

Metabolic Responses to Venezuelan Corn Meal and Rice Bran Supplemented *Arepas* (Breads)

Mercedes Schnell,^{1,2} Emperatriz Pacheco de Delahaye,³ and Yudistira Mezones¹

ABSTRACT

Cereal Chem. 82(1):77–80

The metabolic responses to South American foods remain to be determined. Using glycemic index (GI) and insulinemic index (II) values as references for therapeutic potential of foods, this study investigated the glucose responses to a typical Venezuelan corn bread (*arepa*) and to an *arepa* supplemented with rice bran. Adding rice bran to the bread increased the content of resistant starch and dietary fiber measured as total, soluble, and insoluble dietary fiber. It also increased the protein content of the *arepa*. Three meals, white wheat bread, 100% corn meal *arepa*, and an *arepa* supplemented with 20% rice bran, were administered within a one-week period. Available starch in the foods was determined to provide 50 g of available carbohydrate per meal. To calculate the indices,

bread was used as the reference. The GI and II of the two *arepa* meals were significantly smaller than the GI and II of white wheat bread, although the differences between the two types of *arepas* were not significant. It is concluded that Venezuelan *arepas* (corn meal bread) may have potential health benefits and that the presence of 20% rice bran in the *arepa* meal did not produce a significant improvement in the glucose response. Due to the presence of antioxidant elements in the supplemented *arepa* and its higher protein, dietary fiber, and resistant starch content, it may have a potential preventive effect against the development of other pathologies.

Arepas are staple Venezuelan food made from commercially produced, precooked, white corn meal flour obtained by partially cooking dehusked degerminated corn grain (Garrido et al 1990). Corn has a low nutritional value, as indicated by its low nitrogen content. Researchers have tried to increase the nutritive value by partly substituting corn flour for amaranth flour, which rendered a product with a higher protein energy ratio (PER) and available lysine (Pacheco y Portillo 1990).

Rice bran is a subproduct obtained from the external wall of dehusked rice (Carroll 1990). During grinding, lipases contained in rice oil are activated, producing rancidity of the bran. Using stabilization techniques such as chemical enzyme inactivation or thermal treatment of bran makes possible the production of a stabilized rice bran with a nut flavor. Stabilized rice bran contains 15–20% lipids, with a major proportion of highly unsaturated fatty acids, 12–18% protein, and 23–28% dietary fiber. When defatted, the dietary fiber content increases to 38–47% (Don et al 1999; Pacheco et al 2002) and the bran also shows a high content of vitamin E and group B vitamins. Probably the most important nutritional fact about this bran is that it contains γ -oryzanol, which has been described as a natural antioxidant that reduces plasma cholesterol levels by inhibiting HMG-CoA reductase (Gerhart and Gallo 1998; Serra and Barrera 1998).

In recent years, research indicated that high glycemic response to starches may be a risk factor for the development of diabetes, atherosclerosis, and obesity (Anderson et al 1980, 1982; Behall et al 1989; Brand et al 1991). The glycemic index (GI) is a concept for ranking carbohydrate foods based on their effects on postprandial glycemic response (Jenkins et al 1981, 1994). The studies of bread have shown a very consistent effect regarding glycemic response (Wolever et al 1990; Liljeberg and Bjorck 1994); therefore white bread has been recommended as the reference food. When bread is used as a reference, the GI range of different food stuffs is 20–120%. This is due to different rates of digestion and absorption of the carbohydrates (Blackburn and Johnson 1983; Blackburn et al 1994). Low GI foods are those that release

glucose to the blood at a slower rate. The therapeutic potential of low GI foods is not only for diabetes (Toeller et al 1999) but also for dyslipidemia (Glore et al 1994; Anderson 2003; Brynes et al 2003) and prevention of noninsulin-dependent diabetes mellitus (Jenkins et al 1987; Livesey 2001; Scheppach et al 2001). Long-term studies suggest that a diet rich in low GI food items improves metabolic parameters in rats (Lerer-Metzger et al 1996) and in healthy and diabetic subjects (Anderson 2003; Brynes et al 2003; Murtaugh et al 2003) and is considered in the recommendations from diabetic societies (Toeller et al 1999). GI values for foods prepared and eaten in South America have to be determined.

Most common starchy foods consumed in the Western diet such as bread, breakfast cereals, and potato products have high GI values (Miller and Lobbezoo 1994; Foster-Powell and Brand 1995) because the starch in most of these foods is rapidly digested. A high dietary fiber content of a food does not necessarily provoke a low GI of the meal unless the fiber is part of the botanical structure of the food (Liljeberg and Bjorck 1994). The nutritional interest on dietary fiber coincides with industrially recovered fiber, hence products that were discarded are now used in human nutrition. Rice is the second largest product grown in Venezuela. Rice bran is a by-product of rice polishing and a source of protein (12–16%), lipids (15–20%), dietary fiber (22–28%), carbohydrates (35–52%), vitamins, and minerals. The antioxidant properties of rice bran are well known (Kahlon et al 1996). Stabilized rice bran contains more tocopherols and tocotrienols than other natural food sources. It is also rich in vitamin B, minerals, and essential fatty acids. During grinding of rice bran, lipase activation must be prevented by low-heat stabilization to maintain its functional properties. After stabilization, rice bran has a shelf life of one year. In Venezuela, one of the most common food items is *arepa*, a special corn bread made with precooked corn flour that substitutes white bread. To our knowledge the GI of *arepas* made with regular corn havenot been reported. This report shows the GI and II of corn meal *arepa* and the effect of rice bran addition on these indices.

MATERIALS AND METHODS

Precooked white corn meal flour and rice bran were provided by Industria PROMASA C.A. Rice bran was stabilized using dehydration in a double drum at 121°C followed by freezing until it was mixed with corn meal to make the *arepas*.

¹ Instituto de Medicina Experimental, Facultad de Medicina. Universidad Central de Venezuela, Caracas, Venezuela.

² Corresponding author. Phone: 58-212-7310669. Fax: 58-212-7317306. E-mail: ugliive@cantv.net

³ Instituto de Química y Tecnología. Facultad de Agronomía. Universidad Central de Venezuela, Caracas, Venezuela.

Chemical Composition

The protein (N × 6.25) fat, ash, and reducing sugars were estimated according to the methods described by AOAC (1990) and were reported as the arithmetic mean ± the standard deviation of five observations. Dietary fiber was measured using a kit (Sigma) based on the method described by Prosky et al (1998) and accepted by AOAC (2000). The method measures soluble and insoluble fiber and adds these two values to obtain the total. Determination of available starch in white wheat bread (WWB), *arepa*, and *arepa* with rice bran was made using the method developed by Holm et al (1986) modified by Tovar et al (1990). Resistant starch was measured as in Goni et al (1996) and Saura-Calixto et al (1993).

The hydrolysis of corn meal starch *in vitro* was done as reported by Holm et al (1983). The sample was suspended in phosphate buffer at pH 6.9 and was incubated with pork pancreatic D-amylase (Sigma) (≈200 μg⁻¹ of starch, 37°C). Aliquots (1 mL) were withdrawn at specific time intervals and centrifuged for 5 min at 3,000 × g. A factor of 0.95 was used for the conversion of maltose equivalents to starch. *In vitro* starch hydrolysis curves of the corn meal flours are shown in Fig. 1.

Subjects

Ten normal medical students gave written consent to participate in the study according to the Helsinki ethical guidelines (Helsinki 1997). Body mass index (BMI), cholesterol, triglycerides, glycemia, and blood smear of subjects before entering the protocol were normal. Use of any medication was an exclusion criteria. Approval of the study was given by the ethical committee of the Instituto de Medicina Experimental at the Universidad Central de Venezuela.

Test Meals

Two types of corn meal *arepa* were prepared by the laboratory staff using traditional methods. A mixture of corn meal or corn meal supplemented with 20% rice bran and water (140.44 g and 150.24 g/250 mL) was prepared, followed by kneading for 5 min

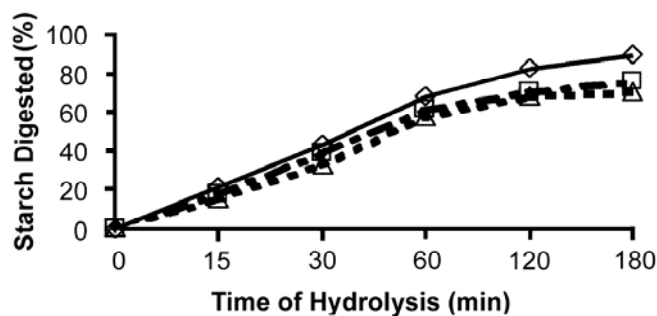


Fig. 1. Time course of *in vitro* starch hydrolysis of two corn-based starchy test meals [(□) *arepa*; (△) rice bran *arepa*] and white bread (◇) used as reference.

TABLE I
Composition of Two Corn Bread *Arepas* Determined by Standard Chemical Analysis (g/100 g)^a

	Control <i>Arepa</i>	Rice Bran <i>Arepa</i>
Humidity	60.50 ± 0.8	61.0 ± 0.55
Ash	0.43 ± 0.02	0.95 ± 0.04
Available starch	35.30 ± 0.88	32.16 ± 0.75
Resistant starch	1.65 ± 0.05	1.86 ± 0.02
Reducing sugars	0.06 ± 0.005	0.18 ± 0.006
Protein	3.0 ± 0.20	3.60 ± 0.20
Lipids	0.46 ± 0.02	1.12 ± 0.05
Total dietary fiber	1.68 ± 0.10	2.79 ± 0.21
Soluble dietary fiber	0.42 ± 0.05	0.7 ± 0.02
Insoluble dietary fiber	1.26 ± 0.04	2.09 ± 0.04

^a Values are mean ± SEM.

until a soft dough was achieved. Round breads of this mixture were cooked in a special toaster for 7 min and allowed to cool for 3 min. The crust of the *arepa* was discarded and the rest was used as the test meal. Composition of the *arepas* is shown in Table I.

The test meals were fed in random order to provide 50 g of available carbohydrate and served with 250 mL of water. The meals were served as breakfasts in random order on three separate occasions, after a night fast, with at least a one-week interval. The subjects were asked to eat the meal in a 10-min period. Blood samples from the antecubital vein were taken before the meal (0 min) and at 30, 45, 60, 90, and 120 min after the meals for glucose and insulin analysis.

Glucose and Insulin Indices

Blood glucose concentration was determined with a glucose oxidase peroxidase reagent (Trinder 1969) and plasma insulin was determined by radio immunoassay (Marschner 1974). Glycemic indices (GI) were calculated from the 120-min incremental postprandial blood glucose using white wheat bread (WWB) as a reference (GI and II of bread = 100) (Jenkins et al 1981, 1984; Wolever 1991 et al).

To calculate the GI areas under the glucose, increment curves were obtained using the computerized method developed by T. M. S. Wolever (*personal communication*). Indices were drawn from the percent relationship between the area of blood glucose increment curve after the test food and the area of the glycemic response curve after the reference meal. The insulinemic indices were calculated in a manner similar to that of the insulin response curves (Bornet et al 1987). Two-way ANOVA was used to compare differences in blood glucose and insulin responses between the test meals. Paired Student's *t*-test (two-tailed) was used to assess statistical significance. Results were expressed as means ± SEM.

RESULTS

Chemical analysis of the *arepas* (Table I) shows that substituting precooked corn meal flour with 20% stabilized rice bran increases the protein, unsaturated fat, soluble and insoluble dietary fiber, and resistant starch content of the corn bread. These results point in the direction of a slow glucose absorption food. Food items rich in dietary fiber and resistant starch have been demonstrated as adequate for improving health (Scheppach et al 2001). More specific research should be conducted to prove this point.

Figure 2 presents the mean increase of glucose responses to the test meals. There are no significant differences between the responses to the *arepa* meals. The bread meal (WWB) used as a reference provoked a higher response during the first 30 min. But no major differences were noted at the late postprandial phase.

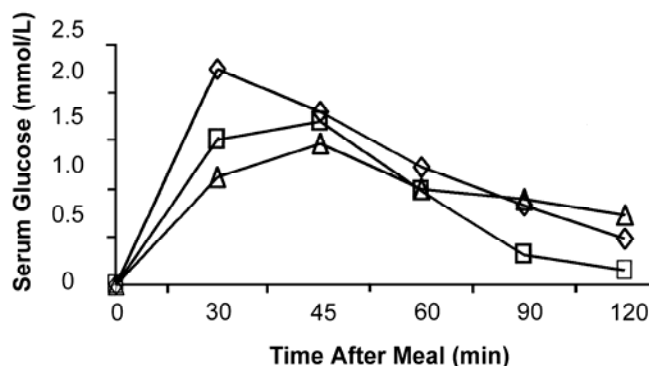


Fig. 2. Mean increase in plasma glucose above baseline in healthy subjects after consumption of the three starchy test foods [(◇) white bread, (□) *arepa*, (△) rice bran *arepa*]. Mean values were lower for the *arepa* meals without reaching statistically significant differences.

Figure 3 shows a different trend in the mean insulinemic responses to the test meals; that is, the insulin response curve generated by bread consumption is higher than the response generated after both *arepa* meals over the total experimental period. This difference is significant ($P < 0.05$) for the first postprandial 60 min.

There were no differences between the areas of the curves after *arepa* consumption. Table II shows that the glycemic and insulinemic indices of the *arepa* meals were significantly lower than that of the reference meal ($P < 0.05$). No differences were noted between the GI and II of the *arepa* meals.

DISCUSSION

In early studies, it was shown that including dietary fiber into bread flattened the postprandial glucose and insulin response curves. The beneficial effects of dietary fiber have been clearly supported by different authors (Anderson et al 1980, 1992, 2000; Jenkins et al 1978, 1987, 2000).

This has been attributed to a number of factors (Truswell 1992), including the amylose-to-amylopectin ratio. Several studies using cereals have shown that a higher amylose content is accompanied by a lower response (Goddard et al 1984; Behall et al 1989; Amelsovoort and Weststrate 1992; Brand Miller 1992). The digestibility of the starch contained in the food has also been related to the glycemic response (Rao 1970; Panlasigui et al 1991). The cause for reduced enzyme availability could be due to recrystallization of amylose, its interaction with lipids (Holm et al 1983; Berry 1986), or the production of resistant starch (Liljeberg et al 1992; Grandfeldt et al 1993, 1994). Jenkins et al (1987) supported this possibility when they reported an inverse relationship between glucose response and nondigested starch present in the meal.

The meals of corn *arepas* produced significantly lower metabolic response than the bread reference meal. Similar low responses for *arepas* were reported previously by Grandfeldt et al (1995) using high-amylose corn *arepas*. The decreased response appears to be related to a decreased rate of enzymatic digestion of the *arepas* (Fig. 1). This could be an effect of the conditions used to prepare the corn flour because there are no significant differences between the metabolic responses of the 100% corn *arepa* meal and the *arepa* meal with 20% rice bran. Holm et al (1983) showed that the formation of amylose lipid complexes diminishes

the hydrolysis rate of starch. But in this case, the amount of fat present in the corn flour is very small, therefore a 50% decrease of the response is very unlikely due to formation of these complexes. In this study, all meals provided 50 g of available starch. The amount of total starch present in these meals was different due to the presence of resistant starch. The resistant starch present in the corn flour could be partially responsible for the diminished absorption. Grandfeldt et al (1993) showed a good correlation between the total amount of starch that passed the rat intestine and the presence of resistant starch in fiber residues. In this study, the *arepa* meals provided a higher dietary fiber content; the bran-supplemented *arepas* had a higher proportion of insoluble dietary fiber. It is well known that soluble dietary fiber (Jenkins 1978) and resistant starch may represent difficulty in starch hydrolysis and glucose absorption. Dietary fiber and resistant starch diminish the relationship of enzyme to substrate, impair starch hydrolysis, and increase the resistance to diffusion of the hydrolysis products. The fact that the glycemic and insulinemic indices of the *arepas* were smaller than the indices of the reference food coincides with the higher resistant starch and dietary fiber content of the *arepas*.

The *in vitro* amylolysis data supports the suggestion that the corn meal *arepas* have a decreased rate of enzymic digestion, possibly due to the corn meal processing because the differences in the rate of digestion between the two types of *arepas* are not significant and the amount of potentially available starch was the same (50 g) in all meals.

We concluded that the *arepas* of either corn meal or corn meal supplemented with rice bran gave low metabolic responses that could not be explained by differences in the amount of available starch. The corn meal processing and the presence of dietary fiber (rice bran in the supplemented *arepas*) could explain the low glycemic index obtained in comparison with the glycemic index of white bread.

ACKNOWLEDGMENTS

This study was funded by Consejo de Desarrollo Científico y Humanístico, Project CDCH PG-01-37-4447-1999 and by the research department of Promesa, División de Alimentos de Industrias Polar, Venezuela.

LITERATURE CITED

- Anderson, J. W. 2003. Whole grains protect against atherosclerotic cardiovascular disease. *Proc. Nutr. Soc.* 62:135-142.
- Anderson, J. W., Chen, W. J. L., Sieling, E. 1980. Hypolipidemic effects of high-carbohydrate, high fiber diets. *Metabolism* 29:551-557.
- Anderson, J. W., Garrity, T. F., Wood, C. L., Whitis, S. E., Smith, B. M., and Oeltgen, P. R. 1992. Prospective, randomised, controlled comparison of the effects of low-fat, low-fat plus high-fiber diets on serum lipid concentrations. *Am. J. Clin. Nutr.* 56:887-94.
- Anderson, J. W., Allgood, L. D., Lawrence, A., Altringer, L. A., Jerdack, G. R., Hegenhold, D. A., and Morel, J. G. 2000. Cholesterol-lowering effects of psyllium intake adjunctive to diet therapy in men and women with hypercholesterolaemia: Meta-analysis of 8 controlled trials. *Am. J. Clin. Nutr.* 71:472-479.
- Asp, N. G. 1996. Dietary carbohydrates: Classification by chemistry and physiology. *Food Chem.* 57:9-14.
- Assoc. Official Analytical Chemists. 2000. Method 991.43 for soluble and insoluble dietary fibre. AOAC Int.: Washington, DC.
- Behall, K. M., Scholfield, D. J., Yuhaniak, L., and Canary, J. 1989. Diets containing high amylose vs. amylopectin starch: Effects on metabolic variables in human subjects. *Am. J. Clin. Nutr.* 49:337-344.
- Berry, C. S. 1986. Resistant starch: Formation and measurement of starch that survives exhaustive digestion with amylolytic enzymes during the determination of dietary fibre. *J. Cereal Sci.* 4:301-314.
- Blackburn, N. A., and Johnson, I. I. 1983. The influence of guar gum on the movement of insulin, glucose and fluid in rat intestine during perfusion *in vivo*. *Pfluegers Archiv.* 397:144-148.
- Blackburn, N. A., Redfern, J. S., Jarjis, H., Holgate, A. M., Hanning, L., Scarpello, J. H. B., Johnson, I. I., and Read, N. W. 1984. The mech-

TABLE II
Glycemic and Insulinemic Indices of Starchy Foods^a

	Glycemic Index (%)	Insulinemic Index (%)
White bread	100	100
Control <i>arepa</i>	77.19 ± 3.0*	55.44 ± 2.1*
Rice bran <i>arepa</i>	85.96 ± 4.2*	56.59 ± 2.9*

^a Values are mean ± SEM; *, difference from white bread ($P < 0.05$).

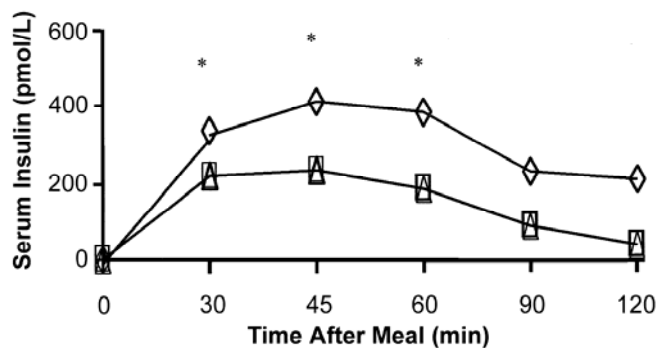


Fig. 3. Mean increase in plasma insulin above baseline in healthy subjects after consumption of the three starchy test foods [(◇) white bread, (□) *arepa*, (△) rice bran *arepa*]. Mean values were significantly lower after the two *arepa* meals than after white bread (*, $P < 0.05$).

- anism of action of guar gum in improving glucose tolerance in man. *Clin. Sci.* 66:329-336.
- Bornet, F. R. J., Costagliola, D., Rizkalla, S. W., Blayo, A., Fontvieille, A.-M., Haardt, M. J., Letanoux, M., Tchobroutsky, G., and Slama, G. 1987. Insulinemic and glycemic indexes of six starch-rich foods alone and mixed in a meal by type 2 diabetics. *Am. J. Clin. Nutr.* 45:588-595.
- Brand, J., Colagiuri, S., Crossman, S., Allen, A., Roberts, D., and Truswell, A. S. 1991. Low glycemic index carbohydrate foods improve long term glycemic control in NIDDM. *Diabetes Care* 14:95-101.
- Brynes, A. E., Edwards, C. M., Ghatei, M. A., Dornhorst, A., Morgan, L. M., Bloom, S. R., and Frost, G. S. 2003. A randomised four-intervention crossover study investigating the effect of carbohydrates on daytime profiles of insulin, glucose, non-esterified fatty acids and triacylglycerols in middle aged men. *Brit. J. Nutr.* 89:207-218.
- Carroll, L. 1990. Functional properties and applications of stabilized rice bran in bakery products. *Food Technol.* April:74-76.
- Don, M., and Zhang, F. 1999. Use of rice bran oil foods. *Food Technol.* 53:50-53.
- Ellis, P. R., Apling, E. C., Leeds, A. R., and Bolster, N. R. 1981. Guar bread: Acceptability and efficacy combined. Studies on blood glucose, serum insulin and satiety in normal subjects. *Brit. J. Nutr.* 46:267-276.
- Foster-Powell, K., and Brand Miller, J. 1995. International tables of glycemic index. *Am. J. Clin. Nutr.* 62:871-875, 893S.
- Garrido, R., Villavicencio, C., and Lola de Plaza y Chavez, J. 1990. Evaluación de la sustitución parcial de harina precocida por harina de arroz en la elaboración de arepas. *Arch. Latin de Nutri.* Vol XL (Dec. 4).
- Gerhardt, A. L., and Gallo, N. B. 1998. Full-fat rice bran and oat bran similarly reduce hypercholesterolemia in humans. *J. Nutr.* 128:865-869.
- Glore, S. R., Van Treck, D., Knehans, A. W., and Guild, M. 1994. Soluble fiber and serum lipids: A literature review. *J. Am. Dietetic Assoc.* 94:425-436.
- Goni, I., Garcia-Diaz, L., Manas, E., and Saura-Calixto, F. 1996. Analysis of resistant starch. A method for foods and food products. *Food Chem.* 56:445-449.
- Granfeldt, Y., Drews, A., and Bjorck, I. 1993. Starch bioavailability in arepas made from ordinary or high amylose corn: Concentration and gastrointestinal fate of resistant starch in rats. *J. Nutr.* 123:1676-1684.
- Granfeldt, Y., Liljeberg, H., and Drews, A. 1994. Glucose and insulin responses to barley products. Influence of food structure and amylose-amylopectin ratio. *Am. J. Clin. Nutr.* 59:1075-1082.
- Granfeldt, Y., Drews, A., and Bjorck, I. 1995. Arepas made from high amylose corn flour produce favorably low glucose and insulin responses in healthy humans. *J. Nutr.* 125:459-465.
- Holm, J., Bjorck, I., Ostrowska, S., Eliasson, A.-C., Asp, N.-G., Larsson, K., and Lundquist, L. 1983. Digestibility of amylose-lipid complexes in vitro and in vivo. *Starch* 35:294-297.
- Holm, J., Bjorck, I., Drews, A., and Asp, N.-G. 1986. A rapid method for the analysis of starch. *Starch* 38:224-226.
- Jenkins, D. J. A., Wolever, T. M. S., Leeds, A. R., Gassull, M. A., Haisman, P., Dilawari, J., Goff, D. V., Metz, G. I., and Alberti, K. G. M. M. 1978. Dietary fibres, fibre analogues and glucose tolerance: The importance of viscosity. *Brit. Med. J.* 1:1392-1394.
- Jenkins, D. J. A., Wolever, T. M., Taylor, R. H., Barker, H. M., Fielden, H., Baldwin, J. M., Bowling, A. C., Newman, H. C., Jenkins, A. L., and Golf, D. V. 1981. Glycemic index of foods: A physiological basis for carbohydrate exchange. *Am. J. Clin. Nutr.* 34:362-366.
- Jenkins, D. J. A., Wolever, T. M. S., Kalmusky, J., Giudici, S., Giordano, C., Patten, R., Wong, G. S., Bird, J. N., Hall, M., Buckley, G., Csima, A., and Little, J. A. 1987. Low-glycaemic index diet in hyperlipidemia: Use of traditional starchy foods. *Am. J. Clin. Nutr.* 46:66-71.
- Jenkins, D. J. A., Wolever, T. M. S., Jenkins, A. L., Josse, R. G., and Wong, G. S. 1994. The glycaemic response to carbohydrate foods. *Lancet* II:381-391.
- Jenkins, J. D. A., Kendall, C. W. C., and Vuksan, V. 2000. Viscous fibers, health claims and strategies to reduce cardiovascular disease risk. *Am. J. Clin. Nutr.* 71:401-402.
- Kahlon, T. S., Chow, F. I., Chiu, M. M., Hudson, C. A., and Sayre, R. N. 1996. Cholesterol-lowering by rice bran and rice bran oil unsaponifiable matter in hamsters. *Cereal Chem.* 73:69-74.
- Kuo, P. T., and Bassett, D. R. 1965. Dietary sugar in the production of hypertriglyceridemia. *Ann. Internal Med.* 62:1199-1212.
- Lerer-Metzger, M., Rizkalla, S. W., Luo, J., Champ, M., Kabir, M., Bruzzo, F., Bornet, F., and Slama, G. 1996. Effects of long-term low-glycaemic index starchy food on plasma glucose and lipid concentrations and adipose tissue cellularity in normal and diabetic rats. *Brit. J. Nutr.* 75:723-732.
- Liljeberg, H., and Bjorck, L. 1994. Bioavailability of starch in bread products. Postprandial glucose and insulin responses in healthy subjects and in vitro resistant starch content. *Eur. J. Clin. Nutr.* 48:151-163.
- Liljeberg, H., Granfeldt, Y., and Bjorck, L. 1992. Metabolic responses to starch in bread containing intact kernels versus milled flour. *Eur. J. Clin. Nutr.* 46:561-575.
- Liljeberg, H. G. M., Akerberg, A. K. E., and Björck, I. M. E. 1999. Effect of the glycemic index and content of indigestible carbohydrates of cereal based breakfast meals on glucose tolerance at lunch in healthy subjects. *Am. J. Clin. Nutr.* 69:647-655.
- Livesey, G. 2001. Tolerance of low digestible carbohydrates: A general overview. *Brit. J. Nutr.* 85:S7-S16.
- Marschner, L. 1974. Group experiments on the radioimmunological insulin determination. *Hormone Metab. Res.* 6:293-296.
- Miller, J. B. C., and Lobbezoo, L. 1994. Replacement of starch with sucrose in a high glycaemic index breakfast cereal lowers glycaemic and insulin responses. *Eur. J. Clin. Nutr.* 48:749-752.
- Murtaugh, M. A., Jacobs, D. R., Jr., Jacob, L., Steffen, L. M., and Marquart, L. 2003. Epidemiological support for the protection of whole grain against diabetes. *Proc. Nutr. Soc.* 62:143-149.
- Panlasigui, L. N., Thompson, L. U., Juliano, B. O., Perez, C. M., Yiu, S. H., and Greenberg, G. R. 1991. Rice varieties with similar amylose content differ in starch digestibility and glycemic response in humans. *Am. J. Clin. Nutr.* 54:871-877.
- Rao, S. P. 1970. Studies on the nature of carbohydrate moiety in high yielding varieties of rice. *J. Nutr.* 101:879-884.
- Riccardi, G., and Rivellesse, A. A. 1991. Effects of dietary fiber and carbohydrate on glucose and lipoprotein metabolism in diabetic patients. *Diabetes Care* 14:1115-1125.
- Saura-Calixto, F., Goni, L., Bravo, L., and Manas, E. 1993. Resistant starch in foods: Modified method for dietary fibre residues. *J. Food Sci.* 58:642-643.
- Scheppach, W., Luehrs, H., and Menzel, T. 2001. Beneficial health effects of low-digestible carbohydrate consumption. *Brit. J. Nutr.* 85S:823-830.
- Schwartz, S. E., and Levine, G. D. 1980. Effects of dietary fiber on intestinal glucose absorption and glucose tolerance in rats. *Gastroenterology* 79:833-836.
- Toeller, M., Buyken, A. E., Heitkamp, G., de Pergola, G., Giorgino, F., and Fuller, J. H. 1999. Fiber intake, serum cholesterol levels, and cardiovascular disease in European individuals with type I diabetes. EURO-DIAB IDDM complications study group. *Diabetes Care* 22S:821-828.
- Tovar, J., Bjorck, I., and Asp, N.-G. 1990. Starch content and amylolysis rate in precooked legume flours. *J. Agric. Food Chem.* 38:1818-1823.
- Trinder, P. 1969. Standard methods of clinical chemistry. *Ann. Clin. Biochem.* 6:24.
- Truswell, A. S. 1992. Glycaemic index of foods. *Eur. J. Clin. Nutr.* 46S:91-101.
- Van Amelsvoort, J. M. M., and Westrate, J. A. 1992. Amylose-amylopectin ratio in a meal affects postprandial variables in male volunteers. *Am. J. Clin. Nutr.* 55:712-718.
- Watkin, D. M., Froeb, H. F., Hatch, F. T., and Gutman, A. B. 1950. Effects of diet in essential hypertension. II. Results with unmodified Kempner rice diet in fifty hospitalised patients. *Am. J. Med.* 9:441-493.
- Wolever, T. M. S. 1990. The glycemic index. *World Rev. Nutr. Diabetes* 62:120-185.
- Wolever, T. M. S., and Miller, J. B. 1995. Sugars and blood glucose control. *Am. J. Clin. Nutr.* 62:212S-227S.
- Wolever, T. M. S., Jenkins, D. J. A., Jenkins, A. L., and Josse, R. G. 1991. The glycemic index: Methodology and clinical implications. *Am. J. Clin. Nutr.* 54:846-854.
- World Medical Association. 1997. Declaration of Helsinki—Recommendations guiding physicians in biomedical research involving human subjects. *JAMA* 277:925-926.

[Received April 26, 2004. Accepted September 21, 2004.]