subjects anthropometric indicators average values

	Range	Mean	SD
Age (years)	20–40	24.3	4.29
Weight (kg)	43.5-78.2	58.2	8.50
Height (m)	1.53-1.78	1.63	0.06
BMI (kg/m^2)	18.6-24.8	21.7	1.90

BMI: body mass index; SD: standard deviation.
Source: direct survey.

Table 2. Study subjects' biochemical indicators values[32]

	RV	Range	Mean	SD
Glucose (mg/dL)	60–110	74–94	84.14	5.47
HbA1c (%)	4–6	4.6–5.6	5.07	0.25
Cholesterol (mg/dL)	< 200	128–232	173.2	29.2
Triglycerides (mg/dL)	< 150	25–180	77.43	40.75

HbA1c: glycosylated hemoglobin; RV: reference value; SD: standard deviation.
Source: data obtained by the clinical laboratory.

conversely, with the standard food, baseline blood glucose levels are reached at minute 120 (Fig. 4).

Discussion

The chemometric analysis by PCA demonstrated that, in the selection of normal population for a food's GI determination, it is important to consider blood cholesterol and triglyceride values.

O. ficus-indica fruit GI and GL could be determined, and were classified as being low and high, respectively.

Prickly pear is known to have several properties that are beneficial for health, which has been reported in different investigations in the past few years. Some attributes of this fruit are its antioxidant and anti-hyperglycemic effects; in addition, most recent investigations carried out with prickly pear juice and extract report pancreatic beta cells regeneration *in vivo*, a decrease in carcinogenic cells and ovarian cells apoptosis *in vivo*, among others[17,27-29].

In a study conducted by Bacardi Gascón et al.[21] in 2007 with 36 patients with type 2 diabetes mellitus, the GI was determined in three regularly consumed Mexican foods, such as *chilaquiles*, burritos, and quesadillas, and they were added *nopal* (*O. ficus-indica* pads) to compare the result between the food alone and the food with *nopal* added. A GI decrease of 30%, 20%, and 48%, respectively, was found in the foods with *nopal* added. A GI of 7 and GL of 35 were found

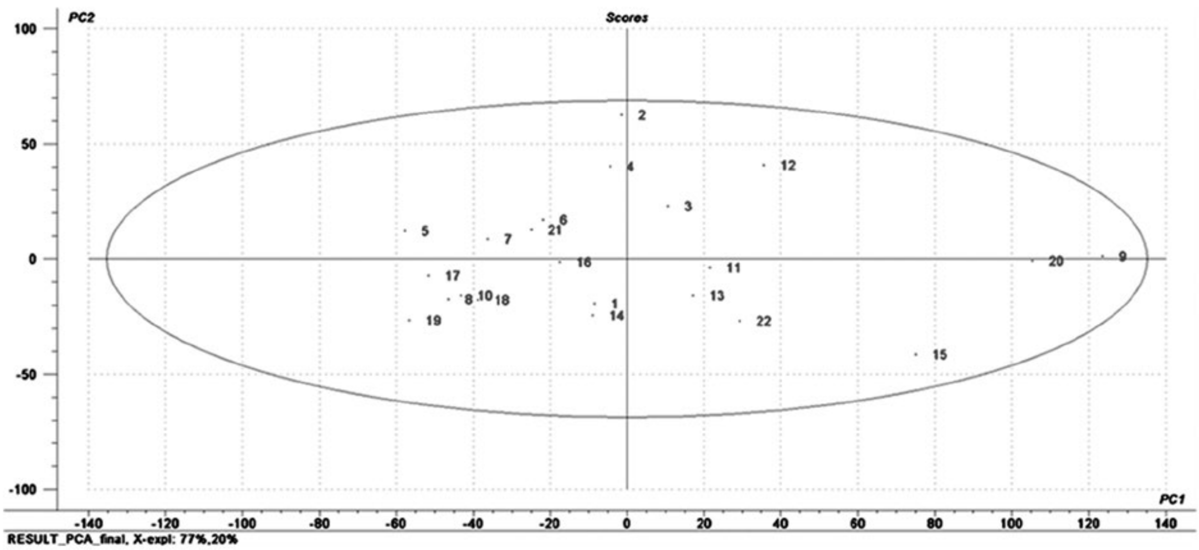

Figure 2. *Dot plot of the main component analysis with two main components and 97% confidence.*

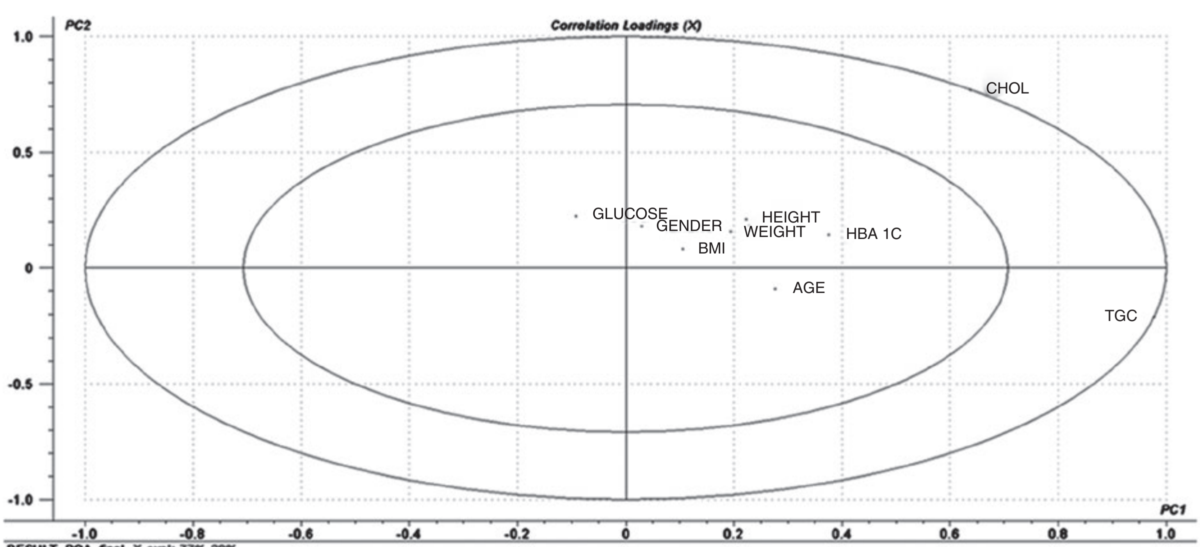

Figure 3. *Plot of biochemical and anthropometric variables loading.*

Table 3. Nutritional composition of the *Opuntia ficus-indica* vegetable species (prickly pear) per 100 g

	Value per 100 g
Energy (kcal)	56.1
Carbohydrates (g)	12.93
Fiber (g)	2.6
Protein (g)	0.8
Lipids (g)	0.1
Moisture (%)	83.2
Ashes (g)	0.37

Table 4. Glycemic index and glycemic load values for the tested food

	Range	Mean	SD	Classification
Area under the curve	-	141.11	54	-
Glycemic index	20.67-77.98	48.01	17.4	Low
Glycemic load	10.33-38.99	24.00	8.7	High

SD: standard deviation.
Source: direct survey.

for *nopal*. The authors attribute the glucose-decreasing action to the content of soluble fiber, with 3 g being reported to be present in 85 g of fresh *nopal*[21].

In another study conducted by Frati Munari et al.[22] in 1991, the GI of several common Mexican foods was studied in healthy patients and in patients with diabetes mellitus. The GI of white and yellow corn tortilla, spaghetti, rice, potato, yellow or black beans, *nopal,* and peanuts was assessed. Of the obtained results, the blood sugar response to the consumption of *nopal* in both groups stands out, since there was no significant change between baseline and subsequent glucose values; the glucose maximum elevation after ingesting *nopal* was 5-9 mg/dL with regard to the value at minute 0, whereas the other foods had an average increase of 10.81 mg/dL above the baseline value. They reported a GI of 15 for *nopal*, which was considered to be low[22]. In spite of the large amount of scientific evidence about the studied fruit in nutritional and physicochemical aspects, prickly pear GI and GL were so far not known; therefore, it was highly important for these parameters to be determined since, currently, there is a need to address the main health problems such as obesity and type 2 diabetes mellitus using products of vegetable origin.

Prickly pear has attracted great interest in the past few years due to its nutritional content. Amaya[30] reported in 2009 that the fruit's composition includes 85-90% moisture, 0.25-0.44% ashes, 19% carbohydrates, 0.75-5.41% protein, and 0.12-0.25% lipids. Similarly, Touil et al.[13] found 89% moisture, 18% carbohydrates, and 0.17% protein. In our bromatologic study, consistency was observed in terms of carbohydrates, protein, lipids, moisture, and ashes, but differences were found for the fiber content since this study reported 2.6%, and Amaya[30] found 0.02%. It should be mentioned that, in our research, the prickly pear bromatologic analysis was performed with the crystalline variety, whereas the referred authors do not specify the variety, and neither do they indicate if the whole fruit or only the pulp was considered, since these differences could modify the fiber content, as well as the food's GI[13,30]. A comparison of the whole fruit and the fruit without the seeds was not performed in the present study.

PCA is a test that was applied to demonstrate that all individuals that were selected for this study had the characteristics required to be classified as healthy. It is a statistical test that helps to visualize the behavior of groups of variables[25,28,31]. The analysis was performed applying two main components that explained 97% of the variance. Fig. 2 shows that subjects 9 and 20 had more dispersion, but fall within the group. When the loadings (variables) plot in fig. 2 was analyzed, we were able to identify that the biochemical parameters that most contribute to this dispersion are cholesterol and triglycerides, since their reference values are broader. The results of this chemometric analysis show the importance of both these biochemical parameters in the inclusion of subjects in the study. It should be mentioned that the variables that contribute the most to the homogeneous distribution are weight, height, BMI, HbA1c, glucose, gender, and age, just as observed in the same figure.

In this study, we found that the analyzed fruit showed a low GI. The GI of food is known to vary according to the type of carbohydrates, the content, and type of fiber, protein, and fat. The determination was made with the fruit peeled and sliced. These results may be due to the fiber content of the food, since the fruit was tested with seeds, or to the type of carbohydrates contained in the pulp. However, the contained carbohydrate types were not determined in the bromatologic analysis, with this being a limitation of our study.

The amount of prickly pear that was administered to the subjects was 387 g, which is equal to approximately 6 medium-sized prickly pears. The GL obtained in our study was classified as high. It should be borne in mind that GL directly depends on the quantity of carbohydrates contained in the portion of the ingested food and on its GI. For this reason, we consider that

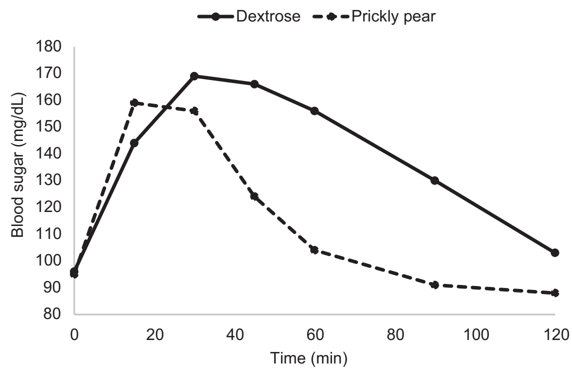

Figure 4. *Blood sugar behavior at different time-points with the consumption of the standard food and the test food.*

if the *O. ficus-indica* fruit portion is reduced, the amount of consumed carbohydrates will decrease and, as a result, the GL will also decrease; therefore, adjusting the portions of this fruit is recommended in patients with obesity or type 2 diabetes mellitus.

As for capillary blood glucose behavior after the ingestion of 50 g of the fruit's carbohydrates, a slight decrease in blood glucose was observed, since capillary blood glucose average at minute 0 was 96 mg/dL and at minute 120 it was 88 mg/dL. No studies reporting such data were found in the literature; however, Abdallah[17] and Hassan et al.[18], in a study on experimental animals, mentioned a hypoglycemic effect after the ingestion of filtered prickly pear juice. Similarly, studying the fruit's hypoglycemic effect after its regular consumption is recommended.

Acknowledgments

The authors would like to thank Dr. Thomas Wolever, from the University of Toronto, Canada, for his advice and support in the development of the project, Dr. Rigoberto Vázquez Alvarado, from the Faculty of Agronomy of the UANL, for his support to identify and obtain the raw material, and Jorge Martín Llaca Díaz, MPH, from the Department of Clinical Pathology of the UANL University Hospital, for his support in the performance of patients' clinical analyses.

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