Lack of Effect of Refining on the Glycemic Response to Cereals

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The blood glucose response to feeding whole and fiber-depleted cereals and cereal products was studied in healthy volunteers. No difference was seen between white and wholemeal bread and spaghetti or between white and brown rice. This lack of effect of cereal fiber on postprandial blood glucose levels suggests that the reported beneficial long-term effects of cereal-based, "natural," high fiber diets on diabetic control must be due to other aspects of the diet or to a different effect of fiber. DIABETES CARE 4: 509–513, SEPTEMBER–OCTOBER 1981.

There has been considerable interest recently in the potential value of dietary fiber in the diabetic diet.[1] Various types of purified fiber have been shown to flatten the glucose tolerance curves in normal[2] and diabetic subjects.[3,4] In addition, high fiber diets with a high carbohydrate content have been associated with improved diabetic control.[5] In those diets where unrefined foods have been used to treat diabetic persons, 40%[5] or more[6] of the total fiber intake was of cereal origin. Yet wheat bran has been shown to have little effect on glucose tolerance.[2] This raises the question as to whether the improved diabetic state was secondary to increased carbohydrate intake, as suggested by some,[6,7] and not to the fiber. Therefore, to see whether fiber depletion impaired the blood glucose response, we tested the effect of feeding refined and unrefined forms of three common cereal foods, bread, pasta, and rice, to healthy volunteers.

MATERIALS AND METHODS

Groups of 6–10 volunteers drawn from a pool of 13 individuals (6 men, 7 women; 30 ± 2 yr; 109 ± 4% desirable weight) took paired test meals containing 50 g carbohydrate from individual foods as calculated from food tables[8] (Table 1). The meals of each pair were taken in random order on the average of 7 ± 2 days apart on separate mornings after overnight fasts. The meal pairs consisted of 101 g white bread (Mothers Pride) and 120 g wholemeal bread (Allison's flour); 60 g white spaghetti (Durum Wheat) and 71 g wholemeal spaghetti (Record Pasta Foods); and 60 g short grain white rice and 62.3 g short grain brown rice. The total time taken by the six who completed more than one pair of food studies was 2.3 mo, with the majority taking the breads first and the spaghetti last. The rice and spaghetti were boiled in the minimum of water such that draining was unnecessary. Foods were eaten with 120 g skinned, pipped tomatoes for palatability and all meals were taken with tea made with one tea bag and containing 50 ml of milk such that the final volume of the meal was at least 600 ml. Meals were eaten over a 10-min period.

Finger-prick blood samples were taken at 0 and 15, 45, 60, 90, and 120 min after the start of the meal using an Autolet Lancet (Owen Mumford Ltd., Woodstock, Oxon, England) and analyzed by a glucose-oxidase method (23AM Glucose Analyzer, Yellow Springs Instruments, Yellow Springs, Ohio).

Glucose tolerance tests were performed on all individuals, 50 g glucose being dissolved in 600 ml of tea containing 50 ml milk.

The results are expressed as means ± SEM and the significance calculated using Student's *t* test for paired and unpaired data. Areas under the curve were calculated using the formula:

$$\frac{\Delta_0 15 \times t}{2} + \Delta_0 15t + \frac{(\Delta_0 30 - \Delta_0 15)t}{2} + \Delta_0 30t \ldots \&c.$$

where Δ_0 is change in blood glucose in mmol/L from zero time to 15 min, 30 min, 45 min, &c., and t is the 15-min interval between blood samples. Where the glycemia went below the starting value, the formula was modified so that only the area above the starting value was calculated, e.g.,

TABLE 1
Composition of test meals

	Weight (g)	Carbohydrate (g)	Protein (g)	Fat (g)	Fiber (g)
Wholemeal bread	120	50	10.5	3.2	10.2
White bread	101	50	8	1.7	2.8
Brown rice	62.3	50	4.9	0.4	3.5
White rice	60	50	3.9	0.6	1.4
Wholemeal spaghetti	71	50	9.7	3.5	7.3
White spaghetti	60	50	8.2	0.6	2.0

All meals contained in addition

	Weight	Carbohydrate	Protein	Fat	Fiber
Tomatoes (skinned + pipped)	120	3.4	1.0	—	1.8
Whole milk	50	2.5	1.5	2.0	—
Tea	550	—	—	—	—
Total		5.9	2.5	2.0	1.8

$[(\Delta_0 90)^2 t]/(\Delta_0 120 + \Delta_0 90)$, where the 120-min value fell below the starting value.

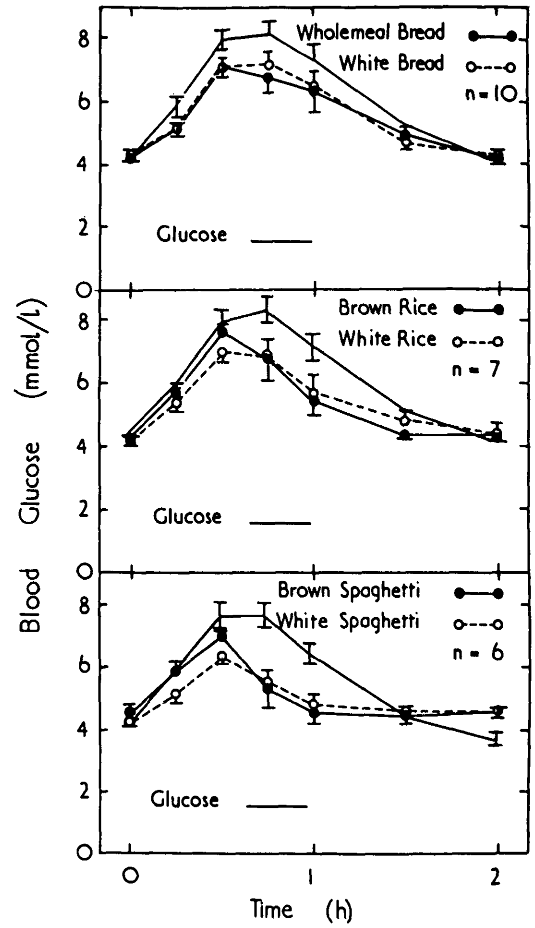

FIG. 1. Effect of fiber depletion on the mean blood glucose curves after eating 50-g carbohydrate portions of bread, rice, and spaghetti compared with 50-g glucose tolerance tests.

RESULTS

No significant difference was seen between any of the foods and their fiber-depleted counterpart either in terms of the total area under the blood glucose curve or at any individual point during the 2-h period (Figure 1, Tables 2 and 3). All six foods, however, were significantly different from glucose with respect to the area under the curve, the percent reductions being wholemeal bread 28 ± 6% ($P < 0.001$), white bread 31 ± 5% ($P < 0.001$), brown rice 34 ± 5% ($P < 0.001$), white rice 28 ± 9% ($P < 0.02$), wholemeal spaghetti 58 ± 4% ($P < 0.02$), and white spaghetti 50 ± 8% ($P < 0.002$).

Among the cereals a notable difference was seen between the mean curves for spaghetti and those for bread and rice. The mean glucose area for wholemeal and white spaghetti was only 52% ($P < 0.01$) of the wholemeal and white bread and 55% ($P < 0.02$) of the brown and white rice (Table 2). The mean peak rise of spaghetti was also lower than that of both bread by 32% ($P < 0.01$) and rice by 32% ($P < 0.002$) (Table 3). Comparison of the paired results of individuals who took part in studies of both spaghetti and bread (five subjects) or spaghetti and rice (four subjects) showed the spaghetti glucose area to be 58% that of bread and 61% ($P < 0.05$) that of the rice. Here, with the reduced number, the bread comparison did not quite reach significance. The mean 50-g GTT areas and peak rises for the groups of volunteers testing each pair of foods were not significantly different (areas, mmol · min/L, of 193 ± 14, spaghetti; 228 ± 24, rice; 237 ± 24, bread; and peak rises, mmol/L, of 3.7 ± 0.3, spaghetti; 4.0 ± 0.3, rice; 4.2 ± 0.3 bread). However, the 50-g GTT glucose areas and peak rises for the spaghetti group tended to be lowest and the respective values for the food tests were therefore adjusted appropriately. After increasing each individual's spaghetti area by 20% and peak rise by 11% to correct for the nonsignificant differences between the mean GTT areas and peak rises of spaghetti and the means of rice and bread, the mean glucose area for spaghetti was still only 62% ($P < 0.05$) that of bread and 65% ($P < 0.05$) that of rice, and the peak rises were lower by 24% than both bread ($P < 0.05$) and rice ($P < 0.01$).

The foods used were taken from a variety of sources obtained over a period of time. Nevertheless, there was no significant difference in the mean glycemic response when 2–3 individuals repeated white bread, wholemeal bread, and brown rice, a mean of 6.6 wk from their original test meals. The mean area of the second meals differed by −14 ± 8% from the first.

TABLE 2
Areas under the curve (mmol·min/L) after eating 50 g carbohydrate as glucose, fiber-rich or fiber-depleted bread, rice, and spaghetti

Bread				Rice				Spaghetti			
Name	Brown	White	GTT	Name	Brown	White	GTT	Name	Brown	White	GTT
MG	316	272	400	PG	236	275	350	RT	61	112	241
JB	118	158	290	HF	156	241	254	HB	111	68	205
DG	223	156	284	RT	165	109	241	HN	78	138	203
HF	252	209	254	DJ	111	215	206	AB	71	48	199
RT	196	235	241	CB	172	152	199	DJ	77	120	163
DJ	167	98	206	AB	101	94	199	TW	72	87	146
HB	159	153	205	TW	112	82	146				
AB	120	152	199								
AJ	119	98	148								
TW	64	94	146								
x̄	173	163	237		150	167	228		78	96	193
SEM	24	19	24		18	29	24		7	14	14

DISCUSSION

The results indicate that the blood glucose response is unaffected by removal of dietary fiber from three common cereal foods. Refining also removes fat and protein, as well as dietary fiber (Table 1). This too would tend to make the blood glucose responses to the refined foods higher. The fact that this is not the case indicates that the small differences in fat and protein content of starchy foods are probably unimportant in their effects on postprandial glycemia. Thus the differences between bread or rice and spaghetti are unlikely to be due to differences in the composition of the foods, which are similar for bread and spaghetti. On the other hand, the responses to bread and rice are similar, although their composition is different with respect to fat, protein, and carbohydrate.

The possibility arose that the difference in response between bread and spaghetti may have been due to a progressive change in glucose tolerance over the experimental period. Against this is the lack of a significant difference between the repeated tests on the same food over a mean time period of 6.6 wk. In addition, in four of the five individuals who did both tests there was no difference in the mean of the 50-g GTT glucose areas for the tests performed just before and just after the bread testing days as compared with those performed at a later date just before and again just after the spaghetti testing days. Expressing the difference in glucose areas between the bread- and spaghetti-related GTTs as a percentage of the bread-related GTT, the difference was only 1 ± 6%. Thus, in these four individuals the mean GTT result remained constant with time. However, the fifth individual (DJ), who performed his spaghetti tests nearly 3 mo after the bread and rice, had a mean 50-g GTT glucose area during the first part of the study of 206 and during the second

TABLE 3
Peak rises of blood glucose (mmol/L) after eating 50 g carbohydrate as glucose, fiber-rich or fiber-depleted bread, rice, and spaghetti

Bread				Rice				Spaghetti			
Name	Brown	White	GTT	Name	Brown	White	GTT	Name	Brown	White	GTT
MG	4.9	4.9	6.1	PG	4.2	3.8	5.6	RT	1.9	2.0	4.6
JB	2.7	3.8	4.7	HF	3.4	3.7	3.9	HB	2.9	2.0	3.9
DG	3.9	4.0	5.2	RT	4.1	2.6	4.6	HN	2.6	2.7	3.8
HF	4.2	3.3	3.9	DJ	3.4	4.7	3.8	AB	2.2	1.6	4.1
RT	3.5	4.3	4.6	CB	3.3	3.1	3.3	DJ	2.3	2.7	2.8
DJ	3.2	2.4	3.8	AB	2.9	2.6	4.1	TW	2.4	2.3	2.9
HB	2.7	3.0	3.9	TW	3.4	2.3	2.9				
AB	4.2	2.9	4.1								
AJ	2.7	2.5	3.2								
TW	1.8	2.2	2.9								
x̄	3.4	3.3	4.2		3.5	3.3	4.0		2.4	2.2	3.7
SEM	0.3	0.3	0.3		0.2	0.3	0.3		0.1	0.2	0.3

of 163 mmol · min/L. For this reason, in Tables 2 and 3 the mean 50-g GTT glucose area and peak rise for DJ for the spaghetti are shown separately from that for bread and rice.

The results confirm earlier work based on unpublished data suggesting that there was no difference between white and wholemeal bread.[9] There have been no previous reports on the differences between white and wholemeal spaghetti and only recently has a study been published on white and brown rice[10] even though for many countries these are major sources of cereal carbohydrate.

In the recently reported study on rice no difference was seen between milled an unmilled rice.[10] Our own finding is in agreement with this. Of further interest in the paper by O'Dea and colleagues was the demonstration that grinding the rice to a paste resulted in a greatly increased blood glucose response.[10] This highlights the effect of food form on blood glucose response and may be relevant in considering the difference we observed between wheat in the form of bread as opposed to pasta. Part of the explanation for the flatter glucose response may be that the more compact nature of the spaghetti reduced accessibility to digestive enzymes by comparison with bread.

Test meal studies comparing the effect of a range of fiber and fiber analogues on glucose tolerance showed that wheat bran was relatively ineffective.[2] This confirmed earlier observations that the effect of bran in reducing the blood glucose rise after taking glucose syrup, although present, was small.[11]

Against this, there is evidence that long-term feeding of cereal fiber and unrefined cereal products may be beneficial. Trowell has pointed out that the increase in fiber consumption during the world wars in Britain, when the extraction rate of flour was increased, corresponded with a fall in deaths from diabetes[12] and cardiovascular disease.[13] The retrospective studies of middle-aged London men by Morris and colleagues[14] indicated a positive association between cereal fiber consumption and freedom from subsequent cardiovascular diseases. Although these studies are subject to alternative explanations, direct experimentation has shown that feeding bran daily to individuals with diverticular disease for 6 mo resulted in imporved glucose tolerance,[15] while with diabetic subjects bran feeding for 1 mo resulted in an overall improvement in glucose tolerance and diabetic control.[16]

In general, the effect of cereal fiber is most apparent on colonic function, as one of the most effective forms of fiber in increasing fecal bulk and decreasing transit time.[17] Its effect on glucose tolerance[2] and on fasting serum lipids[18] is small by comparison with other fibers. Administration of the leguminous seed fiber, guar,[3] and the fruit fiber, pectin, reduces the rise in blood glucose when added to mixed meals and also reduces fasting serum cholesterol levels.[19,20] In addition, both lentils and soya beans result in lower blood glucose responses after they are eaten than would be expected from their carbohydrate content.[21]

Work on the effect of disruption or depletion of fiber in apples has emphasized the importance of food form and indicated that the fiber in unprocessed foods may prevent the "rebound" fall in blood glucose between 120 and 180 min.[22] An associated reduction in the insulin response has also been seen both after addition of purified fiber to test meals and when whole apples as opposed to apple juice or puree were taken.[22]

All reports of foods or fiber additives, which have produced a marked effect on the blood glucose response in diabetic subjects, have shown at least some effect in normals. Although it is possible that a reduction in insulin secretion may occur before a significant reduction is seen in the glucose concentration in venous blood, the capillary blood used in these experiments more closely resembles the arterial blood glucose level, which determines insulin secretion. We feel, therefore, that if differences are found in insulin secretion in this context, they are likely to be small.

Fiber content, as a determinant of the food form, may well be important in modifying the blood glucose response. However, in the case of cereal fiber, the effect on a weight-for-weight basis is, at best, only likely to be small, although in view of the amount of cereal products eaten it could still be important in the long term through some alternative mechanism. It is possible that over a period of time fiber may cause changes in gastrointestinal morphology and function resulting in improved glucose tolerance. Again, such changes will not be seen in acute studies.

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