Wholemeal versus wholegrain breads: proportion of whole or cracked grain and the glycaemic response

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Abstract

Study objective—**To determine the effect on the glycaemic response to bread of the ratio of whole cereal grains to milled flour.**

Design—**Randomised assignment of groups of diabetic volunteers to test and control meals, taken after an overnight fast. Test foods were also analysed for in vitro digestion with human saliva.**

Setting—**Tertiary care centre.**

Patients—**Groups of six drawn from pool of 16 volunteers with diabetes mellitus (11 men, five women; mean age 64 (SE 3); 10 taking insulin, five taking oral agents, one controlled by diet; other characteristics comparable).**

Interventions—**All patients took standard white bread control meals on three occasions spanning the study and on different mornings took test meals containing varying ratios of whole cereal grains (barley or cracked wheat) to milled flour (75:25, 50:50, 0:100). All meals contained 50 g available carbohydrate and were eaten in 15 minutes. Capillary blood samples were taken for determination of glucose concentrations every 30 minutes for three hours.**

End point—**Glycaemic index of foods (=increase in area under blood glucose concentration curve for test food÷increase in area under curve for white bread control×100).**

Measurements and main results—**Significant trend to lower glycaemic index with increasing proportion of whole cereal grains in test bread ($p<0.05$) and with lower in vitro digestibility ($p<0.001$). Breads containing up to 75% whole grain were considered palatable.**

Conclusions—**Breads containing a high proportion of whole cereal grains may be useful in reducing the postprandial blood glucose profile in diabetics because they are more slowly digested. These breads should be called "wholegrain" in distinction to "wholemeal" breads made from milled flour.**

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Introduction

The term "wholegrain" (whole wheat, whole rye, etc) seems inadequate as currently used for cereal products. It is applied equally to cereal products such as pumpernickel bread, in which a large proportion of the whole cereal grain remains intact, and to highly milled products such as wholemeal bread, in which the flour contains all of the original dietary fibre but none of the original form of the food. The importance of this issue is exemplified by the advice given to patients with diabetes to increase their consumption of wholegrain products: the terms wholegrain and wholemeal are used synonymously.[1,2] Nevertheless, there seem to be major differences in the physiological response to wholegrain as opposed to wholemeal foods. Particle size is now recognised as an important determinant of the glycaemic response to cereals such as rice, wheat, rye, and maize.[3-5] Blood glucose concentrations increase less when pumpernickel rye bread containing whole grain is eaten than when bread made with a milled rye flour is eaten.[4]

We studied the effect on the glycaemic response of increasing the proportion of whole barley grains or coarse cracked wheat in breads made from the milled flours of these cereals. We wanted to determine whether a linear response existed between the proportion of whole grains or coarse particles and the glycaemic response and whether the currently accepted nomenclature for products containing wholegrain cereals needed revision.

Methods

Volunteers drawn from a pool of 16 diabetics positive for C peptide were studied (table I). The 11 men and five women had a mean age of 64 (SE 3) and weighed 115 (4)% of their ideal weight.[6] Ten had their diabetes controlled with insulin, five with oral agents, and one with diet alone. They took two or more of the test foods in random order on separate mornings after overnight fasts; six to eight subjects took each test food. All patients also took a control meal of white bread (50 g carbohydrate) on three separate occasions during the test period. All meals contained 50 g available carbohydrate (estimated from food tables[7]) and consisted of barley kernels alone or of bread containing whole barley and barley flour in the ratios 75:25, 50:50, and 0:100, or of bulgur alone or of breads containing cracked wheat in the same ratios.

Ten minutes before each meal patients took their usual dose of insulin or oral hypoglycaemic agent. They attempted to eat each meal within 10 minutes. The grains or bread were taken with two cups of tea or coffee (400 ml) containing a total of 60 ml of 2% butterfat milk. Subjects recorded palatability and satiety on bipolar semantic scales: at the end of each meal they gave it a palatability score of −3 to +3 (−3 being highly disliked and +3 highly delectable), and satiety was scored at 0, 30, 90, and 180 minutes after the start of the meal from −3 (very hungry) to +3 (very full). Capillary blood samples were taken by finger pricks just before the meal and at half hour intervals for three hours thereafter and were analysed by a glucose oxidase method.[8] The glycaemic response (the blood glucose profile with the fasting value as the baseline) was plotted for each meal tested by each subject, and the area under the curve was determined. The glycaemic index was calculated[9]:

$$\text{Glycaemic index} = \frac{\text{Area under the curve for test food}}{\text{Area under the curve for white bread}} \times 100$$

TABLE I—*Details of diabetic patients taking test meals*

Case No	Sex	Age (years)	% Ideal weight	Duration of diabetes (years)	C peptide (ng/l) Fasting	C peptide (ng/l) At 90 minutes	Treatment
1	M	62	102	5	1·40	4·50	Glibenclamide 10 mg twice daily
2	M	57	153	6	2·50	7·00	Glibenclamide 5 mg twice daily
3	M	78	110	7	10·6	16·00	5 Units insulin zinc suspension
4	M	42	129	6	3·40	6·60	Glibenclamide 5 mg thrice daily
5	M	74	124	5	3·65	9·80	Diet only
6	M	70	114	2	1·08	1·56	Glibenclamide 10 mg am, 5 mg pm
7	M	70	96	20	0·94	1·72	32 Units insulin zinc suspension
8	M	76	108	24	1·00	2·60	20 Units insulin zinc suspension
9	F	31	100	2	1·08	1·63	34 Units insulin zinc suspension
10	F	69	126	28	2·40	5·20	34 Units insulin zinc suspension
11	M	69	114	15	11·5	13·00	50 Units insulin zinc suspension
12	F	65	104	10	0·94	1·12	24 Units insulin zinc suspension
13	F	63	119	9	2·02	3·45	68 Units insulin zinc suspension
14	M	68	109	15	3·75	5·30	24 Units insulin zinc suspension
15	F	64	118	4	1·55	4·60	20 Units insulin zinc suspension
16	M	71	108	10	1·92	3·77	Glibenclamide 10 mg twice daily
Mean		64·3	114·6	10·5	3·11	5·49	31·1
SE		3·1	3·5	2·0	0·81	1·06	5·5

In addition portions of the foods containing barley were digested in vitro by pooled human saliva in a dialysis system.[10] Each portion contained 2 g carbohydrate, and five replications were carried out for each test food. The products of carbohydrate digestion were sampled at hourly intervals over three hours and analysed by high performance liquid chromatography.[10]

The significance of differences between foods in each series was assessed by analysis of variance.[11] The regression equations were calculated for the relation of the proportion of whole grain in the meal to the glycaemic index and for the rate of digestion in vitro to the corresponding glycaemic index.

Results

All the meals were eaten within 15 minutes and did not differ significantly from meals containing white bread in terms of palatability, eating time, or satiety with the exception of the 50:50 barley bread, which took 3·0 (SE 1·1) minutes longer to eat than white bread ($p<0·05$).

The glycaemic responses to the meals of barley and bulgur breads and grains decreased when a higher proportion of whole grains of cereal were present (table II). The breads made from 100% wholemeal flour (wheat or barley) resulted in glycaemic responses that were not significantly different from those for white bread. As the proportion of whole or cracked grains in bread increased the glycaemic response decreased. This tendency was significant for both barley ($p<0·05$) and bulgur ($p<0·05$) (fig 1). Table III gives the results of the in vitro tests on the foods containing barley. The glycaemic indices of the test meals containing barley were closely related to their in vitro digestibility expressed as the concentration of total sugars in the dialysis fluid at three hours ($p<0·001$) (fig 2).

Of the foods containing barley, the bread with 50% whole grain resulted in a significantly lower mean glycaemic index than wholemeal barley bread, and both the 75% wholegrain barley bread and the meal of 100% wholegrain barley resulted in lower glycaemic indices than the 50% wholegrain bread. Of the foods containing bulgur, the 75% bulgur bread resulted in a mean glycaemic index significantly below that for wholemeal bread, and the meal including 100% bulgur resulted in a lower mean glycaemic index than either the wholemeal bread or the bread made with 50% bulgur.

Discussion

The glycaemic response decreased when whole or cracked cereal grains were substituted for milled flour in bread. The reduction was greater with breads containing higher proportions of whole grains. This advantage over flours milled from whole grains highlights the inadequacy of the term "wholegrain," which may refer to foods containing the intact grain or those that contain appropriate proportions of all the milled constituents (bran, endosperm, germ) of the grain. It therefore seems important for at least two reasons to reserve the term wholegrain specifically for the intact or cracked kernel. Firstly, advice by diabetes associations has emphasised the nutritional advantages of wholegrain cereals, implying that they may result in lower postprandial blood glucose profiles than their non-wholegrain equivalents.[1,2] Evidence in addition to the present study supports this when the term is interpreted literally.[5] The advantage of wholegrain cereals is not, however, obvious when wholegrain refers to the flour resulting from milling whole grains: no difference has been shown between breads or pasta made from wholegrain flour and from white flour.[12,13] Secondly, evidence of the benefits of cereal products containing intact or cracked grains may support the continued use of traditional products—for example, pumpernickel bread, barley soups, bulgur—and encourage the development of new wholegrain foods such as breads and muffins. We suggest that wholegrain should be used for products containing specified percentages of unmilled components (for example, 80% wholegrain, 50% wholegrain) and some other term, perhaps "wholemeal," should be used to indicate a milled flour product containing all the components of the whole grain.

Our results show the influence of the form of food on the glycaemic response. This has already been shown for rice (ground[3] and parboiled[14]); bread and pasta[12,13,15]; wheat[4]; rye kernels, pumpernickel, and wholemeal rye breads[4]; coarse ground wheat, oats, and maize[5]; ground lentils[10,16]; and whole and puréed apples and apple juice.[17] The importance of particle size was shown by a study in which food was swallowed without chewing, which resulted in a flatter blood glucose response curve than did food chewed normally.[18] Food should not be eaten unchewed, but larger particles in foods may be advantageous.

Although cereal fibre in its disrupted form does not seem to be an important determinant of glycaemic response to cereals, the glycaemic indices for whole barley and barley breads are significantly lower than those for bulgur and cracked wheat breads. This may be due to the presence of the viscous 6-glucan fibre in barley. Viscous soluble fibres rather than particulate insoluble fibres help reduce the postprandial rise in blood glucose concentration.[19] This would also be expected with oats and oat bran, the other cereal rich in 6-glucan fibre.

The size of rice particles has been shown to reduce the rate of gastric emptying which in turn reduces the glycaemic response; no such reduction occurred with legumes.[20] Our study confirmed the relation between glycaemic response and in vitro digestion.[20-22] Even if gastric emptying plays a part, the rate of digestion in the small intestine is probably also important and negatively related to the proportion of whole grains of barley in the meal.

Neither the whole grains nor the breads containing whole grains were considered to be much less palatable than white bread. These foods and others like them may be sufficiently acceptable in the diets of patients with diabetes, certain hyperlipidaemias, and other conditions producing carbohydrate intolerance. Other traditional but neglected foods, such as legumes that elicit a low glycaemic index have been introduced into the diets of diabetics with considerable success.[23] Wholegrain cereals may be added to this list.

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TABLE II—*Mean (SE) glycaemic index for different test meals*

Test meal	Glycaemic index*
Wholemeal bread	92 (11)[a]
50% Bulgur bread	83 (4)[ab]
75% Bulgur bread	69 (4)[bc]
Bulgur	66 (4)[c]
Barley flour bread	96 (6)[a]
50% Barley bread	62 (4)[b]
75% Barley bread	39 (7)[c]
Barley	39 (6)[c]

*Means not sharing same superscript are significantly different ($p<0·05$).

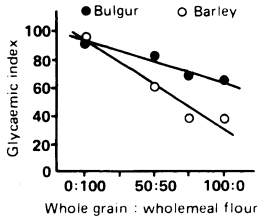

FIG 1—*Glycaemic index for barley and bulgur related to proportion of whole grain in flour used for bread. For barley, glycaemic index=94−0·61× percentage of whole grain; SEM of slope=0·11; p<0·05. For bulgur, glycaemic index= 93−0·28×percentage of whole grain; SEM of slope=0·049; p<0·05*

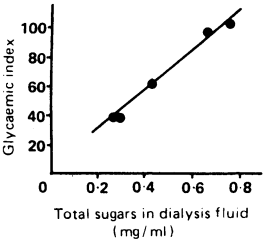

FIG 2—*Glycaemic index for barley related to concentration of total sugars in dialysis fluid at three hours. Glycaemic index= 132×total sugars in dialysis fluid+3·6; SEM of slope=9·63; p<0·001.*

TABLE III—*In vitro digestion of barley, breads containing barley, and white bread. Numbers are mean (SE) concentrations of total sugars (glucose, maltose, and maltotriose) in dialysis fluid after three hours*

Food	Total sugars (g/l)*
White bread (n=6)	0·76 (0·03)[a]
Barley flour bread (n=5)	0·66 (0·02)[b]
50% Barley bread (n=5)	0·43 (0·01)[c]
75% Barley bread (n=5)	0·29 (0·02)[d]
Barley (n=4)	0·26 (0·01)[d]

*Means not sharing same superscript are significantly different from each other ($p<0·005$).

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Relation of serum calcium concentration to metabolic risk factors for cardiovascular disease

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Abstract

Data from a health screening survey with over 18 000 adult participants were used to determine the relations between serum calcium concentration and the cardiovascular risk factors hypertension, hyperglycaemia, and hyperlipidaemia. Blood pressure and serum glucose and cholesterol concentrations were all positively related to each other independent of age, sex, kidney function, and obesity. Similar relations between the risk factors were found in subjects with hypertension or hyperglycaemia independent of the degree of overweight. These results suggested that there might be a metabolic syndrome of cardiovascular risk factors. Serum calcium concentration was positively related to systolic and diastolic blood pressures and serum glucose and cholesterol concentrations. Thus a common feature in the syndrome is an increased serum calcium concentration. The relations between serum calcium concentrations and the cardiovascular risk factors were not limited to the upper parts of the distribution, being seen over a wide range.

Changes in calcium metabolism seem to be related to a metabolic syndrome of hypertension, impaired glucose tolerance, and hyperlipidaemia.

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Introduction

The calcium ion is an essential regulator in many homoeostatic systems, including vascular tone, hormone secretion, and intermediary metabolism.[1] Calcium metabolism is reportedly altered in both hypertension[2] and diabetes mellitus,[3] and a pathogenetic role for calcium in the aetiology of hypertension has been suggested.[4] Hypertension, hyperglycaemia, and hyperlipidaemia are all well known risk factors for the development of cardiovascular disease,[5-7] and their coexistence might therefore be particularly important. We investigated interrelations between these risk factors and their relations to serum calcium concentration using data from a large health screening survey.

Subjects and methods

During 1969-70 all 24 171 inhabitants aged over 25 in a central district of Gävle, Sweden, were invited to participate in a health screening survey; 77% of the invited population took part (8416 men and 10 127 women). The non-participants were mainly from the youngest (25-35) and oldest (>85) age groups. The studied sample was considered to be representative for the ages 35-85 and large enough for us to study interrelations between metabolic variables. The aims of the health screening were to find undetected diseases and to evaluate the effects of such screening. The participants were asked to attend according to home address rather than by age or sex.

A venous blood sample was taken, usually in the afternoon after four hours of fasting, and analysed with a Technicon autoanalyser SMAC 12/60 (Mark Technicon Corp, USA) for serum glucose, cholesterol, calcium, and albumin concentrations and blood urea nitrogen concentration. Particular attempts were made to eliminate sources of error in the measurements. The results were compared with those obtained from standard samples (every fifth to 10th sample) from a large pool of serum calibrated every second week against a commercial reference. The serum calcium concentrations in the study were all adjusted for the serum albumin concentration according to the formula: calcium (adjusted)=calcium (analysed)−0·0077 (albumin−43·3), where 0·0077 was the determination coefficient of the regression analysis and 43·3 the mean albumin concentration in the population.[8]

Body mass index, used as an index of obesity, was defined as weight (kg)/height (m)^2. Blood pressure was measured in the supine position after 10 minutes' rest