POTENTIAL BENEFICIAL EFFECTS OF NATIVE BANANA STARCH ON GLYCEMIA AND INSULIN RESISTANCE IN OBESE NON-DIABETIC WOMEN

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SUMMARY

Several studies have shown benefits from life-style changes in reducing diabetes risk. The aim of this study was to assess the effects of native banana starch (NBS) on glycemic control and insulin resistance in comparison with metformin (MF) in non-diabetic obese women. Forty participants 20-45 years of age, HOMA-IR ≥2.5 were randomly assigned to two groups of 20 subjects each. One group received NBS 30g/day and the other MF 850mg/day, both during eight weeks. Fasting glycemia was decreased by either four weeks NBS or four weeks MF treatment (week 0 vs week 4, $p<0.05$). Progressive declines of fasting insulin and HOMA-IR values were observed after NBS and MF treatments, reaching statistical significance after eight weeks (week 0 vs week 8, $p<-0.05$). The 30 and 60min insulin AUCs after eight weeks NBS supplementation tended to be lower in comparison to 30 and 60min insulin AUCs at baseline. No differences were observed in HOMA-IR response between treatments after four or eight weeks. Data shows that NBS supplementation has beneficial effects in reducing fasting glucose and insulin resistance in a group of obese women and it might represent an inexpensive and accessible alternative to be used in order to prevent complications in the obese population. Clinical Trial Registration Number: ACTRN12610000431022.

Introduction

Obesity is considered as a serious disease affecting a large population around the world. This disease is directly associated to the prevalence of type 2 diabetes, and both conditions show a progressive increase (CDC, 2011). Insulin resistance (IR) is considered the key mechanism unifying obesity to diabetes and heart disease (Bray, 2004). In obese subjects IR often appears as early as 10 years before the onset of type 2 diabetes. In the course of months or years, IR is followed by the increase in β-cell insulin secretion and by different complications known as the insulin resistance syndrome, which is associated with dyslipidemia, hypertension, hyperglycemia and cardiovascular disease (Reaven *et al.*, 2004).

The critical role of a healthy life-style in type 2 diabetes prevention has been understood from large scale intervention studies (Tuomilehto *et al.*, 2001; Knowler *et al.*, 2002; Wadden *et al.*, 2005); it has been shown that healthy diets and exercise programs can reduce diabetes prevalence in high risk subjects. In other studies, subjects reporting higher whole-grain intake have presented lower insulin concentrations (McKeown *et al.*, 2002), while low dietary fiber has been linked to a reduction in insulin sensitivity (Liese *et al.*, 2003). The term 'dietary fiber', although generally accepted, has been recognized as potentially misleading. In 2001 dietary fiber was defined by the Institute of Medicine (IOM) as the "non-digestible carbohydrates and lignin that are intrinsic and intact in plants" (Slavin, 2008). In 2009, the Codex Alimentarius Commision's Committee on Nutrition and Foods for Special Dietary Uses adopted a

KEYWORDS / Banana / Insulin Resistance / Metformin / Obesity / Starch /

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EFECTOS BENÉFICOS POTENCIALES DEL ALMIDÓN NATIVO DE BANANA SOBRE LA GLUCEMIA Y LA RESISTENCIA A INSULINA EN MUJERES OBESAS NO DIABÉTICAS

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RESUMEN

Algunos estudios han mostrado beneficio de cambios en estilo de vida en la reducción del riesgo de diabetes. El objetivo de este estudio fue estimar los efectos del almidón nativo de banano (NBS) o metformina (MF) sobre el control glucémico y la resistencia a insulina en mujeres obesas no diabéticas. Cuarenta mujeres, 20-45 años de edad, HOMA-IR ≥2,5 fueron asignados aleatoriamente a dos grupos de 20 sujetos. Un grupo recibió 30g de NBS/día y el otro 850mg de MF/día, ambos durante ocho semanas. Los niveles de glucosa en ayuno disminuyeron después de cuatro semanas de tratamiento en ambos grupos con respecto a niveles basales (p<0,05). Se observó una disminución progresiva en valores de insulina y HOMA-IR después de ambos tratamientos, alcanzando diferencia significativa en la semana 8 con respecto a valores basales (p<0,05). Las áreas bajo la curva (AUCs) parciales a 30 y 60min tendieron a ser menores en el grupo NBS después de ocho semanas de tratamiento con respecto a valores basales. No se apreciaron diferencias significativas entre los dos tratamientos en los niveles de glucemia, insulina y HOMA-IR después de cuatro y ocho semanas. Los datos demuestran que la suplementación con almidón nativo de banano reduce los niveles de glucemia en ayuno y de insulinoresistencia en mujeres obesas y podría representar una alternativa accesible y barata para prevenir las complicaciones de esta enfermedad. Nº de registro: ACTRN12610000431022.

EFEITOS BENÉFICOS POTENCIAIS DO AMIDO NATIVO DA BANANA SOBRE A GLICEMIA E A RESISTÊNCIA A INSULINA EM MULHERES OBESAS NÃO DIABÉTICAS

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RESUMO

Alguns estudos têm mostrado benefício de mudanças em estilo de vida na redução do risco de diabetes. O objetivo deste estudo foi estimar os efeitos do amido nativo da banana (NBS) ou metformina (MF) sobre o controle glicêmico e a resistência a insulina em mulheres obesas não diabéticas. Quarenta mulheres, 20-45 anos de idade, HOMA-IR ≥2,5 foram designados aleatoriamente a dois grupos de 20 sujeitos. Um grupo recibeu 30g de NBS/dia e o outro 850mg de MF/dia, ambos durante oito semanas. Os níveis de glicose em jejum diminuíram depois de quatro semanas de tratamento em ambos os grupos em relação a níveis basais (p<0,05). Observou-se uma diminuição progressiva em valores de insulina e HOMA-IR depois de ambos os tratamentos, alcançando diferença significativa na semana oito em relação a valores basais (p<0,05). As áreas sob a curva (AUCs) parciais a 30 e 60min tenderam a serem menores no grupo NBS depois de oito semanas de tratamento em relação a valores basais. Não foram apreciadas diferenças significativas entre os dois tratamentos nos níveis de glicemia, insulina e HOMA-IR depois de quatro e oito semanas. Os dados demonstram que a suplementação com amido nativo de banana reduz os níveis de glicemia em jejum e de insulino-resistência em mulheres obesas e poderia representar una alternativa acessível e barata para prevenir as complicações desta enfermidade. Nº de registro: ACTRN12610000431022.

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new definition of dietary fiber as "carbohydrate polymers with 10 or more monomeric units, which are not hydrolyzed by the endogenous enzymes in the small intestine of humans" (Mermelstein, 2009). Thus, resistant starch (RS), which is the portion of starch that resists digestion in the human small intestine, is a recently recognized source of fiber and it is classified as a fiber component which reaches partial or complete fermentation in the colon.

Data concerning studies on the effects of different forms and doses of RS on glucose and insulin responses are not clear (Sharma *et al*., 2008). Some authors have reported lower postprandial glucose and an insulin sensitizing effect (Robertson *et al*., 2003, 2005), while others have not found modifications on fasting insulin concentration (Park *et al*., 2004).

The native banana starch (NBS) used in this study was obtained from unripe bananas (*Musa cavendish* AAA) widely produced in Tabasco, Mexico. This product has a high resistant starch content and has been shown to produce a reduction of glycemic and insulinic responses in healthy and diabetic patients during an oral meal tolerance test (Pérez-Sánchez, 2007). In addition, a lower body weight and increased insulin sensitivity were observed after consumption of 24g/day NBS during four weeks in a group of obese type 2 diabetic women (Ble-Castillo *et al*., 2010). On the other hand, regarding drug therapy, metformin (MF) is the only drug recommended by the American Diabetes Association for using in subjects with high risk for developing diabetes (ADA, 2012). MF is an insulin-sensitizing biguanide derived from *Galega officinalis,* a plant used for centuries for diabetes treatment in traditional medicine (Oubre *et al*., 1997). MF increases insulin-stimulated glucose uptake in skeletal muscle and adipocytes, and acts mainly through inhibition of gluconeogenesis and glycogenolysis (Kirpichnikov *et al*., 2002).

The aim of the present study was to investigate whether NBS supplementation affects glycemia, body weight and insulin sensitivity in a group of obese non-diabetic women at high risk of type 2 diabetes. The effect of NBS supplementation was compared with that of MF, whose effect on the improvement of

hyperinsulinemia and insulin resistance is well known.

Material and Methods

Subjects

The study was conducted from August 2007 to December 2008 in the Zone 46 Hospital General from the Instituto Mexicano del Seguro Social (IMSS). The experimental protocol was approved by the hospital´s ethical committee the in compliance with the ethical principles and guidelines for the protection of human subjects of research. The protocol was registered by the Australian New Zealand Clinical Trials Registry (ACTRN12610000431022). Participants were recruited from hospital workers, their parents and people visiting hospitalized patients. The purpose and risks of the study were explained to the participants before they provided written informed consent. Participant women were included if they were between 18 and 45 years of age, were obese (WHO criterion BMI>30), had fasting glycemia <125mg·dl^{-1}, 2h-post-prandial glycemia <200mg·dl^{-1}, HOMA-IR ≥2.5, had maintained stable weight during three months prior to the study and were under the care of a health care provider from the IMSS. Subjects not included in this study were those with fasting glycemia >126mg·dl^{-1}, 2h postprandial glycemia >200mg·dl^{-1}, BMI<30, with chronic ailments such as renal or hepatic diseases, pregnant, on psychiatric treatments, receiving medical or naturist treatment to reduce body weight, receiving immunosuppressants, or with a history of cigarette smoking or alcoholism.

The criteria for selecting all participants were derived from the medical history, a complete physical examination and clinical laboratory assays, including the oral glucose tolerance test (OGTT). Anthropometric data were obtained from all participants, including height, body weight, and waist and hip circumferences. Body weight and body fat percentage were measured using a Tanita BC-418 Segmental Body Composition Analyzer Scale based on bioelectrical impedance analysis. Waist and hip circumference were measured using a plastic non-elastic measuring tape. Blood pressure readings were taken between 7:00 and 9:00 in a sitting position with a manual sphygmomanometer by trained personnel.

Protocol

In a two-arm, parallel randomized, active-controlled pilot study, the forty selected participants were randomly assigned (computer-generated random number sequence) to consume either 30g NBS dissolved in 240ml of water or 850mg MF per day during eight weeks. NBS was administered before breakfast and MF was taken with breakfast. Body weight and insulin sensitivity were selected as the primary outcome variables. Potential changes on lipids, lipoproteins, blood pressure and hepatic enzymes were considered as secondary outcome variables.

On both treatments patients were instructed not to modify their diet and exercise habits. The treatment compliance was supervised every week through clinical interviews in order to check the amount of consumed supplement, and to determine the study subject's body weights and any side effects of adverse events that occurred. Further information was obtained from the patients through telephonic interviews.

Native banana starch (NBS)

The NBS was provided by the Centro de Investigaciones Agropecuarias of the Universidad Juárez Autónoma de Tabasco, Teapa, Tabasco, Mexico. NBS was obtained from unripe (green) bananas (*Musa cavendish* AAA) from a packing plant situated on Km 43.5 of the Villahermosa-Teapa road. The bananas, with a physiological age of 15 weeks, were processed as described by Flores-Gorosquera *et al.* (2004). Briefly, after washing they were peeled, cut into pieces 5-6cm^3, immediately rinsed in citric acid solution and then macerated at low speed in an industrial blender for 2min. The homogenate was consecutively sieved through screens (30, 80 and 100 US mesh) and washed with distilled water; it was then centrifuged at 10000rpm. The sediment was further purified by washing and centrifugation. The white starch sediment was dried in a convection oven at 40-45ºC, passed through a 100 mesh screen and stored at room temperature in sealed glass jars. The dry basis yield of starch was 80%. The proximate analysis was as follows: 3.4% moisture content, 1.88% protein, 0.4281% fat and 0.78% ash (14.003, 14-057, 14-059 and 14.006, AOAC recommended methods). Water activity (a_w) of NBS was measured using the Aqualab equipment and resulted in 0.59. Resistant starch content measured according to the Goni method (Goni *et al.*, 1996) was found to be 34% on a dry weight basis.

Biochemical measurements

Blood samples were collected by trained personnel after a 12h fasting period at the onset of the study and then after four and eight weeks. Blood serum samples were immediately frozen and stored at -70ºC until biochemical determinations. All laboratory measurements were made blind to the different treatments. Glucose, aspartate aminotransferase (AST), alanine aminotransferase (ALT), cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C) and triglycerides were analyzed by using an ADVIA® 1200 Chemistry System from Siemens Healthcare Diagnostics (intra-assay coefficient of variation: glucose 3.5%, cholesterol 4.9%, LDL 5.2%, HDL-cholesterol 6.1%, triglycerides 5.2%). Human insulin was determined according to the method for the Abbott AxSYM analyzer, based on a microassay microparticle inmunoenzymatic assay. To prevent enzymatic insulin degradation special care was taken to avoid hemolysis during the blood sampling and manipulation.

Insulin resistance was estimated according to the Homeostasis Model Assessment (HOMA-IR) which was calculated by the product of the fasting concentrations of glucose (mg·dl^{-1}) and insulin (μU/ml) divided by 405. Insulin resistance was considered as a HOMA-IR value ≥2.5 (Matthews *et al.*, 1985).

Two OGTT were carried out to compare the effects of treatments on glucose tolerance, one at baseline and the other after finishing the study period (eight weeks). OGTT was performed after a 10-12h overnight fast, in accordance with World Health Organization recommendations. A catheter was inserted into an antecubital vein for blood sampling; after baseline samples were obtained for glucose, insulin and other determinations, subjects received a flavoured glucose drink (75g). Blood for glucose and insulin determination was obtained at 0, 30, 60, 90 and 120min.

Two categories for estimating increased risk for diabetes were used according to the American Diabetes Association (ADA) criteria: impaired fasting glycemia (IFG) as having fasting plasma glucose (FPG) levels of 100-125mg·dl^{-1} and impaired glucose tolerance (IGT) as 2-hours post-prandial glucose in the OGTT values of 140-199mg·dl^{-1}. Normal fasting glucose (NFG) was considered for values of 70-99mg·dl^{-1} and normal glucose tolerance (NGT) values <139mg·dl^{-1} at the 2 hours OGTT.

Statistical analysis

Data were expressed as the mean ±SEM or as the median (25th, 75th percentiles). The

D'Agostino-Pearson normality test was performed to assess if the data were consistent with a Gaussian distribution. On variables with normal distribution, a repeated measures ANOVA was used to detect a significant effect of time (0 *vs* 4 and 8 weeks treatments) and a Tukey-Kramer post hoc testing was used to identify the differences. Variables not normally distributed were analyzed after logarithmic transformation or by nonparametric tests. Intragroup responses were calculated as changes from baseline and the between-group analysis was performed by comparison of the responses of MF versus NBS using unpaired Student t test. The total and partial OGTT area under curve (AUC) was calculated using the trapezoid method. Statistical significance was defined as $p<0.05$. Calculations were made using GraphPAD PRISMA version 5.01 (Graphpad Software, Inc, San Diego, CA, USA).

TABLE I
CHARACTERISTICS OF THE FEMALE OBESE SUBJECTS AT BASELINE

	MF	NBS	P
Subjects (n)	19	16	
Age (years)	32.21 ±7.94	36.7 ±8.32	NS
Height (m)	1.598 ±0.050	1.539 ±0.052	0.0017
Body weight (Kg)	88.23 ±14.35	93.81 ±10.12	NS
Body Mass Index (BMI)	36.96 ±3.73	35.26 ±9.45	NS
Waist circumference (cm)	103.9 ±7.913	107.1 ±10.25	NS
Waist to Hip ratio (WHR)	0.83 ±0.075	0.865 ±0.070	NS
Body fat (%)	45.36 ±3.35	45.47 ±3.04	NS
Systolic Blood Pressure (mm Hg)	115.3 ±10.20	111.8 ±9.51	NS
Diastolic Blood Pressure (mm Hg)	77.63 ±9.48	74.71 ±7.99	NS
Fasting glycemia ($mg \cdot dl^{-1}$)	95.05 ±6.69	95 ±12.75	NS
Cholesterol ($mg \cdot dl^{-1}$)	178.4 ±31.65	199.4 ±39.2	NS
Triglycerides ($mg \cdot dl^{-1}$)	113.0 (76, 165)	142.5 (83.5, 165)	NS
Magnesium ($mEq \cdot l^{-1}$)	1.838 ±0.19	2.004 ±0.47	NS
AST (U/l)	19 (17,23)	19.5 (15.25, 28.75)	NS
ALT (U/l)	20 (16,25)	20.5 (16.25, 32.75)	NS
Fasting insulin (μU/ml)	17.70 (15.1, 26.50)	20.10 (16.23, 29.63)	NS
HOMA-IR	4.060 (3.29, 5.90)	5.21 (3.56, 7.845)	NS

Data are means ± SD or median (25^{th}, 75^{th} percentiles). Student t or Mann-Whitney test were used for comparison. MF: Metformin, NBS: native banana starch, NS: not significant difference.

Results

Characteristics of the patients

Forty eligible participants were randomly assigned to one of the two interventions: NBS or MF group with 20 subjects each. During the study period some participants from each group dropped out or were withdrawn: two from the NBS group due to unwillingness to undergo a second OGTT, another due to gastrointestinal discomfort and a fourth one because of residence change. From the MF group, one dropped out because of gastrointestinal discomfort. At the end of the study the NBS group was reduced to 16 and the MF group to 19 participants. NBS was well tolerated by all participants and no adverse effects were noted in either group.

The baseline characteristics of the selected participants who completed the treatments are shown on Table I. All the participants were young women aged near 30, most of them with obesity class II, mean waist circumference >100cm and mean waist-to-hip ratio (WHR) considered of high risk, with values >0.80. With the exception of height, other variables were not different between MF and NBS groups at baseline. The classification of the individuals according to their increased risk factors for diabetes was as follows: in the NBS group ten subjects had NFG/NGT, five had IFG/NGT and one showed IFG/IGT. In the MF group eleven subjects had NFG/NGT, three had IFG/NGT, three had IFG/IGT and two exhibited NFG/IGT.

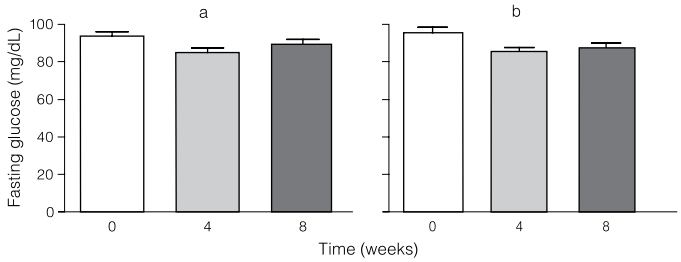

Figure 1. Effects of NBS 30g/day (a) or Metformin 850mg/day (b) administration during four and eight weeks on the fasting glucose concentrations in a group of obese women. Values are mean and SEM. MF, n=19; NBS, n=16. In both treatments 0 *vs* 4, $p<0.05$ (Repeated measures ANOVA).

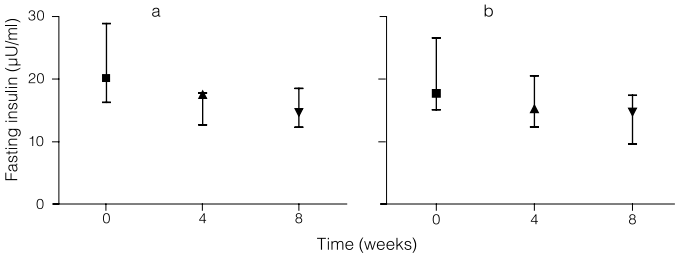

Figure 2. Effects of NBS 30g/day (a) or Metformin 850mg/day (b) administration during four and eight weeks on fasting insulin levels in a group of obese women. Values are median and interquartile range. MF, n=19; NBS, n=16. In both treatments 0 *vs* 8, $p< 0.05$ (Repeated measures ANOVA on log-transformed data).

Effects of NBS or MF on fasting glycemia

Both NBS and MF treatments moderately diminished glycemia levels after four weeks administration in comparison to baseline ($p<0.05$); however, this difference did not persist after a treatment of eight weeks (Figure 1a, b). No significant difference was observed in glycemia levels between treatments after 4 or 8 weeks of supplementation ($p=0.81$ and 0.43, respectively). Considering changes on risk factors for diabetes: after eight weeks NBS supplementation, two from six women with impaired fasting glycemia (IFG) at baseline achieved normal fasting glucose (NFG). In contrast, after eight weeks with MF treatment the five participants with IFG at baseline were found with NFG.

Effects of NBS or MF on fasting insulin and HOMA-IR

Figures 2a and b show that NBS and MF administration tended to reduce fasting insulin levels after four weeks, however, for both groups significant difference was reached only after eight weeks treatment in comparison with their respective baseline values ($p<0.05$). No differences were observed in fasting insulin responses between treatments after 4 or 8 week supplementation ($p=0.741$ and 0.663, respectively). Both interventions reduced HOMA-IR values (Figure 3): NBS diminished from 5.21, (3.56, 7.84) to 3.040 (2.63, 4.08) after eight weeks

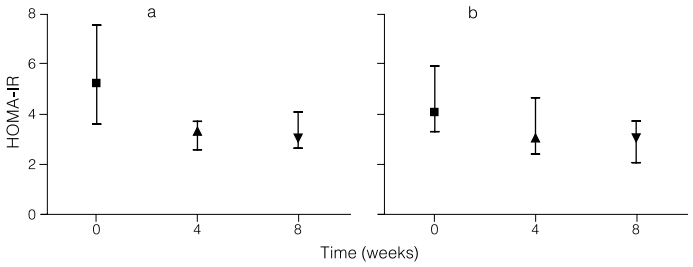

Figure 3. Effects of NBS 30g/day (a) or Metformin 850mg/day (b) administration during four and eigth weeks on HOMA-IR in a group of obese women. Values are median and interquartile range. MF, n=19; MF, n=16; NBS and MF: 0 *vs* 8, $p < 0.05$ (Repeated measures ANOVA on log-transformed data).

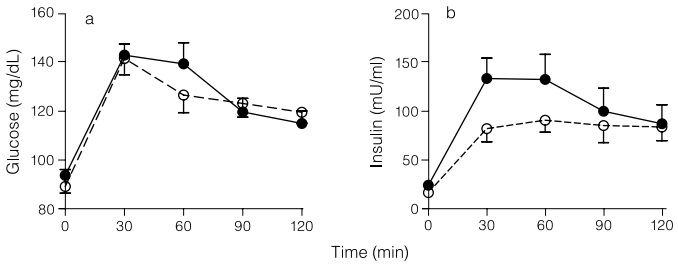

Figure 4. Plasma glucose (a) and insulin concentrations (b) during OGTT 75g at baseline (solid line) and following eight weeks NBS 30g/day supplementation (dashed line). Glucose and insulin concentrations were determined at 0, 30, 60, 90 and 120min. Each point represents 16 subjects mean and SEM.

treatment, $p<0.05$. MF reduced HOMA-IR values, from 4.06 (3.29, 5.90) at baseline to 3.04 (2.02, 3.73) after eight weeks of treatment, $p<0.05$. No differences were observed in HOMA-IR responses between treatments after 4 or 8 weeks of supplementation ($p=0.283$ and 0.662, respectively).

Effects of NBS or MF on body weight

A moderate reduction on body weight (0.747g) was observed in subjects after consuming MF during four weeks, however, this effect was not significant and did not remain after eight weeks of administration. When comparing body weight responses between treatments, MF treatment induced greater weight loss than NBS supplementation after four weeks (0.747 ±1.232 *vs* -0.3867 ±1.766, $p=0.033$). No differences between treatments were observed after eight weeks ($p=0.278$).

Effects of NBS or MF on serum lipids and other parameters

MF reduced cholesterol levels after four weeks treatment ($p<0.05$); however, this effect did not remain after eight weeks (data not shown), while NBS did not modify cholesterol levels. No changes were found in serum triglycerides after NBS or MF administration. No modifications were observed on other parameters as blood pressure, fat percentage, waist circumference, WHR and hepatic enzymes across either treatment or between treatments (data not shown).

Oral glucose tolerance test

When comparing glucose excursion in the NBS group, a major reduction was observed at 60min OGTT after eight weeks in comparison to 60min OGTT baseline values. However, no statistical significance was reached, (Figure 4a). With regard to insulin excursion, the 30 and 60min insulin AUCs tended to be reduced after eight weeks of NBS treatment in comparison to 30 and 60min AUCs values at baseline, but because of a large internal variability there was no statistical significance (Figure 4b). No significant changes on blood glucose and insulin excursion were observed after MF treatment, as can be appreciated by comparing the OGTT at baseline and after MF supplementation (Figures 5a and b).

In the NBS group two subjects with IFG/NGT improved their glycemic control to NFG/NGT and one woman with IFG/IGT improved her glucose tolerance to IFG/NGT. In the MF group one woman with IFG/IGT improved her glycemic control to NFG/NGT and one with NFG/IGT changed to NFG/NGT, however, unexpectedly two women with NFG/NGT were modified to NFG/IGT.

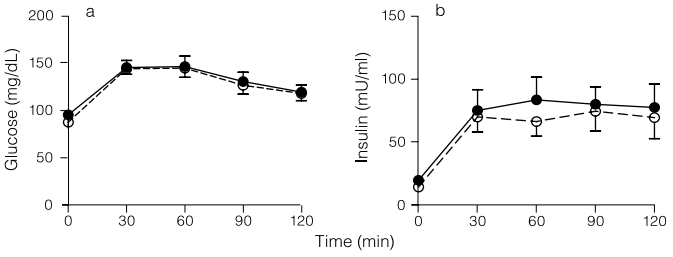

Figure 5. Plasma glucose (a) and insulin concentrations (b) during OGTT 75g at baseline (solid line) and following eight weeks MF 850mg/day treatment (dashed line). Glucose and insulin concentrations were determined at 0, 30, 60, 90 and 120min. Each point represents 19 subjects mean and SEM.

Discussion

This study was designed to examine the effects of NBS supplementation on glycemia and insulin resistance when compared to MF treatment in a group of drug-naïve non-diabetic obese women. Exclusive female participants were included because of the greater incidence of obesity among women in Mexico and due to their major interest in personal health care and participation in clinical trials at the locality. We decided to use MF treatment in the active control group because most of the patients were very obese, with BMI >35kg·m^{-2}, and therefore considered as very-high-risk individuals. MF has been the only drug recommended for use in diabetes prevention according to the results of many clinical trials. Moreover, this substance has demonstrated beneficial effects on weight loss (ADA, 2012). The MF dose was chosen on the basis of our previous clinical experience, taking in account that this substance was administered durig breakfast and, thus, there is a considerable reduction in the extent and delay of absortion. MF reduces elevated blood glucose levels by reducing hepatic glucose output and by enhancing peripheral glucose uptake, improving insulin resistance. In the Diabetes Prevention Program study, MF treatment reduced the incidence of type 2 diabetes by 31% and was found to be more effective in obese participants (Knowler *et al.*, 2002).

In the present study insulin resistance was measured by the homeostatic model assessment of insulin resistance (HOMA-IR). This method is based on the balance between liver glucose output and insulin secretion from basal levels of both glucose and insulin (Matthews *et al.*, 1985). In contrast, the hyperinsulinemic euglycemic clamp, which is considered the gold standard, directly measures insulin action on glucose utilization under steady-state conditions. The main limitations of the latter technique are that it is invasive, time consuming, difficult to perform and utilizes steady-state insulin levels that

may be supraphysiological. For this reason, surrogate fasting-based indices like HOMA-IR have been widely used in clinical research. HOMA-IR correlates well with the glucose disposal rate (M) obtained from the hyperinsulinemic euglycemic clamp test in different populations and has shown ability for monitoring lifestyle interventions in obese persons (Vogeser *et al*., 2007).

Although the favorable effects of resistant starch from other sources have been previously reported, to the best of our knowledge there are no studies focused on the beneficial effect of NBS supplementation on glucose homeostasis in obese women. Here, it is shown that 30g per day NBS during eight weeks reduces fasting glycemia and increases insulin sensitivity in an undistinguishable trend as MF 850mg/day produced during the same period in a group of obese women with comparable insulin resistance.

It must be noted that the used dosis of 30g/day of NBS during eight weeks was based on previous findings from our team, where 24g of NBS was used on diabetic patients during four weeks without any particular adverse effect (Ble-Castillo *et al*., 2010). In addition, other authors have administered 50g of Hi-Maize containing 30g of type 2 resistant starch during four weeks (Robertson *et al*., 2005). Also, mean dietary fiber intake in the adult women from our population has been reported to be 15.5g/day, which is low according to the Dietary Reference Intakes that recommend consumption of 25g/day for adult women, based on epidemiological studies (Barquera *et al*., 2002; Slavin, 2008).

Resistant starch has been classified into four general subtypes termed RS1-RS4. Banana starch belongs to the RS-2 subtype, which describes native starch granules that are protected from digestion by the conformation or structure of the starch granule. This compact structure limits the accessibility of digestive enzymes and accounts for the resistant nature of NBS (Sajilata *et al*., 2006; Fuentes-Zaragoza *et al*., 2010). Thus, the diminished glucose and insulin response observed after NBS in this study could be partially explained by a reduced rate of digestion. The metabolic convertion of RS generally occurs 5-7h after consumption, in contrast to normally cooked starch, which is digested almost immediately. In previous experiments our team has showed that a single oral administration of NBS induces a diminished glycemic and insulinic postprandial response in healthy and diabetic subjects when compared to digestible starch supplementation (Pérez-Sánchez, 2007). The chronic suppression of postprandial blood glucose elevation, which was induced by the consecutive ingestion of NBS in this study, might partially explain the reduced glycemia and the lowered insulin response observed here. The results agree with those from other studies indicating that 60g RS (Novelose 260) supplementation during 24h increased postprandial insulin sensitivity in healthy subjects (Robertson *et al*., 2003) and that a four week supplementation with 30g of type II RS/day improved insulin sensitivity (Robertson *et al*., 2005).

The slow digestion of RS has the potential for regulating the appetite and energy intake. Recently, Bodinham *et al*.. (2010) informed a reduced food intake in healthy subjects after 48g RS over a 24h period and proposed that it may be useful in the management of appetite and metabolic syndrome. Another possible mechanism by which RS might modulate insulin sensitivity is through alterations in the fatty acid flux. RS has been shown to induce an increase on plasma short chain fatty acids (SCFAs), which in turn inhibit adipose tissue lipolysis *in vivo* and mediate the release of glucagon-like-peptide 2 (Robertson *et al*., 2003).

In contrast to the results from a previous report where NBS improved body weight in diabetic patients (Ble-Castillo *et al*., 2010), in this study no effect of NBS on body weight was observed. However, MF moderately reduced body weight after the first four weeks of treatment, although this difference did not reach statistical significance. There is evidence that MF is associated with weight loss in overweight and obese non-diabetic subjects (Golay, 2008). We do not have a rational explanation for the lack of effects of NBS on weight loss in obese subjects.

Considering particular effects on risk factors for type 2 diabetes MF demonstrated more efficacy than NBS. After eight weeks treatment the five participants with IFG at baseline were changed to NFG. In contrast, after NBS for the same period, only two out of six women with IFG achieved NFG. In relation to the tolerance test, after MF treatment for eight weeks, two of the subjects with IGT were changed to NGT; however, other two subjects with NGT at baseline were unexpectedly modified to IGT. In the NBS group one subject with IGT was changed to NGT. Further studies with balanced comparable groups are required to analyze the effects of NBS on risk factors for type 2 diabetes among high risk population.

In summary, the results of this study show that 30g/day NBS during eight weeks reduces glycemia levels and insulin resistance in a group of insulin resistant obese women. Limitations of the study include a small sample size and short intervention period. Thus, replications with a larger sample size including both sexes and a longer evaluation period are warranted. Results are relevant since NBS represents a cheap and accessible alternative to be used in order to prevent complications in the obese population.

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