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Addition of pooled pumpkin seed to mixed meals reduced postprandial glycemia: a randomized placebo-controlled clinical trial

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ABSTRACT

We investigated if pumpkin and flaxseeds could improve postprandial glycemic, food intake, and appetitive responses. Herein, we hypothesize based on the literature that pumpkin seed has potential to lower postprandial glycemic effects. Therefore, we conducted a randomized, single-blind, placebo-controlled, crossover design study involving normoglycemic adults (food intake: n = 25; glycemia: n = 15). Three high-carbohydrate mixed meals presenting no seed (control [C]) or 65 g of the tested seeds (pumpkin seed [P] or flaxseed [F]) were consumed in 3 nonconsecutive days. Test meals had similar nutritional composition. Blood glucose was measured by capillary finger blood at 0 (immediately before), 15, 30, 45, 60, 90, and 120 minutes after the ingestion of each meal, and the incremental area under glycemic response curves (iAUC) were calculated. Appetitive responses were assessed, and dietary records were used to evaluate food intake on testing days. Glucose iAUC was significantly lower in P compared with C (reduction of ~35%, $P = .025$). There was no significant differences in glucose iAUC between F and C ($P = .257$). Glycemic response at each time point did not differ between C, P, and F ($P_{group \times time} = .238$). Fiber consumption was higher in F ($P = .009$) than in C, but there were no differences in appetitive responses, energy, or macronutrient consumptions between dietary interventions. Acute consumption of 65 g of pumpkin seed markedly reduced postprandial glycemia. Pumpkin seed has potential as a hypoglycemic food, which now deserves to be confirmed in long-term studies.

1. Introduction

Type 2 diabetes mellitus (T2DM) is a complex syndrome that is characterized by impaired glucose uptake, leading to hyperglycemia and severe comorbidities such as neuropathy, nephropathy, retinopathy, impaired immune system, and cardiovascular diseases [1]. Because its global prevalence has more than doubled over the last 3 decades as a result of lifestyle changes [2], T2DM is therefore considered a serious public health problem.

Abbreviations: BMI, body mass index; C, control; F, flaxseed; GC, gas chromatography; iAUC, incremental area under the glycemic response curves; MUFA, monounsaturated fatty acid; P, pumpkin seed; *r*, correlation coefficient; T2DM, type 2 diabetes mellitus.

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Glycemic control is one of the major goals in preventing or treating T2DM. Drugs classically used to treat T2DM include insulin, α-glucosidase inhibitors, sulfonylureas, biguanides, and thiazolidinediones [3]. Many of them can lead to a number of serious adverse effects, which instigates the interest of researchers to seek for more effective and safer hypoglycemic agents [4]. Thus, the use of plants with hypoglycemic activity as an adjuvant for T2DM prevention and treatment is popular and used in developing countries as well has recently received attention in the United States and Europe [5,6]. Because of their perceived effectiveness, less or no adverse effects, and relatively low costs, dietary plants and herbal products are consumed even if their real benefits for the prevention/treatment of T2DM in humans have not been experimentally tested [4].

Pumpkin (*Cucurbita maxima*) is a fruit that is widely considered to have antidiabetic properties and has been used as functional food [7]. However, the hypoglycemic effect of pumpkin is frequently attributed to herbal extracts from its pulp, such as pectin and nonpectin polysaccharides, or from its seeds, such as proteins and oil [8]. However, pumpkin seed is a good source of protein, fibers, minerals, unsaturated fatty acids, and phytosterols [7] but the potential hypoglycemic effect of whole pumpkin seed has been examined. This fact increases the interest for the role of whole pumpkin seed consumption on glycemia and not only for its extracts. In addition, flaxseed (*Linum usitatissimum* L) is a good source of soluble fiber (60-80 g mucilage/kg), lignans, and *n*-3 fatty acids, which could present a protective effect against T2DM [9,10].

Animal studies have demonstrated the hypoglycemic activity of pumpkin seed [11,12], flaxseed [13], and pumpkin and flaxseeds mixtures [14]. In humans, the few available studies used pumpkin or flax extracts [15-17] and showed controversial and inconclusive results [9,15,18-20]. To the best of our knowledge, there is no available human study that evaluated the effect of pumpkin seed on glycemic control.

This study aimed to investigate the acute effects of adding pumpkin and flaxseeds to carbohydrate-rich meals on postprandial glycemia. Once both dietary fiber and postprandial glycemia could influence appetitive sensations, we additionally assessed the effect of these seeds on satiety and food intake. We hypothesized that the addition of pumpkin and flaxseeds to a diet could reduce glycemic response in individuals with normal glycemic control, thus providing a means to control T2DM.

2. Methods and materials

2.1. Experimental design

This was a randomized, single-blind, crossover, placebo-controlled, Latin square design study. Throughout the screening visits, participants completed health, demographic, and physical activity questionnaires; had their height, body weight, and body composition measured; and were instructed to record their habitual dietary intake. Body weight was measured to the nearest 0.05 kg using a standard microdigital scale, and height was measured to the nearest 0.5 cm using vertical wall–mounted stadiometer. Body mass index (BMI) was calculated by dividing weight in kilograms by height in meters square. Body composition was assessed by sum of all skinfold thicknesses (biceps, triceps, subscapular, and suprailiac) and was used for the calculation of percentage body fat using the standard equation [21]. Biceps, triceps, subscapular, and suprailiac skinfold thicknesses were measured using Lange skinfold calipers (Cambridge ScientificInstruments, Cambridge, MA) as reported previously [22].

Protocol was assessed on 3 experimental sessions, which occurred on nonconsecutive days. In each experimental session, participants reported to the laboratory after a 10- to 12-hour overnight fasting and consumed one of the test meals within 15 minutes. Test meals were supervised to ensure that the entire breakfast was eaten. Participants were required to refrain from alcohol consumption and strenuous exercise for at least 24 hours before study participation and during the test days.

Participants stayed in the laboratory for the following 120 minutes for postprandial glycemia and appetitive responses assessments. Because blood glucose protocol demands smaller sample size than appetitive and food intake protocol (see next topic), some subjects did not participate of postprandial glucose protocol. No other food or beverage was allowed during that time. Food intake was assessed over the next 24 hours after the test meals consumption. All participants were instructed to maintain their habitual physical activity level during the experiment. Physical activity questionnaire [23] was reapplied at the end of the tests to verify the protocol compliance.

2.2. Subjects

Participants were recruited through posters, local radio, and newspapers advertisements. Twenty-five healthy, normal-weight (BMI between 18.5 and 24.9 kg/m^2), normoglycemic (fasting glucose 3.9-5.5 mmol/L) adults (aged 18-30 years) were recruited to participate in this study. All of them were submitted to assessment of food intake and appetitive responses. Postprandial glycemia was determined in 15 of the participants. Sample sizes were calculated [24] considering the incremental area under the glycemic response curve (iAUC) and energy intake as the main variables for postprandial glucose protocol and appetitive/food intake protocol, respectively. Baseline values (mean ± SD) of energy intake [25] and of glycemic iAUC [26] were adopted during calculation. A statistical power of 90% and an expected difference of 10% in the baseline values were adopted.

The following inclusion criteria were considered: nonsmokers, consumption of less than 30 g of alcohol per day, nonpregnant and nonlactating, no diabetes or glucose intolerance, no family history of diabetes, no recent (in the previous 3 months) changes in diet or physical activities habits, and no use of drugs that affect metabolism. All participants provided a written informed consent before participating in the study. The study protocol was approved by the Ethics Committee of Federal University of Viçosa, Brazil, and was conducted in accordance with the Declaration of Helsinki.

2.3. Test meals

Before meals preparation, peeled pumpkin seeds and whole flaxseeds were sanitized in a solution of sodium hypochlorite at 100 ppm for 15 minutes and then sun-dried at ~30°C for 4 hours. The seeds were crushed at medium speed in a blender

for 5 minutes. Before test meals preparation, crushed seeds were roasted in an indirect dry heat over 230°C for 15 minutes.

Three types of test meals (muffin + shake) were served: control meal (C), no seeds added; pumpkin seed meal (P); and flaxseed meal (F) (Table 1). Seed meals contained 65 g of the respective seed, which were used to prepare muffins and shakes, and considered as a source of dietary fiber. Shakes were prepared by blending the ingredients with ice water for 3 minutes immediately before consumption. Muffins were prepared once a week and stored at –20°C until their consumption at room temperature. Test meals were similarly prepared, stored, and matched as much as possible for volume, appearance, texture, and nutritional composition. Nutritional composition of the test meals was evaluated based on the manufacturer's product information, except for pumpkin seed and flaxseed compositions, which were assessed in the laboratory. The ingredients used to prepare the test meals were obtained from the local marked. Instant passion fruit powder (3.3 g, Clight; Mondeléz International, Paraná, Brazil) was added to all shakes to make the taste similar (Table 1).

2.4. *Chemical characterization of pumpkin and flaxseeds*

The nutritional composition of the crushed and roasted pumpkin seed was determined using standard methods [27]. Briefly, protein contents were determined by semimicro-Kjeldahl method and ashes were quantified by sample incineration in a muffle furnace. Total lipids were extracted with petroleum ether, in a Soxhlet apparatus. Total, soluble, and insoluble dietary fibers were quantified by enzymatic-gravimetric method. Carbohydrates were estimated by difference. Analyses were carried out in triplicate.

Fatty acid compositions were determined after esterification [28] and by gas chromatographic (GC) analysis. Chromatographic analysis was carried out using a Shimadzu GC Solution instrument (Shimadzu Seisakusho Co, Kyoto, Japan) equipped with a flame ionization detector and a Carbowax capillary column (30 m × 0.25 mm). Fatty acid methyl esters prepared from extracted lipid from each seed type (1 μL) were injected in GC with split ratio of 10. Nitrogen was supplied as the carrier gas at a flow rate of 43.2 cm/s. The initial oven

Table 1 – Ingredients and nutritional composition of test meals

Test meal	Preparation type	Ingredients	Added amounts (g)	Energy (kJ)	Protein (g)	Fat (g)	Carbohydrate (g)	Fiber (g)
Control	Shake [a]	Anhydrous glucose	15.0	251.0	0.0	0.0	15.0	0.0
		Albumin powder	12.5	214.2	10.2	0.8	0.8	0.0
		Soybean oil	20.4	768.2	0.0	20.4	0.0	0.0
	Muffin	Sugar	25.0	418.4	0.0	0.0	25.0	0.0
		Anhydrous glucose	25.0	418.4	0.0	0.0	25.0	0.0
		Grated coconut	7.2	133.5	0.0	1.9	3.7	0.5
		Wheat flour	15.0	225.1	1.4	0.2	11.6	0.4
		Maize starch	17.0	284.5	0.0	0.0	14.5	0.0
		Soybean oil	10.0	376.5	0.0	10.0	0.0	0.0
		Eggs	16.7	102.5	2.1	1.7	0.2	0.0
		Albumin powder	13.8	236.4	11.2	0.9	0.9	0.0
	Total		–	3428.8	24.9	35.9	96.7	0.9
Pumpkin seed	Shake [a]	Anhydrous glucose	15.0	251.0	0.0	0.0	15.0	0.0
		Pumpkin seeds	28.3	711.7	8.8	14.0	2.5	1.7
	Muffin	Sugar	25.0	418.4	0.0	0.0	25.0	0.0
		Anhydrous glucose	25.0	418.4	0.0	0.0	25.0	0.0
		Grated coconut	7.2	133.5	0.0	1.9	3.7	0.5
		Wheat flour	15.0	225.1	1.4	0.2	11.6	0.4
		Pumpkin seeds	36.7	927.2	11.5	18.1	3.3	2.2
		Maize starch	12.0	170.7	0.0	0.0	10.2	0.0
		Eggs	16.7	1025.1	2.1	1.7	0.2	0.0
	Total		–	3358.5	23.8	35.9	96.5	4.8
Flaxseed	Shake [a]	Anhydrous glucose	15.0	251.0	0.0	0.0	15.0	0.0
		Flaxseeds	28.3	534.7	5.2	10.2	3.9	8
		Soybean oil	8.0	301.2	0.0	8.0	0.0	0.0
		Albumin powder	12.0	207.5	9.8	0.8	0.8	0.0
	Muffin	Sugar	25.0	418.4	0.0	0.0	25.0	0.0
		Anhydrous glucose	25.0	418.4	0.0	0.0	25.0	0.0
		Grated coconut	7.2	133.5	0.0	1.9	3.7	0.5
		Wheat flour	15.0	225.1	1.4	0.2	11.6	0.4
		Flaxseeds	36.7	693.3	6.7	13.2	5.1	10.4
		Maize starch	7.0	100.4	0.0	0.0	6.0	0.0
		Eggs	16.7	102.5	2.1	1.7	0.2	0.0
	Total		–	3386.1	25.2	36.0	96.3	19.3

The nutritional composition of test meals was based on the manufacturer's product information, except for pumpkin seeds and flaxseeds compositions, which were assessed in our laboratory [25].

[a] Ice water was added to all shakes in sufficient quantities to result in a final volume of 300 mL. The shakes were flavored with 3.3 g of instant passion fruit powder (Clight; Mondeléz International).

temperature was 100°C, maintained for 5 minutes, and then increased to 220°C at 4°C/min and held for 20 min. The flow rate over the column was 1.0 mL/min. The temperatures of the flame ionization detector and the injection port were 200 and 220°C, respectively. Data handling was carried out using the software GC Solution package (Shimadzu Seisakusho Co).

2.5. Postprandial glycemia

Capillary finger-stick blood samples were taken in the fasting state (0 minute), and at 15, 30, 45, 60, 90, and 120 minutes after the start of the test meal. Glucose levels were measured using a One Touch Ultra II (LifeScan Inc, Milpitas, CA, USA) glucometer. The correlation coefficient (r) between the glucometer and the standard laboratory instrument (glucose autoanalyzer YSI Model 2300 STAT, Yellow Springs, OH, USA) was 0.984, and the variations coefficient was less than 2.1% for blood samples with glucose levels higher than 3.9 mmol/L. The iAUC was calculated by the trapezoidal method [29] using the software SlideWrite 7.0 (version 7.0, 2010; Advanced Graphics Software, San Diego County, CA, USA).

2.6. Food intake

Before the beginning of the study, participants were individually instructed to keep free feeding dietary records. Habitual food intake was assessed through 24-hour dietary records filled out on 3 nonconsecutive days (2 weekdays and 1 weekend day). During the test days, food intake was also assessed through 24-hour food records. Each dietary record was reviewed with the participant to ensure accuracy and completeness. Data were analyzed by a single individual using the Avanutri software package (version 3.1.5, 2009; Avanutri and Nutrição Serviços e Informática Ltda Me, Rio de Janeiro, RJ, Brazil).

2.7. Appetitive responses

Hunger ("How hungry do you feel?"), fullness ("How full do you feel?"), and desire to eat ("How much do you think you can eat?") were assessed using 10-unit visual analog scales verbally anchored from their ends, expressing the most positive and the most negative rating [30]. Visual analog scales were applied in the fasting state (0 minute) and 15 (immediately after), 30, 60, 90, and 120 minutes after starting test meals consumption. The iAUC was determined for fullness and the incremental area above the curve was determined for hunger and prospective consumption by trapezoidal method.

2.8. Statistical analyses

Statistical analyses were carried out with SPSS 17 for Windows (SPSS, Inc, Chicago, IL, USA). Data are expressed as means and SEM. Data normality and homoscedasticity were assessed using Kolmogorov-Smirnov and Levene tests, respectively. One-way analysis of variance (ANOVA) or Kruskal-Wallis were used to assess significant differences between dietary treatments. Post hoc comparisons were conducted using Dunnett test to detect significant between-group differences in parametric variables. Two-way repeated-measures ANOVA was conducted to verify time and group factors interactions. An α level of 5% was considered statistically significant.

3. Results

3.1. Subjects

Descriptive characteristics of the study subjects at baseline are summarized in Table 2. All anthropometric data and fasting glucose concentrations were within the acceptable normal ranges. No subject complained of any malaise or discomfort during the experiment and there were no dropouts.

3.2. Chemical characterization of pumpkin and flaxseeds

Both seeds were majority composed by fat and protein, with little carbohydrate contents. Comparatively, pumpkin seed showed greater energy, protein, and fat contents, but lesser carbohydrate and fiber contents compared with flaxseed. Fatty acid profiles differed between seeds once pumpkin seed showed greatest monounsaturated fatty acid content, which was almost 50% of linoleic acid, whereas flaxseed showed greatest polyunsaturated fatty acid content, which was more than 50% of α-linolenic acid. Additional information regarding seeds characterization could be found in Table 3.

3.3. Postprandial glycemia

Glucose iAUC was significantly lower in P compared with C (reduction of ~35%, $P = .025$), but not between F and C ($P = .257$). There were no differences in glycemic response when evaluated at each time point ($P_{group \times time} = .238$) (Figure).

Table 2 – Characteristics of the study subjects at baseline

Characteristics	Postprandial glucose (n = 15; 9 women and 6 men), mean ± SEM	Appetitive responses and food intake (n = 25; 15 women and 10 men), mean ± SEM
Age (y)	23.67 ± 0.86	23.16 ± 0.55
BMI (kg/m^2)	21.02 ± 1.47	22.11± 1.00
Body fat (%)	19.41 ± 1.97	19.80 ± 1.53
Fasting glucose (mmol/L) [a]	4.79 ± 0.09	–

[a] Mean of 3 test days.

Table 3 – Chemical composition of ground and toast pumpkin seed and flaxseeds

Nutritional composition (100 g)	Pumpkin seed	Flaxseed
Energy content (kJ)	2526.7	1889.1
Carbohydrate (g)	8.9	13.9
Protein (g)	31.2	18.2
Total fat (g)	49.3	35.9
Total fiber (g)	6.0	28.3
Soluble fiber (g)	1.0	1.6
Insoluble fiber (g)	5.1	26.7
Ash (g)	4.6	3.7
Fatty acid composition (%)		
14:0	0.0	0.1
16:0	14.3	11.8
18:0	0.0	0.6
18:1	30.1	7.3
18:2	46.4	12.6
18:3	0.0	53.8
20:0	0.4	0.4
Total MUFA	30.1	7.3
Total PUFA	46.4	66.4
Total SFA	14.7	12.9

Analysis was performed in triplicate over dry matters according to Mattes [25]. Total, soluble, and insoluble dietary fibers were quantified by enzymatic-gravimetric method. Fatty acids profile were obtained after esterification [26] by GC.
Abbreviations: MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid

3.4. *Food intake and appetitive responses*

Fiber consumption was greater in F (P = .009) than in C. Despite the significant change in fiber intake, there were no differences in appetitive responses, energy, or macronutrient consumptions between F or P and C, and none between F or C and habitual intake (Table 4).

4. Discussion

The importance of controlling postprandial glucose in T2DM prevention and treatment has long been known. Even modest postprandial hyperglycemia may lead to β-cell dysfunction, leading toT2DM manifestation [31]. Postprandial hyperglycemia is also a more accurate measure of the metabolic defect underlying T2DM [32,33], and it is largely implicated in the development of macrovascular and microvascular complications associated with diabetes [32-34]. Therefore, the identification of effective dietary intervention capable to reduce postprandial hyperglycemia, particularly the use of traditional plant foods, has been of great interest.

This study demonstrated that the acute consumption of pumpkin seed added to carbohydrate-rich meals reduced postprandial glycemic response, which in turn may contribute to glycemic control. The reduction was around 35% of total postprandial glycemic response, which is superior to the effect caused by traditional and well-established oral hypoglycemic agents (eg, acarbose, an α-glucosidase inhibitor, reduces around 30% the postprandial glycemic response) [35]. Furthermore, peeled pumpkin seeds used in this study provided ~31.2 % from protein and ~49.3 % from fat, besides less than 8.9 % from carbohydrate and good lipid profile. Because of its low-carbohydrate content, pumpkin seed consumption by T2DM individuals could be encouraged instead of pumpkin pulp [7] and the inclusion of this seed in mixed meals could be performed with negligible increase in total carbohydrate meal content. In addition, data from another study [36] clearly confirmed the good lipid profile of these seeds. Although saturated fatty acids content ranged from 10% to 15% in pumpkin seeds from several species, total unsaturated fatty acid content ranged from 78% to 95%. These seeds also have a good content of oleic acid, which means that pumpkin seeds may be considered a dietary source of good fatty acids [36].

Besides its nutritional value, pumpkin seed are documented to present several components with hypoglycemic potential. It has been suggested that inositol, zinc, chromium, cobalt, oil from ungerminated pumpkin seed, and protein from germinated pumpkin seed could chronically reduce glycemia [37]. Phenolic compounds and others antioxidant agents such as *p*-hydroxybenzoic acid and caffeic acid could also have antidiabetic properties [14,38], but this effect is likely to be due to their protective role on pancreatic β-cells and not in reducing directly the glycemic response. Other components such as alkaloid trigoneline and vitamin nicotinic acid may have an indirect effect on reducing postprandial glycemia acting against proinflammatory molecules such as tumor necrosis factor α [39] and, thus, preventing insulin resistance [40]. Because of the acutely nature of our experiment and the absence of diabetes of our subjects, we questioned the influence of these components in our results and offered a new perspective about the topic.

Several studies have shown hypoglycemic properties of nonpectin polysaccharides and protein-bound polysaccharides [17,41-46], but they are extracted from pulp and not from seeds [8,43]. Pumpkin polysaccharides are able to reduce glycemia by increasing serum insulin level, reducing blood glucose level, and enhancing glucose tolerance [47]. Crude polysaccharide extract showed α-glucosidase inhibitory effect [48,49], and protein-bound polysaccharide extract showed hypoglycemic and hypoinsulinemic activity in diabetic rats [50]. Water-extracted pumpkin polysaccharides were shown to have superior hypoglycemic properties compared with glibenclamide in alloxan-induced diabetic rats [44]. Whether these polysaccharides are also present in pumpkin seeds remains unknown. However, a recent study [12] demonstrated that pumpkin seed extracts containing polysaccharides present hypoglycemic activity in diabetic rats. Although the exact composition of the extracts was not described [12], these results suggested that pumpkin seeds could also present polysaccharides with hypoglycemic activity.

Flaxseed was associated with increased daily fiber intake. The American Dietetic Association [51] targets a daily dietary fiber consumption of 14 g per 4184 kJ. Considering our subject's energy intake at baseline (2443), they are required to consume 34 g of dietary fiber per day. Flaxseed provided more than half (18.4g) of American Dietetic Association's daily recommendation for fiber intake, but without significant effects over glycemic response.

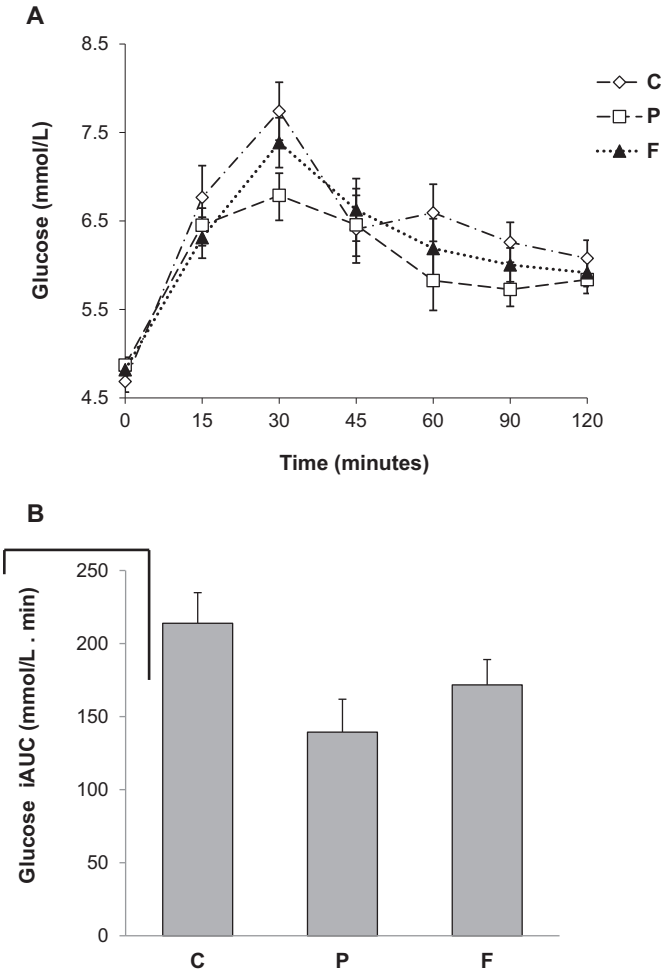

Figure – Means ± SEM postprandial glucose response (A; 0-120 minutes), and postprandial iAUC (B; 0-120 minutes) obtained after the consumption of 3 different test meals (control [C], pumpkin seeds [P], and flaxseeds [F]). *Mean values are significantly different from each other by one-way ANOVA followed by Dunnett test (*P* =0.25). Data assessed in 15 healthy normoglycemic subjects.

Table 4 – Appetitive responses, habitual food intake, and food intake in the next 24 hours after the consumption of the test meals (n = 25)

	Habitual intake, mean ± SEM	24-h food intake		
		Control meal, mean ± SEM	Pumpkin seeds meal, mean ± SEM	Flaxseeds meal, mean ± SEM
Appetitive responses				
Hunger iAAC	–	5393.9 ± 489.4	6109.2 ± 464.8	6009.4 ± 474.3
Fullness iAUC	–	4685.1 ± 436.7	5660.3 ± 528.4	5517.3 ± 499.7
Desire to eat iAAC	–	5589.9 ± 404.6	6622.8 ± 487.8	6227.8 ± 453.6
Energy, macronutrient, and dietary fiber intake				
Energy (kJ)	10,221.1 ± 592.0	11,154.5 ± 539.3	10,878.4 ± 682.4	2809.5 ± 161.7
Carbohydrate (g)	330.1 ± 20.9	329.8 ± 19.9	328.6 ± 23.9	369.0 ± 19.6
Protein (g)	83.1 ± 41.7	92.2 ± 43.6	91.4 ± 60.6	92.3 ± 37.9
Fat (g)	77.9 ± 5.1	99.6 ± 6.7	95.1 ± 5.6	95.0 ± 4.9
Dietary fiber (g)	22.2 ±1.9	19.6 ± 1.9	18.5 ±1.4	29.6 ±2.7 *

Appetitive ratings (120 minutes) were obtained visual analog scales. Habitual intake was assessed at baseline through 24-hour dietary records filled out on 3 nonconsecutive days (2 weekdays and 1 weekend day). Appetitive responses and food intake data were evaluated by ANOVA followed by Dunnett test or Kruskal-Wallis test.

Abbreviations: iAAC, incremental area above the visual analog scale response curve; iAUC, incremental area under glycemic response curve.

* Values differed significantly ($P < .050$) from the control.

Previous study from our laboratory failed to demonstrate the hypoglycemic activity of flaxseed when they were added to liquid meals [20]. However, at that time, we thought that gut transit time of liquid meals may have not been enough to increase the soluble-fiber viscosity of flaxseed responsible for its hypoglycemic effect [52]. In the present study, we added flaxseed to mixed meals containing liquid and solid foods to better explore our previous results and we confirmed the lack of effect. Considering that the results from others studies were inconsistent or demonstrated a significant but very modest effect [9,16,19], we discourage the use of flaxseed with the intention to promote glycemic control.

Because our results unprecedentedly demonstrated a great potential of pumpkin seeds in controlling postprandial hyperglycemia, we strongly encourage the use of pumpkin seeds for human nutrition and its incorporation as a bakery product ingredient. Our study has several strengths. Our study addresses a very recent and attractive topic. Furthermore, it has a great clinical appeal, once we used plant seeds easily found at local marked which could be easily incorporated in drinks and bakery products. Because the study subjects were normoglycemic general healthy individuals, our results have high appliance as a way to improve glycemic control and thus prevent T2DM in overall population. We performed the chemical characterization of pumpkin and flaxseeds at our laboratory using standards and well-accepted methods. Our study had also some limitations. Because of its acute nature, we are not sure if the observed effects are maintained in response to chronic consumption of pumpkin and flaxseed. As we assessed the effect of whole seeds and not specific extracts in postprandial glycemia, further studies are also needed to elucidate the mechanisms by which pumpkin seeds reduce glycemic response.

Acute consumption of pumpkin seed reduces postprandial glycemia when they are added to a carbohydrate-rich meal. Flaxseed increased daily-fiber intake but without change in postprandial glycemic response. The hypoglycemic effect of pumpkin seed should be further investigated to verify its contribution to T2DM prevention and/or treatment.

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