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Postprandial Glucose and Insulin Responses to Grain Products in Diabetics and Healthy Subjects

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Abstract
A study on the commonly consumed cereals products was conducted to elicit their postprandial blood glucose and insulin responses in diabetics and non – diabetics subjects. Bread, acha (hungry rice, fonio), rice, maize and spaghetti were the meals used. The result showed that the low glycaemic index meals (acha and rice) had lowering effect on the blood glucose and insulin responses. Also the meal that is of whole grain had lower responses of blood glucose and insulin. Ingestion of whole grains may cause reduction of postprandial glycemia at the meal in which they were consumed. This effect may prove useful in public health efforts for diabetes prevention and could be a factor in the documented relationship between whole grain intake and lower risk of diabetes. Ingestion of whole grains may cause reduction of postprandial glycemia. However it is important to note that extensive milling or cooking negates the subsequent meal effect. Therefore, whole grains should be consumed in their native state or with minimal processing for full benefit.

Keyword: whole grains, blood glucose, insulin, glycaemic index

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Introduction

Diabetes mellitus (DM) is a syndrome of chronic hyperglycaemia due to relative insulin deficiency, resistance, or both. Diabetes is usually irreversible and, although individuals with diabetes can have a reasonably normal lifestyle, its late complication could result in reduced life expectancy and major costs. In Nigeria according to the National expert committee on Non-communicable Disease Monograph published by the Federal Government of Nigeria (1997) not less than 1.05 million people aged 15 years and above are likely to be diabetic. Of this number, 225,000 are aware of their condition and 198,000 are receiving treatment. Type 2 diabetes is more prevalent than Type I and diet has been a very important basic component in management of the condition. Type 2 diabetes is caused by a combination of decreased insulin secretion and decreased insulin sensitivity. Typically, the early stage of type 2 diabetes is characterized by insulin resistance and decreased ability for insulin secretion causing excessive postprandial hyperglycaemia. This is followed by a gradually deteriorating first-phase insulin response to increased blood glucose concentrations (Bruce *et al.,* 1988).

Grain products are the major source of carbohydrate in the diet of Nigerians, and carbohydrates that produce both low postprandial blood glucose and insulin responses are considered beneficial for health (Järvi *et al.,* 1995). Whole grain foods that undergo processing and reconstitution must deliver the same proportion of bran, germ, and endosperm as that of the original grain to be considered whole grains. The outer bran layer is composed of non-digestible, mainly insoluble, poorly fermentable carbohydrates (such as cellulose, hemicelluloses, arabinoxylan), and the inner germ and starchy endosperm contain viscous soluble fibers, fermentable oligosaccharides, resistant starch, lignans, b-glucan, inulin, numerous phytochemicals, phytosterols, phytin, sphingolipids, vitamins, minerals, polyphenols, oils, and other phytonutrients (Okarter and Liu, 2010).

The 2005 Dietary Guidelines for Americans (DGAs) recommend that individuals should consume 85 grams or more of whole grain products per day, with the rest of the recommended grains coming from enriched or whole-grain products. In general, at least half of the grains should come from whole grains (DGAs, 2005). The 2010 Dietary Guidelines for Americans also support this guidance (DGAs, 2010). Whole grains are defined by U. S. Food and Drug Administration (USFDA) as consisting of the "intact, ground, cracked or flaked fruit of the grain whose principal components, the starchy endosperm, germ and bran, are present in the same relative proportions as they exist in the intact grain (USFDA, 2006)." The protective effects of whole grains may depend on the presence or interaction of several biologically active constituents, including dietary fiber, vitamin E, magnesium, folate, and other nutrients and non - nutrients (Liu, 2004). Magnesium, a rich constituent of the grain germ, is associated with low insulin concentrations and a low incidence of type 2 diabetes (Salmeron *et al.,* 1997a, b).

Dietary phytochemicals are defined as bioactive, non-nutrient plant compounds that are associated with reduced risk of chronic diseases (Liu, 2004). Adom *et al.* (2005) reported that the majority of the beneficial phytochemicals are present in the bran and germ fractions of whole grains. Prospective cohort studies consistently suggest that when consumed in whole foods, these phytochemicals may contribute to important protection against chronic diseases, such as cardiovascular disease and certain cancer (Okarter and Liu, 2010; Slavin, 2004). Food processing, such as thermal processing and milling, can help release these phytochemicals, making them more bioaccessible. Thus, the altered nutrient profile of diets that contain considerable refined grain may increase the glycaemic index, thereby enhancing the risk of type 2 diabetes. Therefore switching to whole grains would be expected to reduce the risk of this condition. Greater consumption of dark bread, wholegrain breakfast cereal and bran were also associated with a significant reduction in the risk of diabetes of a magnitude of 23–46 %. Schulze *et al.* (2004) found that the risk of type 2 diabetes was low in women who consumed more cereal and vegetable fiber.

Under normal circumstances, people rarely consume a meal without stew, soup or vegetables in Nigeria. The physiological properties of a meal changes in relation to other components present in a meal. ADA recognizes that, in addition to its important role in preventing and controlling diabetes, nutrition is an essential component of an overall healthy lifestyle. The objective of this study was to examine the effects of some commonly consumed whole cereal products and vegetables as part of a complete meal on blood glucose and insulin levels in the diabetic and healthy subjects in Nigeria.

Materials and Methods

Subject recruitment: The study protocol was approved by the scientific and ethical committee of Ahmadu Bello University Teaching Hospital Shika, Zaria, Nigeria and each subject was provided written informed consent. The subjects were recruited from the Ahmadu Bello University Teaching Hospital Shika diabetic clinic and its surrounding community. The sample size were 10 diabetic subjects and 6 healthy subjects for each meal according to the recommendation of the World Health Organization (FAO/WHO, 1998) and they were drawn each time from a pool of 17 type – 2 diabetic and 10 control subjects respectively that were recruited from the clinic. The inclusion criteria included: those that were not currently smoking cigarettes; not taking medications that would affect glucose, insulin, lipids for normal subjects; not engaging in a high level of physical activity; not following a special diet (e g, vegetarian); not allergic to any foods; and not planning to change dietary habits, change body weight, move out of town, or take a lengthy vacation during the time of the study. They were informed that the study involved overnight fast each day of the laboratory study and type - 2 diabetic subjects were instructed to stop oral hypoglycaemic agent(s) therapy one week before the commencement of the study. Height and weight were measured while the subjects were standing without shoes and heavy clothing. Body Mass Index (BMI) was calculated, and obesity was defined as a BMI $\geq$ 30 Kg/m^2 (Kuczmarski *et al.,* 1997).

Test meal: The test meals were bread, acha, rice, maize and spaghetti. All ingredients were collected raw and in bulk to avoid differences in quality and quantity. Test meals were prepared according to the usual Nigerian methods and each individual portion was prepared (cooked) separately from the same batches of raw ingredients. The food macronutrients of the raw ingredients were calculated using food composition table by Enwere, (1998) to ensure that 50 gm of carbohydrate was contained in the final cooked product. All portion size consisted of approximately 50 g available carbohydrate (defined as total carbohydrate minus dietary fiber) but energy, protein and fat were variable.

Carbohydrate = 50 grams (53.8%) of the total meal calorie.

Protein = 16.02 - 19.72 grams (19.1%) of the total meal calories.

Fat = 13.9 - 15.33 grams (27.1%) of the total meals calories

Total calorie intake = 398.4 – 420.0 calorie.

The dishes were freshly prepared and served within 1 hour of preparation of the meal. Each volunteer took part in the experiment on two non-successive days. On the first day of the experiment, subjects took glucose anhydrous (50 g) dissolved in 250 ml of water and at the second visit, they ingested the test meal. The food or glucose was consumed within 10 to 15 min and 250 ml of water was drunk with the meals.

Blood collection, biochemical and analysis: Fasting blood samples were drawn after the subjects had fasted overnight for the measurement of glucose, and insulin. Fasting insulin concentrations were measured in the serum. Blood samples were taken 30, 60, 90,120and 150 minutes after consumption of the meals or reference food (glucose). *B*lood samples were collected at all time points into vacutainers without anticoagulants and were allowed to clot, immediately centrifuged and analysis for glucose was done using the enzymatic colorimetric method of Randox (Cat. no. GL 2614 Randox Laboratories Ltd., Antrim,UK) which was of the principle of glucose oxidase method (Trinder, 1969). The serum insulin concentrations were measured by a commercially available enzyme linked Immunosorbent Assay (ELISA) human insulin kit manufactured by DEMEDITEC Diagnostics GmbH D.24145 Kiel Germany (2006).

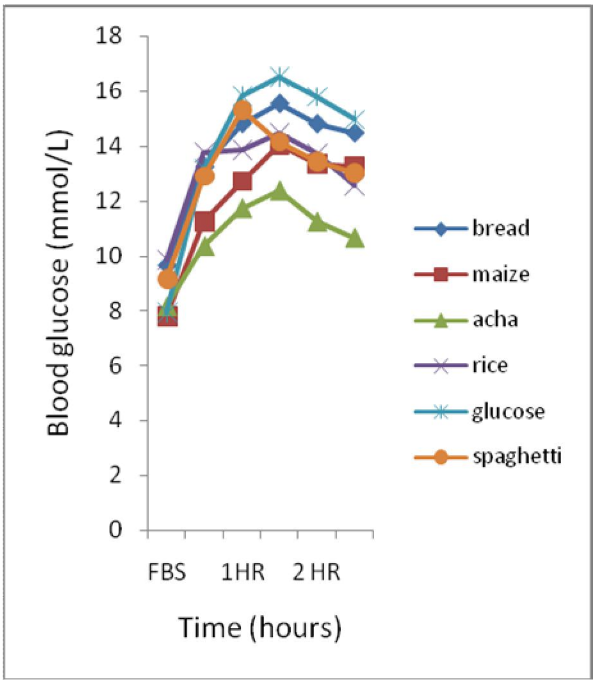
Results

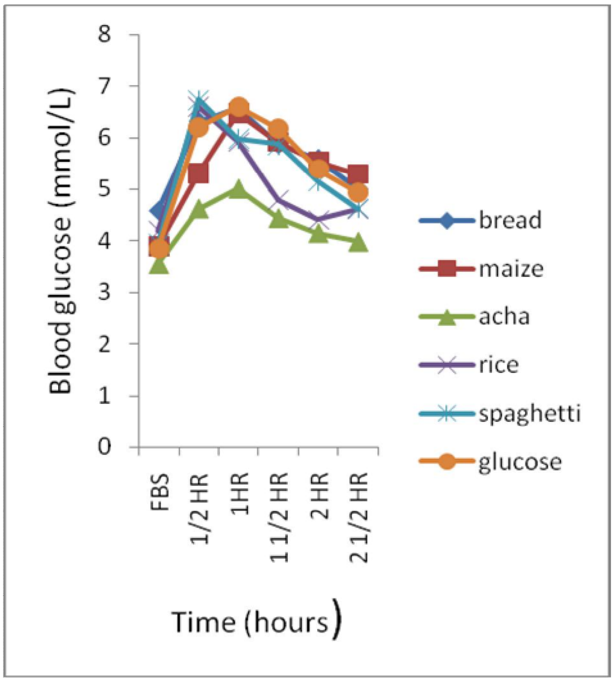
The mean age for Type 2 diabetic and control subjects were 49.00±2.00 years (range 35-60years) and 53.00± 2.35 years (range 40 – 65years) respectively, while the mean body mass indices of the diabetics and the control group were 28.30±1.48 and 29.07±1.20 Kg/m^2 respectively and both were similar at $p>0.05$. The average duration of diabetes mellitus in the diabetic study group was 3.53±0.49 years (range 2-10 years). All the Type 2 diabetics were on one or combinations of hypoglycaemic drugs plus diet except one who was on diet only. Information obtained from the subjects revealed that the major foods regularly consumed before the study were beans, acha, and wheat; other carbohydrate foods were eaten sparingly. The quantity consumed depended on how much they could eat and be satisfied. There was no significant difference in the nutrient compositions of the meals as shown in Table 1.

Table 1 Nutrient composition of the test meals

	Acha	Maize	White bread	Rice	Spaghetti
Total weight (g)					
Available (CHO) (g)	51.89	53.1	51.65	51.05	52.9
Protein (g)	18.12	19.72	16.02	18.3	17.8
Fat (g)	13.9	14.1	14.2	13.9	15.33
Energy (Kcal)	409	418.5	398.4	407.7	420

Figure 1 shows the results of the mean blood glucose after the consumption of the meals and glucose in diabetic and control subjects. The mean blood glucose levels were significantly lower between acha and bread ($p \leq 0.0003$), maize ($p \leq 0.03$), spaghetti ($p \leq 0.001$), rice ($p \leq 0.003$), glucose ($p \leq 0.01$), and also between maize and bread ($p \leq 0.0001$), glucose ($p \leq 0.005$), while in the control there were significantly lower differences between acha and bread ($p \leq 0.0001$), spaghetti ($p \leq 0.01$), maize ($p \leq 0.002$), rice ($p \leq 0.02$), glucose ($p \leq 0.003$), and also significantly different between rice and bread ($p \leq 0.05$). No other significant differences were observed in the mean blood glucose after the consumption meals and glucose when compared between the various meals.





A B

Figure 1: Blood glucose responses after consumption of the cereal meals and glucose in diabetes (A) and control (B)

Figure 2 shows the glycaemic index of the meals in diabetics and control subjects. In the diabetic subjects, the glycaemic index (GI) of the meals when compared with each other showed that acha was significantly lower than bread ($p \leq 0.002$), spaghetti ($p \leq 0.04$), maize ($p \leq 0.003$), and also the GI of maize was significantly higher than bread ($p \leq 0.03$), spaghetti ($p \leq 0.03$), and rice ($p \leq 0.005$), rice was only significantly lower than maize ($p \leq 0.005$) and there was no significant differences with the other meals (figure 2). In the control subjects meal comparisons showed that acha GI was significantly lower than bread ($p \leq 0.02$), spaghetti ($p \leq 0.01$), maize ($p \leq 0.04$), and also the GI of bread was significantly higher than rice ($p \leq 0.03$). No other significant differences were observed in the glycaemic indices between the meals and also between diabetics and control subjects.

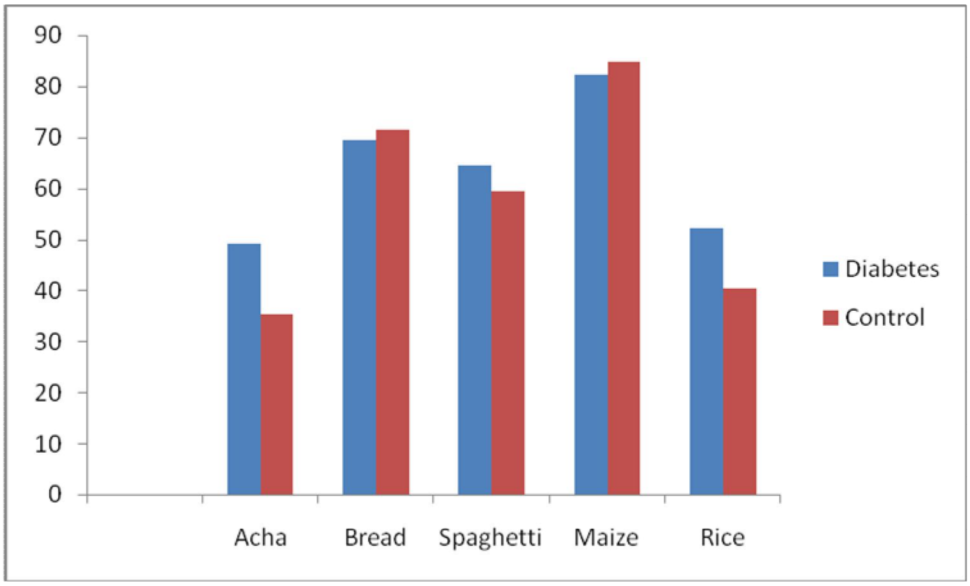
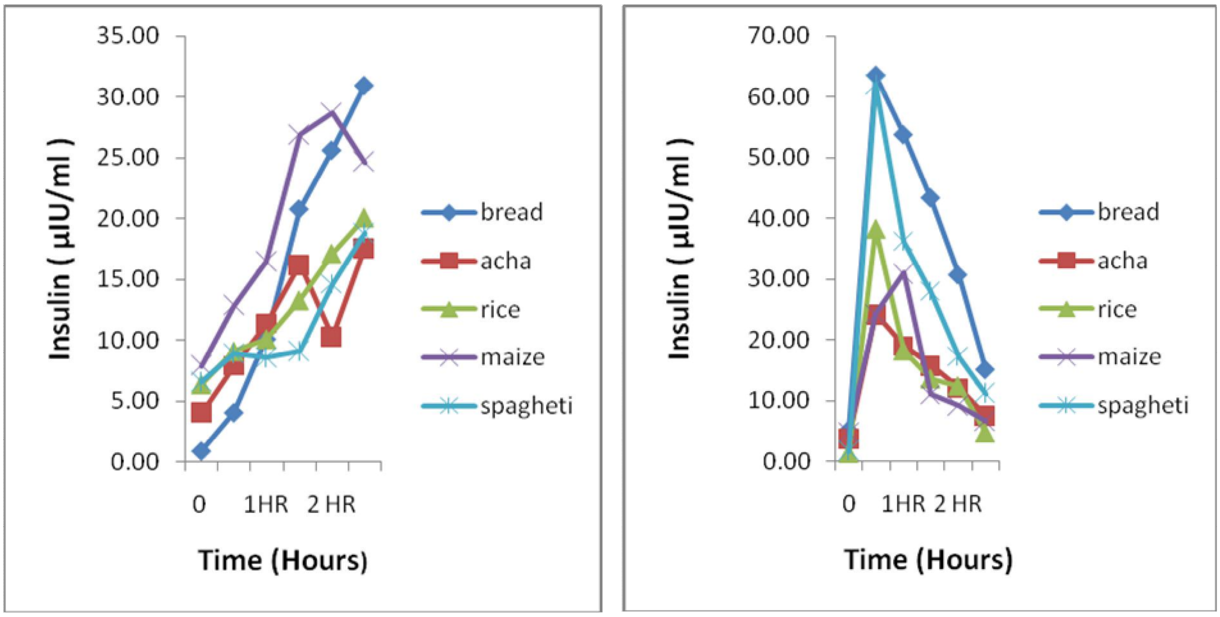


Figure 2: Glyceamic index of the cereal meals in diabetics and control subjects

Figure 3 shows insulin responses in both diabetics and control subjects. The insulin responses in the diabetic's subjects were significantly lower in acha, rice and spaghetti than maize while in the control it was significantly lower in acha, rice, maize and spaghetti than bread. Also in the control it was significantly lower in rice than spaghetti and no other significant differences were observed in the insulin responses between the meals.



A B

Figure: 3: Insulin responses after consumption of bread, acha, rice, maize and spaghetti meals in diabetic (A) and control (B).

Discussion

Acha had lower GI than the other cereal products except rice. This could be explained by the fact that acha and rice meal in this study are whole cereal. The whole grain bioactive constituents such as dietary fibre trace minerals, vitamins, lignans and phytochemicals have been reported to be potential contributors (Anderson *et al.,* 2000; Slavin, 2003; Mann, 2007). However, diets rich in whole-grain foods have been associated with a reduction in the risk of coronary heart disease and type 2 diabetes, independent of the effects of selected nutrients found in whole grains (McKeown *et al.,* 2004; Liese *et al.,* 2005; Du *et al.,* 2008). The influence of whole grains on cardiovascular disease risk may be mediated through multiple pathways, for example, a reduction in blood lipids (Johnston *et al.,* 1998) an enhancement of insulin sensitivity, and an improvement in blood glucose control (Jenkins *et al.,* 2000).

In the statement of the American Diabetes Association there are some evidences to support the role of whole grain or dietary fibre in reducing the risk of type 2 diabetes (Franz *et al.,* 2002). There is a consensus that intact botanical structure protects the encapsulated starch of the kernel against hydrolysis (Brand *et al.,* 1990; Granfeldt *et al.,* 1992). Although rice is a whole grain but chewing is required to break it down to smaller particles before swallowing. This could explain the significant difference observed between rice and maize. Acha was used as whole grain in form of stiff dough to be swallowed while rice was boiled and most of the clients chewed the rice before swallowing. Even a less extreme disruption of the botanical tissue such as that occurring during rolling of steamed cereal grains is enough to increase blood glucose and insulin responses. It was shown previously that rolling of steamed oat grains increased the accessibility of the starch for digestion and absorption compared with boiled intact oat kernels (Granfeldt *et al.,* 1995). The postprandial and insulin responses to starchy foods may be modified by a variety of factors, including the processing conditions (Bjo¨rck, 1996). Thus, processes that gelatinize the starch granules or disrupt the food structure increase the glycaemic and insulinemic responses as seen in maize and bread in this study. Whole grain cereal products with low-GI characteristics might thus be particularly advantageous with respect to the insulin resistance syndrome since from this study the low glycaemic index meals (acha and rice) had lower responses compared with the remaining cereals products.

The glycaemic index of maize was significantly higher than the other cereals in the diabetic subjects; this may be due to the method of processing and preparation. In order to make the maize meal it was ground into flour and in preparation, it was gelatinized by boiling and cooking until firmed dough is formed. A study by Snow and O'Dea, (1981) showed that a disruption of the structure present in native starch by gelatinization (i.e., swelling of the granules in the presence of heat and water) increases its susceptibility to enzymatic degradation *in vitro* therefore its availability for digestion and absorption in the small intestine. A more prominent rise in blood glucose and insulin has thus been reported with consumption of cooked as opposed to raw starch (Collings *et al.,* 1981). Consequently, glucose and insulin responses in healthy subjects were found to be significantly higher after ingestion of cooked compared with raw starch from corn (Collings *et al.,* 1981).

Acha and rice produced lower blood glucose and insulin in both diabetics and control subjects. The structure of food is a factor in the postprandial responses to starchy foods. Boiled intact cereal grains such as rye, oats, wheat and barley cause low glucose and insulin responses (Granfeldt *et al.,* 1995). On the other hand, when the raw materials were ground into flour before boiling, the postprandial glucose and insulin responses increased significantly compared with boiled intact seeds (Granfeldt *et al.,* 1994; Liljeberg *et al.,* 1992; Tovar *et al.,* 1992). Reduced insulin demand may be another protective mechanism associated with higher intake of whole grain. In general, because of their physical form and high content of viscous fiber, wholegrain products tend to be slowly digested and absorbed and thus have relatively low glycaemic indexes.

Whole ground maize in the present study had no profound effect on the blood glucose. Some studies also reported that the amount of whole kernels in the bread is more effective in reducing the glucose and insulin responses than the high fiber content (Jenkins *et al.,* 1986; Liljeberg *et al.,* 1992). Greater intake of many constituents of whole grains, including dietary fiber, vitamin E, and folate, have been independently associated with reduced risk of cardio – vascular heart disease (Anderson and Hanna, 1999; Chandalia *et al.,* 2000).

These results suggest that the main nutritional factor that influenced the glycaemic and insulinaemic responses to mixed meal is the type, composition and processing. Dietary fiber may slow the absorption of nutrients in the gut, thereby attenuating the glycaemic response to ingested carbohydrates (Jenkins *et al.,* 2002). High amylase starch granules are hydrolyzed more slowly by the intestinal enzymes and the resultant reduction in blood glucose decreases the quantity of insulin required to clear glucose from the blood, and this, in turn, may lead to up-regulation of insulin receptors on cells, thereby increasing insulin sensitivity.

Conclusion

Ingestion of whole grains may cause reduction of postprandial glycemia. However it is important to note that extensive milling or cooking negates the subsequent meal effect. Therefore, whole grains should be consumed in their native state or with minimal processing for full nutritional benefit. However, it is necessary to develop more acceptable recipes and their responses from the various grains used for this research.

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