Journal of Dietary Supplements, Early Online:1–8, 2016

DOI: 10.3109/19390211.2016.1156798

ARTICLE

Effects of a Bioavailable Arabinoxylan-enriched White Bread Flour on Postprandial Glucose Response in Normoglycemic Subjects

Anna Giulia Falchi, MD, Ilaria Grecchi, MSc, Chiara Muggia, MD, Giuseppina Palladini, MSc, & Stefano Perlini, MD

Department of Internal Medicine, IRCCS Policlinico S. Matteo Foundation, University of Pavia, Pavia, Italy

ABSTRACT. The beneficial effects of soluble fibers on carbohydrate metabolism are well documented. In this regard, we tested an arabinoxylan-enriched white bread flour, obtained by a patented process by which the bran extracted from the milling process is enzymatically hydrolyzed in order to separate the soluble fraction fiber from the insoluble fiber. We recruited 24 healthy normoglycemic volunteers [Age 34–61 ± 12.5 y; Body Mass Index (BMI) 22.1 ± 2.5 kg/m^2; Waist circumference (WC) 84.43 ± 8.0 cm; Fat Mass (FM) 22.7 ± 8.0%] attending the Dietetics Outpatient Clinic of the Internal Medicine Department at IRCCS Policlinico S. Matteo Foundation, University of Pavia, Pavia, Italy. Subjects acutely consumed arabinoxylan-enriched white bread (weight: 100 g) or isoenergetic control breads, in a double-blind crossover study design. Plasma glucose levels were measured just before bread administration and 30 minutes afterwards. The 30-minute peak postprandial glucose concentrations after arabinoxylan-enriched meals were significantly lower than after the control meal (107±4.6 mg/dL *vs.* 121 ± 5.2 mg/dL; $p < 0.05$). The here-reported results show how postprandial glucose responses were improved by ingestion of the arabinoxylan-enriched meal. Further studies are needed to clarify whether daily consumption of arabinoxylan-enriched bread will benefit patients with type 2 diabetes mellitus.

KEYWORDS. arabinoxylan, bread flour, glucose, soluble fiber

INTRODUCTION

During the last century, Western world lifestyle and nutrition have undergone profound changes. A sedentary lifestyle has replaced the much more active previous one, and there has been a net reduction of the intake of dietary carbohydrates, in favor of a high-fat and high-protein diet. Furthermore, the few carbohydrates that are currently used are obtained from refined flours, increasingly lacking fiber content. Such a low-fiber intake coupled with a high-fat and high-protein diet has

Address correspondence to: Giuseppina Palladini, Deptartment of Internal Medicine, IRCCS Policlinico S. Matteo Foundation, University of Pavia, pz. Golgi 19, 27100 Pavia, Italy. (E-mail: giuseppina.palladini@unipv.it)

been associated with an exponential growth of diseases such as obesity, metabolic syndrome, type 2 diabetes and cardiovascular disease, which are currently representing a real emergency issue in public health (Seal and Brownlee, 2015). Currently a proper diet is universally recognized as a fundamental measure aiming at reducing the risk of diseases and maintaining a healthy lifestyle (Gerber and Hoffman, 2015; Lattimer and Haub, 2010). The beneficial effect of soluble fiber on carbohydrate metabolism is well documented (Wang et al., 2016; Brennan, 2005; Venn and Mann, 2004; Meyer et al., 2000). A major component of dietary fiber in cereal grains are arabinoxylans, polysaccharides belonging to the category of hemicellulose, which are characterized by units of linked xylose monomers (xylans), ramified with arabinose (Bartlomiej, 2012). A unique feature of the arabinoxylans is the presence of hydroxycinnamic acid and especially ferulic acid, which act as a liaison between the transverse polysaccharides and polyphenols that possess strong antioxidant properties, which are associated with reduced risk of cardiovascular disease, diabetes, neurodegenerative disorders, and tumors (Kunyanga, 2011). Several studies have shown that the major beneficial effects of wheat bran are largely attributable to the soluble fiber (Aller et al., 2004; Ou et al., 2001; Lu et al., 2000). In fact, the insoluble fiber, favoring the gastrointestinal tract emptying, may cause, especially in susceptible individuals, colon irritation, abdominal bloating and swelling. Furthermore, it gives the characteristic bitter taste that is typical of the whole wheat flour. Unfortunately, the vast majority of pentosans and ferulic acid contained in the bran is not bioavailable. In fact, they are particularly represented in a layer that contains the starchy grain endosperm (aleurone layer). Since the aleurone layer is tightly bound to the outer skins (bran), it is easily removed during the wheat grinding process. Its recovery, obtainable with various food technologies, has led to the formulation of soluble fiber-enriched flour, to be used for the preparation of many products that can be evaluated for their potential positive health properties. Wheat bread might be of particular interest in this field, being not only consumed in significant quantities in the Mediterranean area, but also characterized by a high glycemic index value, due to its cellular structure and to the high digestibility of its starch component. From a theoretical standpoint, such an enrichment in bran fibers in white bread, largely consumed, may result in a slower carbohydrate absorption, modulating the glycemic response to bread ingestion

AIM

The aim of this study was to investigate the acute effects of an arabinoxylan-enriched white bread on postprandial glucose levels in healthy volunteers. Thus, we hoped to evaluate if an arabinoxylan-enriched white bread could be used in the management of carbohydrate absorption for those who usually do not consume wheat bread.

SUBJECTS AND METHODS

Subjects

Twenty-four normal-weight and normoglycemic healthy volunteers were recruited from institute staff and from among student faculty. Subjects with chronic diseases, current or previous gastrointestinal infections or in any drug treatment were excluded from the study. For every subject, body weight, height, BMI (Body Mass Index) and abdominal circumference were measured. Body weight was measured using a digital scale to the nearest 0.1 kg; height was measured with a wall-mounted stadiometer to the nearest 0.1 cm and abdominal circumference was measured with a non-stretchable measuring tape to the nearest 0.1 cm. Height and weight were recorded using standard techniques with minimal clothing and without shoes. BMI was calculated as body weight (kg)/height^2 (m^2). Body fat composition was assessed by bioelectrical impedance (Omron BF 302). The protocol for the study was approved by the Institutional Review board of the medical center and each patient gave written informed consent.

Experimental Design

The study was designed as a double-blind, crossover acute intervention. The subjects were randomized to eat either a white bread containing “traditional” refined wheat flour (Group 1; n = 12) or a white bread containing soluble fiber-enriched flour (Group 2; n = 12), after a 4-hour fasting.

The flour has been produced by a company (flour company Varvello & Co.) and breads were baked, the morning of test, by a professional baker. White bread with arabinoxylan and without arabinoxylan was similar in terms of color, shape, and flavor. They were isoenergic (1187 kJ) and of a similar total weight (100 g). Bread was made with flour (40%), water (60%), yeast (1.3%) and salt (1%).

The test was performed in a double-blind fashion so that both the subjects and the investigator were unaware of the consumed bread. Assessment of capillary blood glucose was performed by a glucometer (FreeStyleOptium Blood Glucose Monitoring System-Abbott) just before (time 0) and 30 minutes after (time 30) the bread meal.

Crossover

The study had a randomized, double-blind, within-subject crossover design (Figure 1). We decided to consider a crossover design since it could yield a more efficient comparison of treatments than a parallel design. Every patient received both bread types in a random order. With this type of study, every patient served as his or her own matched control. After one week (wash out period), the bread administration was repeated so that every subject alternatively received one “traditional” refined wheat flour and one soluble fiber-enriched flour bread serving. Such a protocol was followed in order to minimize the uncontrolled variability and to improve subject homogeneity.

Arabinoxylan-Rich Fiber Preparation

This bread was made with a soft wheat flour, obtained by a patented process by which the bran extracted from the grinding process was enzymatically hydrolyzed in order to separate the soluble fraction from the insoluble fiber. The resulting bran product was then reintegrated in the white flour.

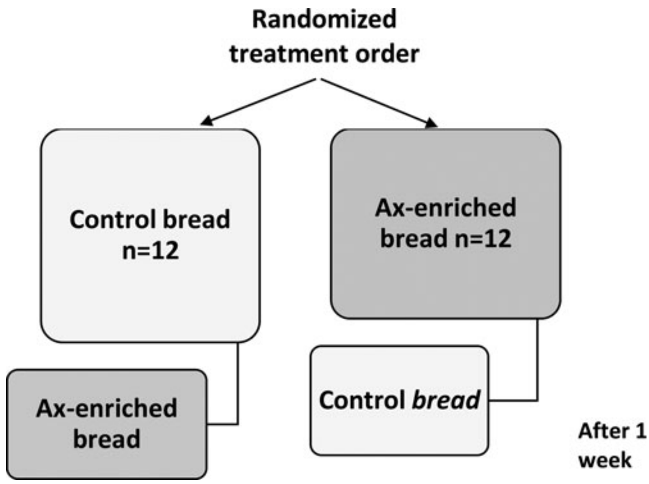

FIGURE 1. Crossover study design. Every patient received both bread types in a random order. After one week (wash out period), the bread administration was repeated so that every subject alternatively received one "traditional" refined wheat flour and one soluble fiber-enriched flour bread serving.

The compositions of arabinoxylan-enriched white bread and control white bread, used in this study, are shown in Table 1. The arabinoxylan-enriched bread contained 3.2% of dietary fiber, all soluble.

Statistics

The results were expressed as mean ± standard error (M ± SE). The sample size was estimated based on the available literature (Lu et al., 2000; Möhliget et al., 2005) showing that differences in the average postprandial blood glucose between types of bread made with different flours were within a 15–20% range. The comparison was performed by applying the Student's Test. A p value <0.05 was considered statistically significant. Analyses were performed by the Software MedCalc Ver. 13.

TABLE 1. Composition of control and arabinoxylan-enriched bread

	Control bread (100g)	Arabinoxylan-enriched bread (100g)
Energy (KJ)	1187	1187
Total protein (g)	8.1	9.93
Available carbohydrates (g)	64.7	55.86
Fat (g)	0.2	1.1
Dietary fibers (g)	1.7	3.2
Soluble fibers (g)	1.7	3.2
Insoluble fibers (g)	0.3	0.3
Free ferulic acid (mg)	0.125	0.165

Values are referred to 100g of bread made from flour nonenriched or enriched with fibers

TABLE 2. Baseline characteristics of participants. Values are means ± SE

Parameters	Normoglycemic subjects (n = 24)
Sex (n) F/M	18/6
Age (years) F/M	35.1 ± 13.1/33.0 ± 11.2
Body weight (kg) F/M	59.6 ± 5.2/77.2 ± 7.6
Height (mt) F/M	1.7 ± 0.1/1.8 ± 0.1
BMI (Kg/m^2) F/M	21.6 ± 2.3/24.2 ± 2.5
Body fat (%) F/M	23.7 ± 7.9/17.7 ± 7.3
Waist Circumferences (cm) F/M	81.5 ± 5.9/93.8 ± 6.6
Capillary blood glucose (mg/dL) F/M	85.7 ± 10.6/83.0 ± 7.4

Abbreviations: F, Female; M, Male; BMI, body mass index

RESULTS

The present study evaluated, in acute, the glycemic responses to two types of bread made with wheat refined flour and with wheat flour supplemented with soluble, enzymatically-hydrolyzed fiber bran, in 24 normal weight and normoglycemic healthy subjects. The anthropometric characteristics of the subjects are shown in Table 2. Fasting glucose was not different between the two groups. As expected, bread administration was associated with a sharp rise in blood glucose at 30 minutes. The peak of postprandial glucose response after soluble fiber-enriched bread was significantly lower than after bread without fiber (107 ± 4.59 mg/dL vs. 121 ± 5.23 mg/dL; $p < 0.05$). Arabinoxylans-enriched bread reduced capillary glucose by 20 percent. The mean glucose response to the tested bread types is shown in Figure 2.

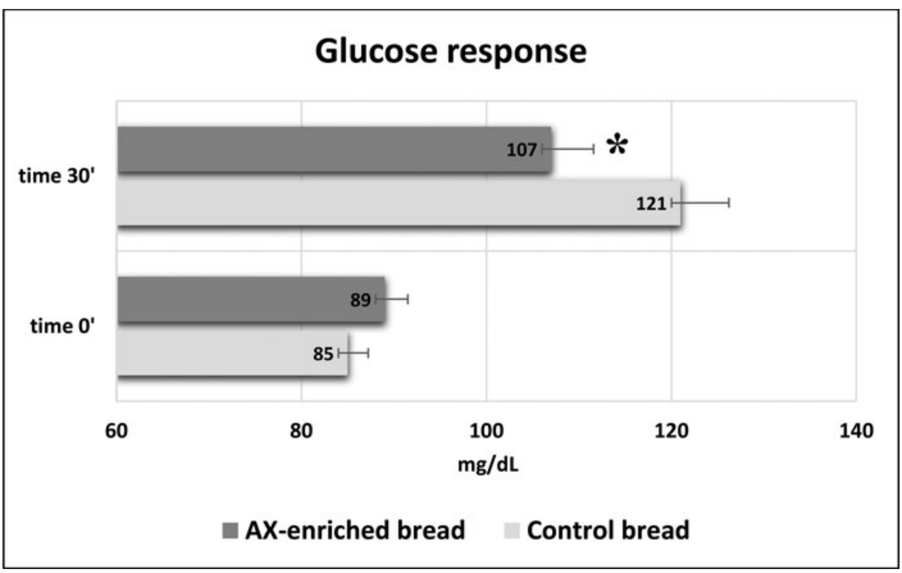

FIGURE 2. Effect of arabinoxylan (AX)-enriched bread on the postprandial glucose response over 30 min *vs.* a control bread in normoglycemic subjects. Values are expressed as mean (±SD).*Significantly (p < 0.05) different from the control wheat flour bread.

Sensory evaluation

No significant differences were observed by the study subjects between the two bread formulations in terms of flavor, color, texture, and overall quality.

DISCUSSION

The intake of a single bread portion, made with two different types of wheat flour, refined and enriched in soluble fiber bran showed a markedly different postprandial glucose profile in healthy normoglycemic volunteers. The addition of 3.2 g arabinoxylans-enriched fibers to bread significantly reduced postprandial glucose in healthy persons. Furthermore, white bread containing soluble fiber was shown to have palatability equal to that of whole-wheat bread.

The mechanisms by which arabinoxylans-enriched fibers reduced the postprandial glucose response are not yet clear. The viscosity-altering behavior of these soluble fibers within the small intestine must account for some of these effects, however, fibers also appear to alter the structure of the foods and hence the accessibility of the starch granules to the amylase enzymes (Brennan et al., 1996; Tudorica et al., 2002).Viscosity, or gel-forming capacity, is a physicochemical property associated with dietary fibers, especially soluble dietary fibers (Dikeman and Fahey, 2006). This phenomenon is related to their ability to absorb water and form a gelatinous mass, increasing the viscosity of the contents of the gastrointestinal tract. This may explain the delayed gastric emptying often associated with the ingestion of fibers. There are some indications that some viscous fibers delay gastric emptying, and that slowly digested starch and resistant starch increase satiety. In addition, dietary fiber was associated with insulin sensitivity, and improved the ability to delay the absorption of carbohydrates and secrete insulin adequately to overcome insulin resistance, resulting in lower postprandial blood glucose and insulin levels (Montonen et al., 2005; Liese et al., 2003).

Many byproducts of the food industry are rich in fiber. In food processing operations, incorporation of soluble fiber in food products is more beneficial as it provides viscosity, the ability to form gels and/or act as emulsifiers, as compared to insoluble fiber. These fiber-rich byproducts can be incorporated in food products as inexpensive, non-caloric bulking agents. These can be used for partial replacement of flour and or fat and enhance the water and oil retention to improve the emulsion and or oxidative stabilities. However, the maximum level of fiber incorporation in different food products varies, because it may cause undesirable changes in the color and texture of foods. This study has demonstrated that the addition of as little as 3.2 g arabinoxylans-rich fiber to bread is sufficient to lowered postprandial glucose. This effective concentration can be added to obtain a white bread flour. In perspective, such a finding may be very important in a clinical scenario in which it has been reported a remarkably poor adherence to nutritional recommendations for the treatment of certain diseases such as diabetes, obesity and metabolic syndrome. Such an issue is mainly due to difficulties in initiating and maintaining lifestyle changes (Sofi et al., 2006; Rivellese et al., 2008) involving dietary habits and culinary traditions (Vaccaro, 2013). Total fiber consumption remains low compared to the nutritional recommendations. A nutrition education strategy that takes into account the dietary habits and traditions could be a "winning move" in achieving a sizable improvement in the adherence to dietary recommendations. The addition of a highly bioavailable bran extract that is rich in soluble fibers (arabinoxylans) to a white wheat flour may allow the production of a bread that is very similar to the commonly used white bread. This may improve the patient compliance in consuming a bread that shares many of the beneficial properties of the wheat bread.

In conclusion, the present study showed beneficial effects of arabinoxylans-enriched bread on the postprandial glycemic response in healthy persons. Moreover, these results may suggest the potential positive role of fortified foods not only in the general population but also in the setting of metabolic syndrome. These encouraging preliminary results should stimulate the need of extending the use of soluble fiber bran-enriched bread in a larger population, for a longer period of treatment, and in patients prone to metabolic disease.

ACKNOWLEDGMENTS

We thank Farine Varvello & Co. S.r.l., Piazza Castello 2, 20121 Milan, Italy for the supply of wheat refined flour and integrated fiber bran Integralbianco® used for the production of bread.

Declaration of Interest: The study was conducted with the financial support of the Varvello Company. The authors assure that the methods, results, and data depicted in this paper truly reflect the procedures used and raw data collected during the studies. All authors are employed by Department of Internal Medicine, IRCCS Policlinico San Matteo Foundation, University of Pavia, Pavia, Italy. The authors alone are responsible for the content and writing of this paper.

ABOUT THE AUTHORS

Anna Giulia Falchi and Illaria Grecchi performed experiments and provided critical data, and provided patient samples and collected data. **Chiara Muggia** provided patient samples and collected data. **Giuseppina Palladini** conceived and designed experiments, analyzed data, and wrote the manuscript. **Stefano Perlini** conceived and designed experiments, and supervised the research.

REFERENCES

Aller R, de Luis DA, Izaola O, La Calle F, del Olmo L, Fernandez L, Arranz T, Hernandez JM. Effect of soluble fiber intake in lipid and glucose levels in healthy subjects: a randomized clinical trial. Diabetes Res Clin Pract. 2004;65(1):7–11.

Bartłomiej S, Justyna RK, Ewa N. Bioactive compounds in cereal grains—occurrence, structure, technological significance and nutritional benefits—a review. Food Sci Technol Int. 2012;18(6):559–68.

Brennan CS. Dietary fibre, glycaemic response and diabetes. Mol Nutr Food Res. 2005;49(6):560–70.

Brennan CS, Blake DE, Ellis PR, Schofield JD. Effects of guar galactomannan on wheat bread microstructure and on the in vitro and in vivo digestibility of starch in bread. J. Cereal. Sci. 1996;24:151–60.

Dikeman CL, Fahey GC. Viscosity as related to dietary fiber: a review. Crit Rev Food Sci Nutr. 2006;46(8):649–63.

Gerber M, Hoffman R. The Mediterranean diet: health, science and society. Br J Nutr. 2015;113 Suppl2:S4–10.

Kunyanga CN, Imungi JK, Okoth MW, Biesalski HK, Vadivel V. Antioxidant and type 2 diabetes related functional properties of phytic acid extract from Kenyan local food ingredients: effects of traditional processing methods. Ecol Food Nutr. 2011;50(5):452–471.

Lattimer JM, Haub MD. Dietary fiber and its Components on Metabolic Health. Nutrients. 2010;2(12):1266–1289.

Liese AD, Roach AK, Sparks KC, et al. Whole-grain intake and insulin sensitivity: the Insulin Resistance Atherosclerosis Study. Am J Clin Nutr. 2003;78:965–971.

Lu ZX, Walker KZ, Muir JG, Mascara T, O'Dea K. Arabinoxylan fiber, a byproduct of wheat flour processing, reduces the postprandial glucose response in normoglycemic subjects. Am J Clin Nutr. 2000;71(5):1123–1128.

Meyer KA, Kushi LH, Jacobs DR Jr, Slavin J, Sellers TA, Folsom AR. Carbohydrates, dietary fiber, and incident type 2 diabetes in older women. Am J Clin Nutr. 2000;71(4):921–930.

Möhlig M, Koebnick C, Weickert MO, Lueder W, Otto B, Steineger J, Twilfer M, Meuser F, Pfeiffer AFH, Zunft HJ. Arabinoxylan-enriched Meal Increases Serum Ghrelin Levels in Healthy Human. Horm Metab Res. 2005;37(5):303–308.

Montonen J, Jarvinen R, Heliovaara M, et al. Food consumption and the incidence of type II diabetes mellitus. Eur J Clin Nutr. 2005;59:441–448.

Ou S, Kwok K, Li Y, Fu L. In vitro study of possible role of dietary fiber in lowering postprandial serum glucose. J Agric Food Chem. 2001;49(2):1026–1029.

Rivellese AA, Boemi M, Cavalot F, Costagliola L, De Feo P, Miccoli R, Patti L, Trovati M, Vaccaro O, Zavaroni I. Mind.it Study Group Dietary habits in type II diabetes mellitus: how is adherence to dietary recommendations? Eur J Clin Nutr. 2008;62(6):660–664.

Rudkowska I. Functional foods for health:Focus on diabetes. Maturitas. 2009;62(3):263–269.

Seal CJ, Brownlee IA. Whole-grain foods and chronic disease: Evidence from epidemiological and intervention studies. Proc Nutr Soc. 2015;11(6):1–7.

Sofi F, Innocenti G, Dini C, Masi L, Battistini NC, Brandi ML, Rotella CM, Gensini GF, Abbate R, Surrenti C, Casini A. Low adherence of a clinically healthy Italian population to nutritional recommendations for primary prevention of chronic diseases. Nutr Metab Cardiovasc Dis. 2006;16(6):436–444.

Tudorica CM, Kuri V, Brennan CS. Nutritional and physicochemical characteristics of dietary fiber enriched pasta. J. Agric. Food Chem. 2002;50:347-56.

Vaccaro O. Gruppo di Studio TOSCA. IT Abitudinialimentarideipazienti con diabete di tipo 2:Impatto delle tradizioni gastronomiche regionali. G It Diabetol Metab. 2013;33:135–140.

Venn BJ, Mann JI. Cereal grains, legumes and diabetes. Eur J Clin Nutr. 2004;58(11):1443–1461.

Wang PY, Fang YC, Gao ZH, Zhang C, Xie SY. Higher intake of fruits, vegetables or their fiber reduces the risk of type 2 diabetes: A meta-analysis. Diabetes Investig. 2016;7:56–69.