Glycaemic index of different coconut (Cocos nucifera)-flour products in normal and diabetic subjects

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The glycaemic index (GI) of commonly consumed bakery products supplemented with increasing levels of coconut (Cocos nucifera) flour was determined in ten normal and ten diabetic subjects. Using a randomized crossover design, the control and test foods were fed in random order on separate occasions after an overnight fast. Blood samples were collected through finger prick before and after feeding and were analysed for glucose levels using a clinical chemistry analyser. The significantly low-GI (<60) foods investigated were: macaroons (GI 45.7 (SEM 3.0)) and carrot cake (GI 51.8 (SEM 3.3)), with 200–250 g coconut flour/kg (P<0.05). The test foods with 150 g coconut flour/kg had GI ranging from 61.3 to 71.4. Among the test foods, pan de sal (GI 87.2 (SEM 5.5)) and multigrain loaf (GI 85.2 (SEM 6.8)) gave significantly higher GI with 50 and 100 g coconut flour/kg respectively (P<0.05). On the other hand, granola bar and cinnamon bread with 50 and 100 g coconut flour/kg respectively gave a GI ranging from 62.7 to 71.6 and did not differ significantly from the test foods with 150 g coconut flour/kg (P<0.05). A very strong negative correlation (r = −0.85, n 11, P<0.005) was observed between the GI and dietary fibre content of the test foods supplemented with coconut flour. In conclusion, the GI of coconut flour-supplemented foods decreased with increasing levels of coconut flour and this may be due to its high dietary fibre content. The results of the present study may form a scientific basis for the development of coconut flour as a functional food. However, the fat content of coconut flour-supplemented foods should always be considered to optimize the functionality of coconut fibre in the proper control and management of diabetes mellitus.

Glycaemic index: Coconut flour: Diabetes

Dietary guidelines recommend increased intake of dietary fibre for better control and proper management of chronic diseases such as diabetes mellitus, cardiovascular disease and cancer (Scientific Review Committee, Health and Welfare Canada, 1990; Food and Nutrition Research Institute, Department of Science and Technology, Philippines, 2000). The physical and chemical properties of dietary fibre, e.g. viscosity and fibrous structure, have an important role in the release and absorption of nutrients in the gastrointestinal tract. The glycaemic index (GI), a classification of food based on their blood glucose response relative to a starchy food, e.g. white bread, has been proposed as a therapeutic principle for diabetes mellitus by slowing carbohydrate absorption (Jenkins et al. 1982; Creutzfeldt, 1983). Low-GI food, e.g. food with added dietary fibre, has been shown to have reduced postprandial blood glucose and insulin responses and improved the overall blood glucose and lipid concentrations in normal subjects (Jenkins et al. 1987) and patients with diabetes mellitus (Collier et al. 1988; Fontvieille et al. 1988; Brand et al. 1991; Wolever et al. 1992). Our previous study has shown that coconut (Cocos nucifera) flour from coconut residue, a by-product of the coconut-milk industry, contained 600 g total dietary fibre/kg (560 g insoluble and 40 g soluble fibre/kg; Trinidad et al. 2001). The present study aimed to determine the GI of coconut-flour products from normal and diabetic subjects. Results from the present study may form a scientific basis for the development of coconut flour as a functional food and in the production of coconut products in the Philippines.

Materials and methods

Subjects

Ten normal and diabetic (type 2) subjects were physically examined by a medical doctor and evaluated by an endocrinologist on the basis of the following criteria: normal subjects, BMI 20–25 kg/m2, fasting blood glucose 4–7 mmol/l, age 35–60 years, no physical defect and non-smokers; diabetic subjects, fasting blood glucose 7.5–11.0 mmol/l, age 35–60 years, no intake of drugs, no complications.

Abbreviation: GI, glycaemic index.

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and non-smokers. Each subject was interviewed for assessment of physical activity levels and was asked to fill in a 3 d food intake recall form (Appendix). Subjects with normal food intake (pattern) and physical activity were included in the study. The diabetic subjects were managed through dietary consultations and advice. The subjects signed voluntary consent forms approved by the National Human Ethics Committee, Philippine Council for Health Research and Development, Department of Science and Technology, Metro Manila, Philippines.

Test foods

The control food was white bread prepared at the Nutrient Availability Laboratory, Food and Nutrition Research Institute, Department of Science and Technology, in a bread maker (KCTNO4584; Regal Kitchen Pro Collection, Institute, Department of Science and Technology, Metro Manila, Philippines). The control food was white bread prepared at the Nutrient Research and Development, Department of Science and Human Ethics Committee, Philippine Council for Health Technology, in a bread maker (KCTNO4584; Regal Kitchen Pro Collection, Institute, Department of Science and Technology, Metro Manila, Philippines.

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subjects were able to consume all test foods (white bread three times, test foods twice and standard glucose once; twenty-four occasions). The proximate analysis of coconut flour was as follows (per kg): moisture 36, ash 31, fat 109, protein 121, carbohydrate 703. Coconut flour contained 600 g dietary fibre/kg (560 g insoluble and 40 g soluble/kg). All tests foods with coconut flour were analysed for fat, protein, and dietary fibre. Table 2 shows the nutrient content of the test foods fed to the subjects. There was an increasing trend in dietary fibre content of the test foods fed at increasing level of coconut flour-supplemented foods, with macaroons having a significantly greater dietary fibre content (14·3 (SEM 0·2) g/kg, \( P < 0·05 \)) than the other test foods. As expected, white bread had a significantly lower dietary fibre content (2·3 (SEM 0·1) g/kg, \( P < 0·05 \)) than the other test foods. On the other hand, macaroons had a significantly higher fat content (33·5 (SEM 0·8) g/kg, \( P < 0·05 \)) among the test foods while white bread was significantly lower (0·3 (SEM 0·1) g/kg, \( P < 0·05 \)). Pan de sal had a significantly higher protein content (12·1 (SEM 0·1) g/kg, \( P < 0·05 \)) while granola bar (4·4 (SEM 0·1) g/kg, \( P = 0·05 \)) and choco chip cookies (4·4 (SEM 0·4) g/kg, \( P < 0·05 \)) had significantly lower protein content.

Table 3 shows the GI of the test foods. The GI of the standard white bread determined from the incremental area under the glucose response curve from white bread divided by the incremental area under the glucose response curve from the standard glucose was found to be 104 (SEM 4·0) in normal and diabetic subjects respectively. The GI of all test foods did not differ significantly between normal and diabetic subjects except for choco crinkles (61·2 (SEM 5·4) and 77·0 (SEM 4·4) respectively). The significantly low GI (<60) foods investigated were: macaroons (45·7 (SEM 3·0)) and carrot cake (51·8 (SEM 3·3)) (Table 3, Figs. 1 and 2), containing 200–250 g coconut flour/kg (\( P < 0·05 \)). The test foods with 150 g coconut flour/kg had GI ranging from 61·3 to 71·4.

Among the test foods, pan de sal (87·2 (SEM 5·5)) and multigrain loaf (85·2 (SEM 6·8)) had significantly higher GI (50 and 100 g coconut flour/kg respectively, \( P < 0·05 \)). On the other hand, granola bar and cinnamon bread with

### Table 2. Nutrient content of test foods fed to subjects*

<table>
<thead>
<tr>
<th>Test foods</th>
<th>Coconut flour (g/kg)</th>
<th>CHO (g)</th>
<th>Dietary fibre (g)</th>
<th>Fat (g)</th>
<th>Protein (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean SEM</td>
<td>Mean SEM</td>
<td>Mean SEM</td>
<td>Mean SEM</td>
<td>Mean SEM</td>
</tr>
<tr>
<td>White bread</td>
<td>0 50</td>
<td>2·3(^{a})</td>
<td>0·3(^{a})</td>
<td>7·3(^{a})</td>
<td>0·1</td>
</tr>
<tr>
<td>Pan de sal</td>
<td>50 50</td>
<td>4·6(^{a})</td>
<td>2·8(^{a})</td>
<td>12·1(^{a})</td>
<td>0·1</td>
</tr>
<tr>
<td>Granola bar</td>
<td>50 50</td>
<td>5·8(^{a})</td>
<td>9·9(^{a})</td>
<td>4·4(^{a})</td>
<td>0·1</td>
</tr>
<tr>
<td>Cinnamon bread</td>
<td>100 50</td>
<td>7·3(^{a})</td>
<td>14·2(^{a})</td>
<td>8·5(^{a})</td>
<td>0·4</td>
</tr>
<tr>
<td>Multigrain loaf</td>
<td>100 50</td>
<td>7·4(^{a})</td>
<td>4·0(^{a})</td>
<td>9·8(^{a})</td>
<td>0·2</td>
</tr>
<tr>
<td>Choco chip cookies</td>
<td>150 50</td>
<td>7·5(^{a})</td>
<td>9·9(^{a})</td>
<td>4·4(^{a})</td>
<td>0·4</td>
</tr>
<tr>
<td>Hotcake</td>
<td>150 50</td>
<td>7·4(^{a})</td>
<td>1·5(^{a})</td>
<td>9·5(^{a})</td>
<td>0·1</td>
</tr>
<tr>
<td>Choco crinkles</td>
<td>200 50</td>
<td>8·2(^{a})</td>
<td>9·4(^{a})</td>
<td>4·7(^{a})</td>
<td>0·3</td>
</tr>
<tr>
<td>Carrot cake</td>
<td>200 50</td>
<td>10·2(^{a})</td>
<td>19·3(^{a})</td>
<td>5·9(^{a})</td>
<td>0·1</td>
</tr>
<tr>
<td>Macaroons</td>
<td>250 50</td>
<td>14·3(^{a})</td>
<td>33·3(^{a})</td>
<td>7·6(^{a})</td>
<td>0·3</td>
</tr>
<tr>
<td>Brownies</td>
<td>250 50</td>
<td>10·5(^{a})</td>
<td>15·0(^{a})</td>
<td>6·3(^{a})</td>
<td>0·1</td>
</tr>
</tbody>
</table>

CHO, carbohydrate.

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### Table 3. Glycaemic index of test foods in normal and diabetic subjects*

<table>
<thead>
<tr>
<th>Test foods</th>
<th>Coconut flour (g/kg)</th>
<th>Normal Mean SEM</th>
<th>Diabetic Mean SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean SEM</td>
<td>Mean SEM</td>
<td>Mean SEM</td>
</tr>
<tr>
<td>Pan de sal</td>
<td>50 87·2(^{ax})</td>
<td>5·5</td>
<td>96·6(^{ax})</td>
</tr>
<tr>
<td>Granola bar</td>
<td>50 65·1(^{bx})</td>
<td>4·9</td>
<td>71·6(^{bx})</td>
</tr>
<tr>
<td>Cinnamon bread</td>
<td>100 62·7(^{bx})</td>
<td>4·3</td>
<td>71·4(^{bx})</td>
</tr>
<tr>
<td>Multigrain loaf</td>
<td>100 85·2(^{ax})</td>
<td>6·8</td>
<td>92·5(^{ax})</td>
</tr>
<tr>
<td>Choco chip cookies</td>
<td>150 61·3(^{bx})</td>
<td>4·6</td>
<td>71·4(^{bx})</td>
</tr>
<tr>
<td>Hotcake</td>
<td>150 65·0(^{bx})</td>
<td>3·3</td>
<td>72·3(^{bx})</td>
</tr>
<tr>
<td>Choco crinkles</td>
<td>200 61·3(^{bx})</td>
<td>5·4</td>
<td>77·3(^{bx})</td>
</tr>
<tr>
<td>Carrot cake</td>
<td>200 51·8(^{cx})</td>
<td>3·3</td>
<td>55·6(^{cx})</td>
</tr>
<tr>
<td>Macaroons</td>
<td>250 45·7(^{cx})</td>
<td>3·0</td>
<td>46·6(^{cx})</td>
</tr>
<tr>
<td>Brownies</td>
<td>250 60·1(^{bx})</td>
<td>5·4</td>
<td>61·3(^{bx})</td>
</tr>
</tbody>
</table>

---

*Mean values with a column with unlike superscript letters were significantly different (\( P < 0·05 \)).

x,yMean values within a row with unlike superscript letters were significantly different (\( P < 0·05 \)).

* For details of subjects, products and procedures, see Tables 1 and 2 and p. 552.
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Discussion

The results of the present study showed that even at a constant amount of available carbohydrate in the test foods, there was a significant variation in the GI, confirming that equi-carbohydrate portions of different foods may not necessarily have the same glycaemic effect in human subjects (Wolever et al. 1994). The blood glucose response may be influenced by insulin responses in the presence of protein (Nuttall et al. 1984; Simpson et al. 1985; Gannon et al. 1988), and differences in the rates of digestion and absorption influenced by the presence of dietary fibre, fat, cooking, anti-nutrients, particle size, food form and starch structure (Wursch, 1989; Wolever, 1990). The protein content of the test foods fed to the subjects ranged from 4.4 to 12.1 g (Table 2). According to several investigators (Nuttall et al. 1984; Simpson et al. 1985; Gannon et al. 1988), 20–30 g dietary protein is needed to increase insulin responses sufficiently to reduce glycaemic responses, especially in subjects with non-insulin-dependent diabetes mellitus. Therefore, the protein content of the test foods may not have any effect on the variability of GI in the test foods investigated.

A wide variability in fat content of the test foods ranging from 0.28 to 33.5 g/kg was observed (Table 2). We do not believe that fat strongly affected the GI of the test foods investigated in the present study. There was only one test food that contained >20 g fat/kg in the study: macaroons (33.5 g fat/kg, Table 2). The amount of fat present in macaroons in the present study may not be sufficient enough to affect its overall glycaemic response, and similarly of the other test foods used in the study. In another study, it was shown that the addition of fat (about 23 g) to a carbohydrate-based meal caused an early (0–90 min) decrease in glucose response; however, the overall glucose response was the same between the carbohydrate meal and the added-fat meal, suggesting that fat did not affect the overall glucose response to the food (Peters & Davidson, 1993). The early decrease in the glucose response may be due to a delay in gastric emptying that may be mediated through an effect of fat on the duodenum and/or ileum (Welch et al. 1987). To further support the non-significant effect of fat on the GI of the test foods investigated in the present study, a multi-regression stepwise analysis using the SPSS statistical program was done to look at the interaction between GI and dietary fibre while controlling for fat content. A significant contribution of dietary fibre (87.4%) in the variability of the GI from all test foods for both normal and diabetic subjects (P<0.001) and a non-significant contribution from fat were obtained. This result also supported the corresponding low GI of the test foods at higher concentration of dietary fibre from coconut flour. Dietary fibre contributed to delaying the glycaemic responses of the coconut flour-supplemented food, a finding similar to previous work on dietary fibre and GI of foods (Jenkins et al. 1982; Welch et al. 1987; Peters & Davidson, 1993). Moreover, purified soluble fibre reduces glycaemic responses to a greater extent than purified insoluble fibre (Jenkins et al. 1978). Considering the dietary fibre present in whole foods, insoluble fibre was related more strongly to the GI than soluble fibre content (Jenkins et al. 1989). Coconut flour contains 600 g total dietary fibre/kg (560 g insoluble and 40 g soluble/kg; Trinidad et al. 2001).

The significant differences between the GI of choco crinkles in normal and diabetic subjects is difficult to explain. The differences in glucose responses between the two
groups may be due to rates of digestion and absorption in relation to the food ingested.

In conclusion, the GI of coconut flour-supplemented foods decreased with increasing levels of coconut flour and this effect may be due to its high dietary fibre content. The fat content of the test foods may have little or no effect on the GI of the test foods investigated. The results of the present study may form a scientific basis for the development of coconut flour as a functional food. However, the fat content of coconut-supplemented foods should always be considered in order to optimize the functionality of coconut fibre in the proper control and management of diabetes mellitus.

Acknowledgements

The authors wish to thank Professor Thomas M. S. Wolever, Department of Nutritional Sciences, University of Toronto, Toronto, Canada, for personal consultations regarding the calculation of the GI of the standard and test foods. The authors also wish to thank Zoilo B. Villanueva, Adorie D. Sabenecio, Josefina A. Desnacido and Revelita L. Cheong of the Nutritional Biochemistry Section, Food and Nutrition Research Institute, Department of Science and Technology for their technical assistance, and Ms Ana Marie Tumbokon of the Food Processing Division, Philippine Coconut Authority and the Bakers Kingdom, Rustan’s Cubao, Quezon City, Metro Manila, for the preparation of food samples. This project would not have been possible without the support from the Philippine Council for Health Research and Development, Department of Science and Technology and the Philippine Coconut Authority, Department of Agriculture.

References


Fontvieille AM, Acosta M, Rizkalla SW, et al. (1988) A moderate switch from high to low glycemic index foods for three weeks improves the metabolic control of type I (IDDM) diabetic subjects. Diabetes Nutr Metab 1, 139–143.


Appendix

Food record

Subject’s name: ___________________________ Date ________ (month-d-year)

<table>
<thead>
<tr>
<th>Date/time</th>
<th>Food/beverage and description (one item per line)</th>
<th>Quantity</th>
</tr>
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<tr>
<td></td>
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</table>

Is this a usual day? Yes _____ No _____
If no, please explain: