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Original article

The consumption of bread enriched with betaglucan reduces LDL-cholesterol and improves insulin resistance in patients with type 2 diabetes

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Abstract

Aim. – Previous studies have shown that the water-soluble dietary fibre betaglucan, a natural component of oats, reduces cholesterol and postprandial hyperglycaemia. The aim of the present study was to investigate the effect of betaglucan-enriched bread consumption on the lipid profile and glucose homoeostasis of patients with type 2 diabetes (T2D).

Methods. – We conducted a randomized, double-blind study in which 46 patients with T2D and LDL-C greater than 3.37 mmol/l (130 mg/dl) were randomized to incorporate into their diet, for 3 weeks, either bread enriched with betaglucan (providing 3 g/day of betaglucan) or white bread without betaglucan.

Results. – The consumption of bread containing betaglucan led to significant reductions (vs the control group) in LDL-C of 0.66 mmol/l (15.79%) versus 0.11 mmol/l (2.71%) ($P = 0.009$), in total cholesterol of 0.80 mmol/l (12.80%) versus 0.12 mmol/l (1.88%) ($P = 0.006$), in Fasting plasma insulin (FPI) of 3.23 μU/ml versus an increase of 3.77 μU/ml ($P = 0.03$) and in Homa-IR (Homoeostasis model assessment–insulin resistance) by 2.08 versus an increase of 1.33 ($P = 0.04$).

Conclusions. – Betaglucan enriched bread may contribute to the improvement of the lipid profile and insulin resistance in patients with T2D.

Keywords: Betaglucan; Oat bran; Type 2 diabetes; Cholesterol; Insulin resistance

Résumé

Le pain enrichi en bêtaglucanes réduit le cholestérol-LDL et la résistance à l'insuline chez des diabétiques de type 2.

Objectif. – La réduction du cholestérol et de la glycémie post-prandiale est un effet des bêtaglucanes (fibres alimentaires hydrosolubles), un composant naturel de l'avoine. Le but de ce travail était d'étudier les effets du pain enrichi en bêtaglucanes sur le profil lipidique et l'homéostasie du glucose chez les patients DT2.

Méthodes. – Une étude randomisée en double insu a été menée chez 46 patients atteints de DT2 et ayant une LDL-cholestérolémie supérieure ou égale à 3,37 mmol/l (130 mg/dl). Les patients ont été randomisés en deux groupes consommant quotidiennement, pendant trois semaines, soit du pain enrichi en bêtaglucanes (3 g de bêtaglucanes par jour), soit du pain blanc.

Résultats. – La consommation de pain enrichi en bêtaglucanes versus le groupe témoin a entraîné une réduction significative de LDL-C de 0,66 mmol/l (15,8 %) versus 0,11 mmol/l (2,7 %) ($P = 0{,}009$), du cholestérol total de 0,80 mmol/l (12,8 %) versus 0,12 mmol/l (1,9 %) ($P = 0{,}006$), du taux d'insuline de 3,23 μU/ml versus une augmentation de 3,77 μU/ml ($P = 0{,}03$) et du Homa-IR de 2,08 versus une augmentation de 1,33 ($P = 0{,}04$).

Conclusions. – Le pain enrichi en bêtaglucanes peut améliorer le profil lipidique ainsi que la résistance à l'insuline de patients DT2.

Mots clés : Bêtaglucanes ; Son d'avoine ; Diabète de type 2 ; Cholestérol ; Résistance à l'insuline

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1. Introduction

Betaglucan is a non-starch polysaccharide present in oats, barley, yeast, rye and mushrooms. In 1997, an intake of 3 g/day of betaglucan was recommended by the US Food and Drug Administration (FDA) via its ruling that allowed oat bran, oat flour and rolled oats to be registered as cholesterol-reducing foodstuffs [1]. This health claim was based on results from several studies showing that the consumption of oat products (rich in betaglucan) leads to a decrease in serum cholesterol [2–6]. A meta-analysis of 12 trials concluded that a daily intake of 3 g of soluble fibre from oat products for a period of 18 days to 3 months resulted in a modest, but statistically significant, reduction in total cholesterol (TC) of 0.13 mmol/l [7].

Patients with type 2 diabetes (T2D) mellitus are at high risk for cardiovascular disease (CVD) as, besides hyperglycaemia, they are often obese, and have dyslipidaemia and hypertension. The recently published American Diabetes Association (ADA) guidelines indicate that, in individuals without overt CVD, the primary goal is an LDL-cholesterol (LDL-C) level less than 2.6 mmol/l (100 mg/dl). Pharmaceutical treatment, however, is recommended in cases where the patient's response to lifestyle modifications and improved glucose control proves inadequate [8].

It has also been shown that, besides the improvement in lipid profile, betaglucan consumption can improve postprandial glycaemia and insulinaemia in people with and without T2D [9–15]. To our knowledge, the long-term effects of oat bran concentrate (OBC) products on the lipid and glucose profiles of patients with diabetes have been studied only in a small pilot study with eight patients [10]. Therefore, the aim of the present study was to investigate the effects on the lipid profile and glucose control in patients with T2D of consuming oat betaglucan-enriched bread before the introduction of any lipid-lowering medications.

2. Patients and methods

The 3-week double-blind, randomized study involved 63 subjects who regularly consumed at least 120 g/day of bread, and who were screened from a pool of patients with T2D attending the outpatients diabetes centre at Laiko University Hospital in Athens, Greece. To be included in the study, patients needed to have an LDL-C greater or equal to 3.36 mmol/l (130 mg/dl) and an HbA_{1c} less or equal to 9%, and not be receiving any lipid-lowering drugs. Patients with a history of CVD or with abnormal electrocardiography (ECG) findings at baseline were excluded from the study. All participants gave their written consent to participate in the study, which was approved by the ethics committee of Laiko Hospital.

Patients were randomized in two groups using computerized software. One group received betaglucan-enriched loaves of bread, made up of 7760 g of wheat flour, 2600 g of oat flour (OBC N15), 1100 g of leavening, 200 g of malt, 240 g of yeast, 230 g of salt and 8950 g of water. The other group received identical-looking loaves of bread, but without betaglucan, made up of the same ingredients except that all the flour was wheat flour. All loaves of both breads weighed 480 g each, and were distributed weekly by courier. Both types of bread could be found in Greek markets, but were specially prepared as identical loaves by Karamolengos SA Bakery in Athens. Both types of bread used in our study were commercially available, and so their macronutrient composition (described in Table 1) had already been assessed by the Greek general chemical state laboratory.

Table 1
Macronutrient composition of the two study loaves of bread (per 100 g).

	Betaglucan bread	Control bread
Carbohydrate (g)	25.24	48.39
Protein (g)	12.34	9.35
Fat (g)	2.20	1.10
Fibre (g)	17.59	2.60
Salt (mg)	390	393
Energy (kJ)	711.79	1025.81

The study participants were asked to visit the diabetes centre on two occasions separated by a 3-week interval. All antihypertensive and antidiabetic medications remained stable during the 3-week period. At the first visit, all participants were interviewed by a dietitian to assess their eating habits. Consequently, the dietitian provided each participant with general dietary instructions, and explained healthy nutritional choices according to the ADA and the Diabetes Nutrition Study Group (DNSG) of the European Association for the Study of Diabetes (EASD) guidelines on Medical Nutrition Therapy (MNT) for patients with diabetes [16]. However, no specific dietary plan was provided, and participants were not instructed to lose weight. The dietitian also explained how to incorporate the study bread into their daily diet (four small slices, 30 g each, providing 3 g/day of betaglucan in the betaglucan group). Due to the higher caloric and carbohydrate content of the control bread (Table 1), patients in that group were instructed to slightly reduce their carbohydrate intake from other sources. All patients were asked to record their daily bread consumption in a diary provided for this purpose.

Measurements of body weight, height, waist circumference (WC) and sitting blood pressure (BP) were obtained at each of the two scheduled visits. All biochemical measurements were obtained at both visits after a 12-hour overnight fast. Plasma glucose was measured by the hexokinase method. Glycated haemoglobin (HbA_{1c}) was measured on whole blood using the Tina-quant immunological assay, standardized according to the IFCC, and transferable to DCCT/NGSP. TC was measured using the cholesterol-oxidase method, triglycerides (TG) using the GPO-PAP method and HDL-cholesterol using the direct HDL-C clearance method. Fasting plasma insulin (FPI) was measured in duplicate using BioSource INS-Irma immunoradiometric assay kits. LDL-C was estimated by the formula: LDL-C = TC–HDL-C–TG/5. Non-HDL-C was estimated by subtracting HDL-C from TC. The Homa-IR index was computed by calculating fasting plasma glucose (FPG; mmol/l) multiplied by FPI (μU/ml) and divided by 22.8 [17].

Statistical analysis of the data was performed using the SPSS 11.5 statistical software package. All data were assessed for normal distribution of values. Categorical data were compared using the Chi^2 test, while comparisons of normally

distributed data within groups were performed by the paired-samples Student's *t* test and comparisons of normally distributed data between groups by the independent-samples Student's *t* test. Simple correlations were done using either Pearson's or Spearman's correlation coefficient as appropriate. Multivariate stepwise linear-regression analysis was used to test for independent associations. P values < 0.05 were considered statistically significant.

3. Results

Of the 46 patients randomized, 41 patients completed the study. Five were discontinued: two (both in the control group) because of increased glucose values on self-monitoring; and three (one from the betaglucan group and two from the control group) because of the inconvenience caused by the bread delivery schedules. The clinical and biochemical characteristics of those who dropped-out of the study did not differ from those of the total study population. Patients in both groups reported that they consumed more than 80% of their bread during the study. The amount of betaglucan used in the study was not associated with any adverse effects, including gastrointestinal symptoms.

The demographic, clinical and biochemical characteristics at baseline of the participants who completed the study are shown in Table 2. Patients in the betaglucan group were older and had higher body mass index (BMI) and plasma TG compared with patients in the control group.

Changes in clinical and biochemical parameters at the end of the study period are presented in Table 3. Compared with baseline, the betaglucan group showed a significant decline in BMI, WC, LDL-C, TC, non-HDL-C, FPG, HbA_{1c} and systolic BP. Although there was a decreasing trend in FPI and Homa-IR, these changes did not reach statistical significance. As for the control group, no significant changes were observed in the above parameters, although there was an increasing trend in FPI and Homa-IR (Table 3).

Comparing the changes in clinical and biochemical parameters between the two groups, we found that LDL-C, TC, non-HDL-C, FPI and Homa-IR were reduced to a significantly greater degree in the betaglucan group compared with the controls (Table 3). The ratio between TC and HDL-C (also known as

Table 2
Baseline demographic, clinical and biochemical characteristics of the study participants who completed the study.

Characteristic	Betaglucan	Control	*P*
Number of patients (*n*)	23	18	
Age (years)	60.22 (9.13)	66.50 (8.86)	0.03
Males/females (*n*)	12/11	11/7	0.27
Weight (kg)	81.64 (12.20)	74.35 (12.28)	0.07
BMI (kg/m^2)	29.61 (4.75)	27.01 (3.69)	0.03
Waist circumference (cm)	98.72 (10.16)	95.24 (9.91)	0.28
LDL-cholesterol (mmol/l)	4.18 (0.68)	4.06 (0.57)	0.56
Total cholesterol (mmol/l)	6.25 (0.69)	5.88 (0.53)	0.08
HDL-cholesterol (mmol/l)	1.28 (0.26)	1.31 (0.22)	0.77
Non-HDL cholesterol (mmol/l)	4.97 (0.74)	4.58 (0.58)	0.08
Total cholesterol/HDL-cholesterol	5.05 (1.11)	4.64 (0.96)	0.22
Triglycerides (mmol/l)	1.73 (0.96)	1.15 (0.42)	0.01
Duration of diabetes (years)	7.6 (6.0)	10.1 (8.2)	0.08
Diet/oral antidiabetic drugs (*n*)	4/19	3/15	0.73
Fasting plasma glucose (mmol/l)	8.81 (2.39)	7.73 (2.63)	0.18
HbA_{1c} (%)	7.29 (1.61)	6.91 (1.50)	0.45
Fasting plasma insulin (μU/ml)	18.56 (21.03)	10.75 (5.10)	0.11
Homa-IR	6.36 (4.18)	3.60 (1.85)	0.12
Presence of hypertension (*n*)	15	16	0.39
Systolic blood pressure (mmHg)	141.62 (17.9)	131.19 (11.0)	0.08
Diastolic blood pressure (mmHg)	84.84 (9.83)	80.51 (9.06)	0.32

Data are presented as mean values (SD) or *n*; Homa–IR: Homoeostasis model assessment–insulin resistance.

Table 3
Changes in clinical and metabolic parameters between baseline and the end of the study.

	Betaglucan group		Control group		
	Change	P_1	Change	P_2	P_3
Weight (kg)	−1.03 (1.64)	0.006	−0.39 (1.18)	0.18	0.28
BMI (kg/m^2)	−0.38 (0.60)	0.007	−0.12 (0.40)	0.22	0.17
Waist circumference (cm)	−1.63 (3.19)	0.02	−0.61 (2.19)	0.25	0.76
LDL-cholesterol (mmol/l)	−0.66 (0.80)	0.001	−0.11 (0.45)	0.32	0.009
Total cholesterol (mmol/l)	−0.80 (1.03)	0.001	−0.12 (0.38)	0.22	0.006
HDL-cholesterol (mmol/l)	−0.05 (0.19)	0.23	−0.03 (0.25)	0.59	0.81
Non-HDL cholesterol (mmol/l)	−0.75 (0.94)	0.001	−0.08 (0.45)	0.44	0.005
Total cholesterol/HDL cholesterol	−0.50 (0.73)	0.004	−0.21 (1.67)	0.60	0.07
Triglycerides (mmol/l)	−0.21 (0.93)	0.29	−0.06 (0.29)	0.43	0.24
Fasting plasma glucose (mmol/l)	−0.72 (0.93)	0.04	−0.07 (1.41)	0.83	0.18
HbA_{1c} (%)	−0.28 (0.35)	0.002	−0.13 (0.45)	0.28	0.44
Fasting plasma insulin (μU/ml)	−3.23 (10.78)	0.20	3.77 (7.45)	0.06	0.03
Homa-IR	−2.08 (5.93)	0.13	1.33 (2.80)	0.08	0.04
Systolic blood pressure (mmHg)	−9.14 (13.66)	0.005	−1.24 (10.31)	0.63	0.06
Diastolic blood pressure (mmHg)	−0.77 (10.20)	0.72	0.24 (9.28)	0.92	0.75
Hypertensive patients					
Systolic blood pressure (mmHg)	−12.16 (13.23)	0.001	−2.0 (12.14)	0.27	0.03
Diastolic blood pressure (mmHg)	−0.84 (9.96)	0.66	−0.17 (8.87)	0.85	0.69

Data are presented as means (SD); P_1: change from baseline in betaglucan group; P_2: change from baseline in control group; P_3: difference between betaglucan and control groups; Homa–IR: homoeostasis model assessment–insulin resistance.

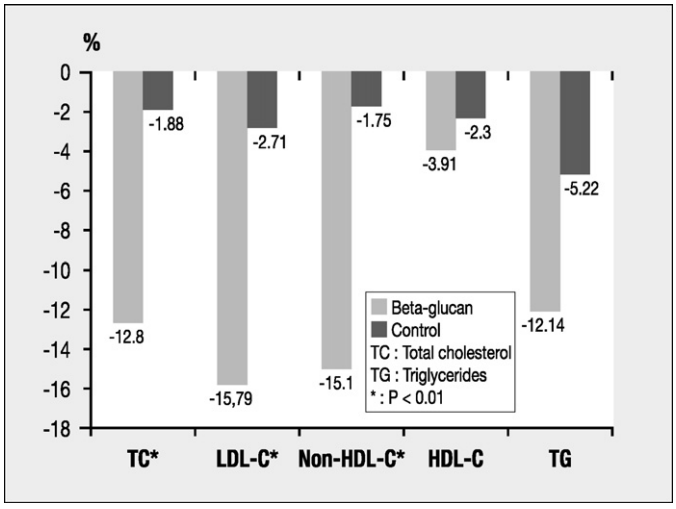

Fig. 1. Percentage changes in lipid parameters during the 3-week study period.

Table 4
Multivariate linear-regression model showing the difference between LDL-C (mg/dl) at baseline and at the end of the 3-week study ($LDL\text{-}C_b$–$LDL\text{-}C_e$) as the dependent variable.

Variable	B	SE	β	*P*
Age	0.02	0.40	0.007	0.96
Gender (female)	9.48	7.24	0.17	0.20
LDL-C at baseline	0.49	0.15	0.43	0.002
Betaglucan bread (yes)	16.47	7.84	0.30	0.04
BMI reduction	14.44	6.90	0.28	0.04

B: regression coefficient; SE:standard error of B; β:standardized regression coefficient.

the "atherogenic index") decreased significantly in the betaglucan group compared with the controls. The percentage changes in all lipid parameters during the study are shown in Fig. 1.

Overall, patients receiving betaglucan had a greater (borderline statistical significance) reduction in systolic BP compared with the controls (Table 3). In the subgroup of hypertensive patients ($n = 12$ in the betaglucan group; $n = 11$ in the control group), this difference was clearly statistically significant (12.16 mmHg vs 2.0 mmHg, $P = 0.03$).

Univariate analyses revealed a statistically significant, positive correlation between the reduction in BMI and reductions in LDL-C and TC for the total population ($r = 0.47$, $P = 0.002$ and $r = 0.33$, $P = 0.04$, respectively). A multivariate linear-regression model was created, using the change in LDL-C (LDL-C at baseline minus LDL-C at the end) as the dependent variable (Table 4). In this model, the consumption of betaglucan-enriched bread was independently associated with a reduction in LDL-C. BMI reduction and a high baseline LDL-C were also independent predictors of reduced LDL-C.

4. Discussion

The effects of a betaglucan-enriched diet on the lipid profile and glucose control of patients with T2D were examined in a pilot study [10] of eight male patients who consumed 9 g/day of soluble fibre from OBC, incorporated into bread and bread products, for a total period of 24 weeks. Their TC and LDL-C plasma levels decreased significantly by 14 and 24%, respectively, reductions that were higher than those observed in our present study, probably due to the lower consumption of soluble fibre (3 g/day of betaglucan). This interventional intake was chosen on the basis of the FDA's health claim regarding the consumption of betaglucan from whole oats [1]. In addition, the results of several studies examining the cholesterol-lowering effects of betaglucan derived from oat products were inconsistent, with reductions of TC ranging from −18% to 0. Furthermore, many of these studies provided no information on the betaglucan content of their experimental products. In the meta-analysis by Ripsin et al. [7], a dose–response relationship was observed, particularly when the betaglucan dose exceeded 3 g/day. The carefully designed study by Davidson et al. [5] examined the cholesterol-lowering dose–response effect of betaglucan, and found that a daily intake similar to that of our study (4.0 g of betaglucan) for 6 weeks decreased TC by 9.5% and LDL-C by 15.9%. However, when 6 g/day of betaglucan were consumed, the cholesterol-lowering effect did not increase. These results are similar to those observed in our study, where the net decrease in TC and LDL-C (after subtracting the control bread effect) was 10.9% and 13.08%, respectively. This decrease (by 15.79% in LDL-C and 12.80% in TC) is clinically important as it has been shown that, for every 10% reduction in TC, coronary heart disease mortality is reduced by 15% and total mortality by 11% [18].

The non-HDL-C was also significantly reduced in patients receiving betaglucan compared with controls (Table 3). Indeed, it has been suggested that non-HDL-C may be especially useful in predicting CVD risk in patients with T2D [19]. It could also be used as a target for cholesterol-lowering therapy when TG levels exceed 2.26 mmol/l (200 mg/dl) [20]. As with most previous observations, HDL-C did not change significantly from baseline in either of our study groups. However, the ratio between TC and HDL-C (the atherogenic index) was significantly decreased with betaglucan compared with the controls (Table 3). It has even been suggested that this ratio has greater predictive value for CVD than either serum TC or LDL-C [21].

The cholesterol-lowering effect of betaglucan may be explained by the increased binding of bile acids in the intestinal lumen, leading to a decrease in the enterohepatic circulation of bile acids and a subsequent increase in hepatic conversion of cholesterol to bile acids [22,23]. Another suggested mechanism is that the presence of betaglucan soluble fibres in the small intestine leads to the formation of a thick, undisturbed water layer adjacent to the mucosa, which may act as a physical barrier against the absorption of bile acids [24].

During our 3-week study, patients in both groups lost weight (1.03 kg in the betaglucan group and 0.39 kg in the controls), with the weight reduction being statistically significant only with betaglucan intake. The between-group difference, however, was not significant (Table 3). It is difficult to explain the cause(s) of the observed weight losses, as no specific energy plan was given to our patients during the study and their everyday food intake was not recorded. Although this is a limitation of our study, we did not ask patients to follow a specific energy-intake

plan because we wished to examine the effect of incorporating betaglucan-enriched bread into their usual everyday lifestyle. In other words, our clinical study aimed to investigate the effects of advising people with T2D during their regular visits to the dietitian to consume oat betaglucan-enriched bread instead of white-flour bread (on top of the usual dietary instructions).

Another study limitation is that physical activity was not recorded during the 3-week study period.

The weight loss in both our groups may also have been partly due to a higher motivation of the patients as a result of their conversation with a dietitian, despite the fact that the dietitian gave them no instructions to lose weight. The higher weight reduction in the betaglucan group could also be partly attributed to the lower caloric content of the betaglucan-enriched bread. However, this was only a 318.21 kJ (76 Kcal) deficit per day, resulting in a 6682.45 kJ (1596 Kcal) total deficit over 3 weeks (the total duration of the study). Furthermore, as already explained above, patients in the control group were instructed to reduce their carbohydrate intake from other sources to compensate for their higher-calorie bread. In a recent 8-week study, it was shown that men following the American Heart Association (AHA) Step II diet plus bread containing 6 g/day of betaglucan experienced a significantly greater weight loss than those on the AHA diet alone [25]. Thus, we cannot rule out the possible benefit of betaglucan bread consumption on weight reduction, although further studies are needed to explore this possibility.

The observed LDL-C and TC reductions were positively correlated with the reduction in BMI, and baseline LDL-C and TC values, respectively. It is well known from previous studies that weight loss is accompanied by a decline in LDL-C and TC. However, 0.8 and 1.0% decreases in LDL-C and TC, respectively, may be expected for every 1.0 kg of weight lost [26]. In our study, patients in the betaglucan group experienced a mean weight loss of 1.03 kg (1.27% of initial body weight), while the observed decrease in their LDL-C was 15.71%. In the controls, a mean weight loss of 0.39 kg (0.53% of initial body weight) was accompanied by a 2.7% reduction of LDL-C. On multivariate linear-regression analyses after adjusting for age and gender, the consumption of betaglucan-enriched bread, the amount of BMI reduction and the LDL-C value at baseline were independent predictors of LDL-C decline during the study (Table 4). LDL-C was included in the model because the betaglucan group had slightly higher (but not statistically significant) levels of LDL-C at baseline (Table 2). When not included, the beneficial effect of betaglucan consumption was even greater (beta coefficient: 0.344, $P = 0.023$).

At the end of the present study, we observed interesting changes in diabetes-related parameters. HbA_{1c} decreased significantly in the betaglucan group by 0.28%, while the control group showed a (non-significant) reduction of 0.13%. The between-group difference was not statistically significant. In the small pilot study by Pick et al. [10], the daily glucose profile was attenuated by 46% in men with T2D when white bread was replaced by bread products containing OBC for 24 weeks. According to our results, FPG was significantly reduced in the betaglucan group by 0.72 mmol/l ($P = 0.04$). Nevertheless, although FPG remained virtually unchanged in the controls (−0.07 mmol/l), the between-group difference was not significant, probably due to the high standard deviation of glucose changes in both groups (Table 3). However, we observed statistically significant changes between the two groups in fasting serum insulin and Homa-IR, both measures of insulin resistance (IR). These parameters showed a decreasing trend in the betaglucan group and an increasing trend in the controls (Table 3). It should be noted that the gold-standard method for assessing IR is the euglycaemic-clamp technique. While our results should be interpreted with caution, it has been shown that the Homa-IR index correlates sufficiently well with measures of IR derived from euglycaemic-clamp techniques [17].

The reduction of IR indices in the betaglucan group compared with the controls may be partly attributed to betaglucan consumption. Betaglucan has been shown to reduce postprandial glycaemia and insulinaemia in individuals both with and without T2D [9–15]. Several amounts of betaglucan supplementation have been used. Breakfast cereals enriched with 4.0 g of betaglucan decreased maximum glucose and insulin postprandial values by 38 and 34%, respectively, compared with a continental breakfast containing the same amount of carbohydrates [14]. In addition, even a small amount (1.8 g) of a betaglucan-enriched bedtime snack has been shown to significantly decrease postprandial glucose in children with type 1 diabetes [15]. It has been proposed that the increased viscosity of food in the small intestine due to the increased presence of betaglucan leads to the formation of a thick, undisturbed water layer adjacent to the mucosa. This layer may act as a physical barrier to reduce the rate of glucose absorption, leading to a lower glycaemic response and lower insulin serum concentrations [27]. In one prospective study [28], it was shown that a high intake of dietary fibre, particularly of the soluble type (50 g total fibre, 25 g of soluble fibre), improves glycaemic control and decreases hyperinsulinaemia in patients with T2D. Another factor that may have contributed to the improved glucose control in the betaglucan group is the weight loss. Patients in the betaglucan group exhibited a significant decrease in body weight (1.03 kg) at the end of the 3-week study. We found no correlation, however, between the change in BMI and HbA_{1c} reduction in these patients.

Systolic BP was significantly reduced in the betaglucan group by 9.14 mmHg, although the between-group difference was not statistically significant (Table 3). However, in patients with a history of hypertension, the difference was statistically significant (Table 3). Weight losses in both the betaglucan and control groups may partly explain the systolic BP changes. We found no correlation, however, between weight loss and systolic BP reduction in either group. Another factor which might have contributed to the systolic BP reduction is the improved insulin sensitivity in the betaglucan group compared with the controls. It had previously been shown that a diet containing soluble-fibre-rich whole oats can significantly reduce the need for antihypertensive medication and improve BP control [29].

Our results show that, in patients with T2D treated with diet or oral antidiabetic drugs and a baseline LDL-C greater than 3.37 mmol/l (130 mg/dl), the advice to consume bread containing 3 g of betaglucan from OBC daily, instead of white

bread without betaglucan, led to a significant reduction in LDL-C, TC, non-HDL-C, FPI and Homa-IR after 3 weeks. At the same time, the systolic BP of the hypertensive patients consuming betaglucan-enriched bread improved significantly compared with those eating the control bread.

In conclusion, bread enriched with betaglucan from OBC may be used as part of a medical nutritional therapy in patients with T2D, as it can contribute to improvements in lipid profile and insulin resistance.

Conflicts of Interest

All authors have no conflicts of interest to declare.

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