

1 **Effect of commercial breakfast fibre cereals compared with corn flakes on postprandial**  
2 **blood glucose, gastric emptying and satiety in healthy subjects: a blinded crossover**  
3 **randomized controlled trial**

4  
5 *Joanna Hlebowicz<sup>1</sup>≠, Jennie Wickenberg <sup>3</sup>≠, Rickard Fahlström <sup>3</sup>≠, Gassan Darwiche<sup>1</sup>≠, Ola*  
6 *Björgell<sup>2</sup>≠, Lars-Olof Almér<sup>1</sup>≠*

7  
8 *<sup>1</sup>Dept. of Medicine, Malmö University Hospital, University of Lund, +46-40-331000*

9 *<sup>2</sup>Dept. of Radiology. Malmö University Hospital, University of Lund, +46-40-33100*

10 *<sup>3</sup>Medical School, Malmö Univeristy Hospital, University of Lund, +46-40-33100*

11 *≠ Contributed equally*

12  
13 *Address correspondence to Dr. Joanna Hlebowicz, Dept. of Medicine, Malmö University*  
14 *Hospital, Ingång 35, 205 02 Malmö. Telephone nr +46-40-331000, Fax nr +46-40-336208 E-*  
15 *mail: [Joanna.Hlebowicz@skane.se](mailto:Joanna.Hlebowicz@skane.se)*

16  
17 *MD, PhD, Gassan Darwiche, E-mail: [Gassan.Darwiche@skane.se](mailto:Gassan.Darwiche@skane.se)*

18 *MD, PhD, Ola Björgell, E-mail: [Ola.Bjorgell@med.lu.se](mailto:Ola.Bjorgell@med.lu.se)*

19 *MD, PhD, Lars-Olof Almér, E-mail: [Lars-Olof.Almer@med.lu.se](mailto:Lars-Olof.Almer@med.lu.se)*

20 *Student, Jennie Wickenberg, E-mail: [Mamma\\_jennie@hotmail.com](mailto:Mamma_jennie@hotmail.com)*

21 *Student, Rickard Fahlström, E-mail: [lak02rfa@student.lu.se](mailto:lak02rfa@student.lu.se)*

22  
23 *Tables 2*

24 *Figures 3*

25

## Abstract

26  
27  
28 *Background:* Dietary fibre food intake is related to a reduced risk to develop diabetes mellitus.  
29 However, mechanism of this effect is still not clear. The aim of this study was to evaluate the  
30 effect of commercial fibre cereals on the rate of gastric emptying, postprandial glucose response  
31 and satiety in healthy subjects.

32 *Methods:* Gastric emptying rate (GER) was measured by standardized real time  
33 ultrasonography. Twelve healthy subjects were assessed using a randomized crossover blinded  
34 trial. The subjects were examined after an 8 hours fast and assessment of normal fasting blood  
35 glucose level. Gastric emptying rate was calculated as the percentage change in antral cross-  
36 sectional area 15 and 90 minutes after ingestion of sour milk with cornflakes (GER1), All-Bran  
37 flakes (GER2) or wholemeal oat flakes (GER3).

38 *Results:* The median value of GER1 was 42 %, GER2 was 33 % and GER3 was 51%. The  
39 difference between the GER after ingestion of All-Bran flakes compared to wholemeal oat  
40 flakes was statistically significant ( $p < 0.05$ ). The postprandial delta blood glucose level was  
41 statistically significantly lower at 40 min and 120 min after the All-Bran flakes meal ( $p < 0.05$ ).  
42 There was no statistical significance between the cereals regarding AUCs regarding blood  
43 glucose and satiety.

44 *Conclusions:* The result of this study demonstrates that the intake of cereal bran flakes and oat  
45 flakes have no effect on the total postprandial blood glucose response or satiety when compared  
46 to corn flakes. However, this study shows that the intake of cereal bran flakes slows the GER  
47 when compared to oat flakes and corn flakes, probably due to a higher content of fibre. Since  
48 the benefit of these products does not differ regarding the glucose response and satiety on  
49 healthy subjects, they should be considered as equal in this matter.

50

## Background

51  
52  
53 In Sweden and worldwide the incidence of type 2 diabetes mellitus is increasing rapidly. To  
54 prevent development of diabetes mellitus it is recommended by the American Diabetes  
55 Association to reduce the caloric intake and consume dietary fibre and food containing whole  
56 grain [1]. An increased intake of fibre has been shown to reduce risk of diabetes [2, 3]. If low  
57 glycemic index food prevents diabetes mellitus is still unclear [2, 4-7]. However, low-glycemic  
58 index diet that reduces postprandial hyperglycemia is recommended by the American Diabetes  
59 Association (ADA) to control glycaemia in patients with diabetes [8-9].  
60 Fibres have been shown to delay gastric emptying rate, reduce the glycaemic response and  
61 delay the return of hunger in healthy subjects [10]. Another hypothesis that has been  
62 discussed is that fibre fermented in the colon by the bacterial flora release short chain fatty  
63 acids and therefore lowers postprandial glucose levels [11]. Insoluble fibres have been shown  
64 to ferment in the colon by bacteria to short-chain fatty acids [12], which leads to suppression  
65 of the hepatic glucose production and serum free fatty acids [13]. The effect of colonic  
66 fermentation, measured with breath hydrogen test, has been observed as a second meal effect  
67 of a reduced insulin and glucose response after a meal of ingestible carbohydrates [14].  
68 However, another study showed that meals with what was assumed as fermentable  
69 carbohydrates did not improve glucose or insulin response at the second meal [15]. Recently  
70 published study show that increased intake of insoluble fibre for 3 days in obese subjects with  
71 increased hydrogen breath test improved whole- body insulin sensitivity [16].  
72 The  $\beta$ -glucan effect is not fully understood. Products enriched with  $\beta$ -glucan have been shown  
73 to reduce postprandial glucose and insulinemic responses in healthy subjects [17-19] and in  
74 type 2 diabetes patients [20-22]. Reduced postprandial glucose and insulin concentrations after  
75 consumption of viscous types of fibres have been discussed to be caused by delayed mouth-to

76 caecum transit and delayed absorption of glucose in the small intestine [23]. The viscosity of  
77 oat gum, an extract from oat composed of  $\beta$ -glucan, has been shown to cause a reduction in  
78 plasma glucose and insulin levels [24]. However, lower postprandial glucose and insulin  
79 concentrations have not been shown result from the effect of fermentation of  $\beta$ -glucan in the  
80 colon [25]. Another mechanism that has been discussed is that  $\beta$ -glucan delays gastric  
81 emptying. The result of one of our not yet published study demonstrates that intake of  $\beta$ -glucan  
82 reduces postprandial blood glucose without affecting gastric emptying or satiety in healthy  
83 subjects.

84 Healthy subjects are recommended to consume products with fibres to prevent development  
85 of diabetes mellitus. Also, patients with diabetes consume commercial products with fibres  
86 and low glycemic food to control the blood glucose levels. This study was designed to  
87 determine whether there is a delay in gastric emptying, affecting postprandial blood glucose  
88 levels and satiety after consumption of commercial popular fibre cereals in healthy subjects.

89

90

## Methods

91

92 Twelve healthy subjects (six men and six women; mean age  $28 \pm 4$  years [range 23- 36 years];  
93 mean BMI  $22 \pm 2$  kg/m<sup>2</sup> [range 19 – 24 kg/m<sup>2</sup>], without symptoms or a prior history of  
94 gastrointestinal disease, abdominal surgery or diabetes mellitus were included in the study.

95 One subject had been appendectomized. None of the subjects used any drugs the examination  
96 day. Three of the women including one with polycystic ovary syndrome had birth control  
97 medication. The subject with the polycystic ovary syndrome had a BMI 21 kg/m<sup>2</sup> and was  
98 previously examined with a glucose tolerance test that was normal. All subjects were  
99 recruited from the population in a southern county of Sweden. Four of the subjects were  
100 smokers and two were snuff users. The subjects were examined between 8:00 and 10:00 a.m

101 after an 8 h fast. Smoking and snuff-taking were prohibited for 8 h before and during the test.  
102 Each subject was checked for normal fasting blood glucose concentration on the day of the  
103 examination. If the subjects on the study day reported symptoms from the gastrointestinal  
104 tract (diarrhoea or constipation) the examination was postponed. The test meals consisted of  
105 300 g sour milk (Skånemejerier, 205 03 Malmö, Sweden) (caloric value 135 kcal) and 50 g  
106 All-Bran Kellogg's (Kellogg's, Sverige Konsumentkontakt, Box 742, 194 27 Upplands  
107 Väsby, Sweden) (caloric value 163 kcal) or Wholemeal Oatflakes (Frebaco Kvarn AB, BOX  
108 878, 531 18 Lidköping, Sweden) (caloric value 185 kcal. The reference meal, consisting of 50  
109 g Kellogg's cornflakes (Nordisk Kellogg's, Sverige Konsumentkontakt, Box 742, 194 27  
110 Upplands Väsby, Sweden) (caloric value 185 kcal), also had the same brand and quantity sour  
111 milk as the test meal (Table 1). The meals were served in a random order more than one week  
112 apart. Each meal was ingested within 5 minutes.

113 GER was estimated using a previously described standardised ultrasound method [26]. The  
114 sonographic examination was performed using two different ultrasound machines (Siemens  
115 Acuson Sequoia 512 and Aloka Prof. Sound) with an abdominal transducer multi-MHz. For  
116 every single calculation of gastric emptying rate the same machine was used. The  
117 measurements of the gastric antrum were performed by the same radiologist who was blinded  
118 with regard to the meals. At each observation of the gastric antrum the abdominal aorta and  
119 the left lobe of the liver were used as internal landmarks. The subjects were examined in a  
120 lying position, but were sitting between the examinations. The measurements were taken 15  
121 and 90 minutes after the end of meal ingestion. Gastric emptying was expressed as the  
122 percentage change of the antral cross-sectional area from 15 to 90 min. At each examination  
123 three measurements of the longitudinal (d1) and anteroposterior (d2) diameters were done and  
124 mean values were used to calculate the cross-section area of the gastric antrum using  
125 following formula:

126  
127  
128  
129  
130  
131  
132  
133  
134  
135  
136  
137  
138  
139  
140  
141  
142  
143  
144  
145  
146  
147  
148  
149  
150

$$\text{Antrum area} = \pi \times r^2 = \pi \times d1 / 2 \times d2 / 2 = \pi \times d1 \times d2 / 4$$

The gastric emptying (GER) was calculated using following formula:

$$\text{GER} = [1 - (\text{Antrum area 90 min} / \text{Antrum area 15 min})] \times 100$$

Finger-prick capillary samples were taken before and 0, 20, 30, 40, 60, 80, 100 and 120 min after the end of the meal to measure glucose. Blood glucose concentrations were measured with HemoCue Glucose system (HemoCue AB, Ängelholm, Sweden). Validated satiety score scale was used according to the method of Haber et al on the basis of a scoring system with grades from -10 (extreme hunger) to 10 (extreme satiety) [27]. Satiety score were estimated before the meal and at 0, 20, 30, 40, 60, 80, 100 and 120 min after the end of the meal by using a scoring graded from -10 for extreme hunger, to 10 for extreme satiety.

The study was performed according to the Helsinki declaration.

Median values with quartiles (q1 to q3) are presented for the antral cross-sectional areas and the GER. The areas under the curves (AUCs) for each subject were determined for the delta blood glucose and satiety (Graph Pad PRISM, version 4, San Diego). The area under the curve was calculated above zero. The AUCs values are presented as means  $\pm$  SEMs. All statistical calculations were performed in SPSS for Windows. Significant differences of GER, gastric antral cross-sectional areas, delta blood glucose and AUCs were evaluated with Wilcoxon t-test. Values of  $P < 0.05$  were considered significant.

151  
152  
153  
154  
155  
156  
157  
158  
159  
160  
161  
162  
163  
164  
165  
166  
167  
168  
169  
170  
171  
172  
173  
174  
175

## Results

### Postprandial blood glucose response

Ingestion of Kellogg's All-Bran Flakes resulted in a significantly lower blood glucose response in the initial postprandial phase (40 min) than did the reference meal Kellogg's Corn Flakes ( $p < 0.05$ ) (**Figure 1**). Ingestion of Kellogg's All-Bran Flakes resulted in a significantly lower blood glucose response in the late postprandial phase (120 min) than did Frabaco Wholemeal Oat Flakes ( $p < 0.05$ ) (**Figure 1**). However, the blood glucose AUCs did not differ significantly between Kellogg's All-Bran Flakes, Frabaco Wholemeal Oat Flakes and Kellogg's Corn Flakes (**Table 1**).

### Gastric emptying rate

The median values of the antral cross-sectional area after ingestion of the Kellogg's All-Bran meal were  $641 \pm 197 \text{ mm}^2$  (range 418 to 1035  $\text{mm}^2$ ) ( $q_1 = 524 \text{ mm}^2$ ,  $q_3 = 824 \text{ mm}^2$ ) and  $331 \pm 253 \text{ mm}^2$  (range 137 to 924  $\text{mm}^2$ ) at 15 and 90 min respectively after the end of the study meal. In the same subjects the median values of the antral cross-sectional area after the ingestion of the Frabaco Wholemeal Oat flakes meal were  $743 \pm 240 \text{ mm}^2$  (range 498 to 1188  $\text{mm}^2$ ) ( $q_1 = 568 \text{ mm}^2$ ,  $q_3 = 1003 \text{ mm}^2$ ) and  $331 \pm 226 \text{ mm}^2$  (range 149 to 852  $\text{mm}^2$ ) ( $q_1 = 205 \text{ mm}^2$ ,  $q_3 = 626 \text{ mm}^2$ ) at 15 and 90 min after the end of the meal. In the same subjects the median values of the antral cross-sectional area after the ingestion of the Kellogg's cornflakes meal were  $716 \pm 187 \text{ mm}^2$  (range 170 to 740  $\text{mm}^2$ ) ( $q_1 = 436 \text{ mm}^2$ ,  $q_3 = 905 \text{ mm}^2$ ) and  $481 \pm 227 \text{ mm}^2$  (range 380 to 1008  $\text{mm}^2$ ) ( $q_1 = 251 \text{ mm}^2$ ,  $q_3 = 495 \text{ mm}^2$ ) at 15 and 90 min after the end of the meal. There were no significant differences between gastric antral cross-sectional at 15 or 90 min between

176 the different meals. The median value of GER after the Kellogg's All-Bran meal was estimated  
177 at 28% (range -8% to 73%) (q1= 15%, q3= 56%) compared to the median value of GER after  
178 the Frebaco Wholemeal Oat Flakes meal which was estimated at 50 % (range 25% to 73 %)  
179 (q1= 38%, q3= 70%). The median value of GER after the Kellogg's cornflakes meal was  
180 estimated at 39 % (range 21% to 73 %) (q1= 31%, q3= 49%). Kellogg's All-Bran meal had a  
181 significantly lower gastric emptying rate compared to Frebaco Wholemeal Oat Flakes ( $p < 0.05$ )  
182 (**Figure 2**). There were no significant differences between Kellogg's All-Bran or Frebaco  
183 Wholemeal Oat Flakes compared to Kellogg's cornflakes considering gastric emptying rates  
184 (Figure 2).

185

186

### Satiety

187

188 Ingestion of Kellogg's All-Bran Flakes or Frebaco Wholemeal Oat Flakes did not result in a  
189 significantly higher satiety compared to the reference Kellogg's cornflakes meal (**Table 3**,  
190 **Figure 3**).

191

192

### Discussion

193

194 The results from this study show that the presence of fibres in a semisolid meal does not  
195 affect total postprandial blood glucose or satiety responses in healthy subjects, despite the  
196 delay in gastric emptying for the product containing the higher amount of fibre (All-Bran  
197 Flakes).

198 This study was designed to evaluate the effect of commercial cereals on blood glucose, satiety  
199 and the gastric emptying rate. The postprandial glucose response was reduced at the initial  
200 postprandial phase after the All-Bran Regular meal compared to the Kellogg's cornflakes

201 meal. Similar results have previously been presented showing a lower early postprandial  
202 blood glucose response after the intake of cereal bran flakes when compared to corn flakes  
203 [28]. In the same study it was shown that this lower postprandial blood glucose response was  
204 related to a higher initial postprandial plasma insulin response after a meal composed of  
205 119.2g Kellogg's All-Bran Flakes compared to a meal of 60.9g Kellogg's cornflakes [28].  
206 However the total postprandial insulin AUC was the same for the two meals and gastric  
207 emptying was not measured [28]. It's obvious that healthy subjects have a sufficient insulin  
208 response giving a normalized blood glucose response thus also giving similar total  
209 postprandial blood glucose AUC for the products in our study. Besides those factors the All-  
210 Bran meal had a smaller amount of carbohydrates than the cornflakes meal. However, if we  
211 had used the same amount of carbohydrates from each cereal brand in our study we would  
212 have had a larger difference in energy, which could potentially influence the results on GER.  
213 An increased caloric value of a meal can delay the gastric emptying rate [29]. The lowest total  
214 caloric value had the All-Bran Regular meal, 298 kcal compared to the other meals 320 kcal.  
215 Still, the difference between GER was only significant between the All-Bran Regular meal  
216 and Wholemeal Oat Flakes, probably due to the higher amount of fibre in the all bran meal.  
217 Also, the glucose response was reduced at the end of the postprandial phase after the All-Bran  
218 meal compared to the Oat meal (Figure 1) which could be related to the lower gastric  
219 emptying rate (Figure 3). However, in patients with type 2 diabetes oat bran flour containing  
220 9.4 g  $\beta$ -glucan lowered the postprandial glycaemia [22]. In the same study on type 2 diabetes  
221 patients using oat bran crisps containing 3.0g  $\beta$ -glucan was also reduced the postprandial  
222 glycaemia but the reduction was only half as large as compared to oat bran flour containing  
223 9.4 g  $\beta$ -glucan [22]. It has previously been shown in type 2 diabetes patients that each gram of  
224  $\beta$ -glucan in food can lower the GI by four GI units [21]. The Frebaco Wholemeal Oat Flakes  
225 meal contained only 0.5 g  $\beta$ -glucan. Probably was the amount of  $\beta$ -glucan too small to affect

226 the blood glucose response. In this study we could not show any significant difference in  
227 satiety despite a delayed gastric emptying after the All-Bran Flakes meal compared to  
228 Wholemeal Oat Flakes. A delay in gastric emptying rate has previously been shown to  
229 increase satiety [30]. In one of our not yet published studies we could show that the reduction  
230 in postprandial glucose responses after meal with 4 g  $\beta$ -glucan compared to corn flakes in  
231 healthy subjects could not be explained by delayed gastric emptying rate.

232 The American Diabetes Association (ADA) recommends an intake of 14g fibre/1.000 kcal  
233 and foods with whole grains to prevent diabetes [1]. Intake of total dietary fibre, particularly  
234 insoluble and cereal fibre has been shown to have an inverse association with diabetes type 2  
235 [2]. Insoluble fibre and fibres from fruit, vegetables, or legumes has been shown to be  
236 unrelated to diabetes [2]. It is still unclear if low glycemic index food prevents diabetes  
237 mellitus but ADA recommends low-glycemic index foods that are rich in fibre [1]. However,  
238 the composition of the commercial product should be of greater importance rather than the  
239 fibre content solely.

240

## 241 **Conclusions**

242

243 The result of this study demonstrates that the intake of cereal bran flakes and oat flakes have  
244 no effect on the total postprandial blood glucose response or satiety when compared to corn  
245 flakes. However, this study shows that the intake of cereal bran flakes slow the GER when  
246 compared to oat flakes and corn flakes, probably due to a higher content of fibre. Since the  
247 benefit of these products does not differ regarding the glucose response and satiety on healthy  
248 subjects, they should be considered as equal in this matter.

249

250

### Competing interest

251

252 All author(s) declare that they have no competing interest.

253

254

### Author's contribution

255

256 JH participated in the design of the study, performed the statistical calculations and the graphs  
257 and drafted the manuscript. RF and JW in the design of the study, recruited subjects, collected  
258 the data and drafted the manuscript. GD participated in the design of the study, performed the  
259 statistical calculations and the graphs, paid for the study and participated in drafting of the  
260 manuscript. OB participated in the design of the study and performed the ultrasound  
261 examinations. LOA participated in the design of the study and drafting of the manuscript. All  
262 authors read and approved the final manuscript. All authors lacked any conflict of interest.

263

264

### Referenses

265

- 266 1. Bantle JP W-RJ, Albright AL, Arovian CM, Clark NG, Franz MJ, Hoogwerf BJ,  
267 Lichtenstein AH, Mayer-Davis E, Mooradian AD, Wheeler ML. **Nutrition**  
268 **recommendations and interventions for Diabetes-2006: a position statement of**  
269 **the American diabetes association.** *Diabetes care* 2006, **29**(9):2140-2157.
- 270 2. Meyer KA, Kushi LH, Jacobs DR, Jr., Slavin J, Sellers TA, Folsom AR.  
271 **Carbohydrates, dietary fibre, and incident type 2 diabetes in older women.** *Am J*  
272 *Clin Nutr* 2000, **71**(4):921-930.

- 273 3. Schulze MB, Liu S, Rimm EB, Manson JE, Willett WC, Hu FB. **Glycemic index,**  
274 **glycemic load, and dietary fibre intake and incidence of type 2 diabetes in**  
275 **younger and middle-aged women.** *Am J Clin Nutr* 2004, **80**(2):348-356.
- 276 4. Janket SJ, Manson JE, Sesso H, Buring JE, Liu S. **A prospective study of sugar**  
277 **intake and risk of type 2 diabetes in women.** *Diabetes Care* 2003, **26**(4):1008-1015.
- 278 5. Salmeron J, Ascherio A, Rimm EB, Colditz GA, Spiegelman D, Jenkins DJ, Stampfer  
279 MJ, Wing AL, Willett WC. **Dietary fibre, glycemic load, and risk of NIDDM in**  
280 **men.** *Diabetes Care* 1997, **20**(4):545-550.
- 281 6. Colditz GA, Manson JE, Stampfer MJ, Rosner B, Willett WC, Speizer FE. **Diet and**  
282 **risk of clinical diabetes in women.** *Am J Clin Nutr* 1992, **55**(5):1018-1023.
- 283 7. Salmeron J, Manson JE, Stampfer MJ, Colditz GA, Wing AL, Willett WC. **Dietary**  
284 **fibre, glycemic load, and risk of non-insulin-dependent diabetes mellitus in**  
285 **women.** *Jama* 1997, **277**(6):472-477.
- 286 8. Lundgren H, Bengtsson C, Blohme G, Isaksson B, Lapidus L, Lenner RA, Saaek A,  
287 Winter E. **Dietary habits and incidence of noninsulin-dependent diabetes mellitus**  
288 **in a population study of women in Gothenburg, Sweden.** *Am J Clin Nutr* 1989,  
289 **49**(4):708-712.
- 290 9. Sheard NF, Clark NG, Brand-Miller JC, Franz MJ, Pi-Sunver FX, Mayer-Davis E,  
291 Kulkarni K, Geil P. **Dietary carbohydrate (amount and type) in the prevention**  
292 **and management of diabetes: a statement by the american diabetes association.**  
293 *Diabetes Care* 2004, **27**(9):2266-2271.
- 294 10. Benini L, Castellani G, Brighenti F, Heaton KW, Brentegani MT, Casiraghi MC,  
295 Sembenini C, Pellegrini N, Fioretta A, Minniti G. **Gastric emptying of a solid meal**  
296 **is accelerated by the removal of dietary fibre naturally present in food.** *Gut* 1995,  
297 **36**(6):825-830.

- 298 11. Barry JL, Hoebler C, Macfarlane GT, Macfarlane S, Reed KA, Mortensen PB,  
299 Nordgaard I, Rowland IR, Rumney CJ. **Estimation of the fermentability of dietary**  
300 **fibre in vitro: a European interlaboratory study.** *Br J Nutr* 1995, **74(3)**:303-322.
- 301 12. Nyman M, Asp NG, Cummings J, Wiggins H. **Fermentation of dietary fibre in the**  
302 **intestinal tract: comparison between man and rat.** *Br J Nutr* 1986, **55(3)**:487-496.
- 303 13. Thorburn A, Muir J, Proietto J. **Carbohydrate fermentation decreases hepatic**  
304 **glucose output in healthy subjects.** *Metabolism* 1993, **42(6)**:780-785.
- 305 14. Brighenti F, Benini L, Del Rio D, Casiraghi C, Pellegrini N, Scazzina F, Jenkins DJ,  
306 Vantini I. **Colonic fermentation of indigestible carbohydrates contributes to the**  
307 **second-meal effect.** *Am J Clin Nutr* 2006, **83(4)**:817-822.
- 308 15. Liljeberg HG, Akerberg AK, Bjorck IM. **Effect of the glycemic index and content of**  
309 **indigestible carbohydrates of cereal-based breakfast meals on glucose tolerance**  
310 **at lunch in healthy subjects.** *Am J Clin Nutr* 1999, **69(4)**:647-55.
- 311 16. Weickert MO, Mohlig M, Schofl C, Arafat AM, Otto B, Viehoff H, Koebnick C, Kohl  
312 A, Spranger J, Pfeiffer AF. **Cereal fibre improves whole-body insulin sensitivity in**  
313 **overweight and obese women.** *Diabetes Care* 2006, **29(4)**:775-780.
- 314 17. Casiraghi MC, Garsetti M, Testolin G, Brighenti F. **Post-prandial responses to**  
315 **cereal products enriched with barley beta-glucan.** *J Am Coll Nutr* 2006, **25(4)**:313-  
316 320.
- 317 18. Bjorck M, van Rees A, Mensink RP, Onning G. **Changes in serum lipids and**  
318 **postprandial glucose and insulin concentrations after consumption of beverages**  
319 **with beta-glucans from oats or barley: a randomised dose-controlled trial.** *Eur J*  
320 *Clin Nutr* 2005, **59(11)**:1272-1281.

- 321 19. Makelainen H, Anttila H, Sihvonen J, Hietanen RM, Tahvonen R, Salminen E, Mikola  
322 M, Sontag-Strohm T. **The effect of beta-glucan on the glycemic and insulin index.**  
323 *Eur J Clin Nutr* 2006.
- 324 20. Tappy L, Gugolz E, Wursch P. **Effects of breakfast cereals containing various**  
325 **amounts of beta-glucan fibres on plasma glucose and insulin responses in**  
326 **NIDDM subjects.** *Diabetes Care* 1996, **19**(8):831-834.
- 327 21. Jenkins AL, Jenkins DJ, Zdravkovic U, Wursch P, Vuksan V. **Depression of the**  
328 **glycemic index by high levels of beta-glucan fibre in two functional foods tested**  
329 **in type 2 diabetes.** *Eur J Clin Nutr* 2002, **56**(7):622-628.
- 330 22. Tapola N, Karvonen H, Niskanen L, Mikola M, Sarkkinen E. **Glycemic responses of**  
331 **oat bran products in type 2 diabetic patients.** *Nutr Metab Cardiovasc Dis* 2005,  
332 **15**(4):255-261.
- 333 23. Jenkins DJ, Wolever TM, Leeds AR, Gassull MA, Haisman P, Dilawari J, Goff DV,  
334 Metz GL, Alberti KG. **Dietary fibres, fibre analogues, and glucose tolerance:**  
335 **importance of viscosity.** *Br Med J* 1978, **1**(6124):1392-1394.
- 336 24. Wood PJ, Braaten JT, Scott FW, Riedel KD, Wolynetz MS, Collins MW. **Effect of**  
337 **dose and modification of viscous properties of oat gum on plasma glucose and**  
338 **insulin following an oral glucose load.** *Br J Nutr* 1994, **72**(5):731-743.
- 339 25. Battilana P, Ornstein K, Minehira K, Schwarz JM, Acheson K, Schneiter P, Burri J,  
340 Jequier E, Tappy L. **Mechanisms of action of beta-glucan in postprandial glucose**  
341 **metabolism in healthy men.** *Eur J Clin Nutr* 2001, **55**(5):327-333.
- 342 26. Darwiche G, Almér L, Björgell O, Cederholm C, Nilsson P. **Measurement of Gastric**  
343 **Emptying by Standardized Real-Time Ultrasonography in Healthy Subjects and**  
344 **Diabetic Patients.** *Journal of Ultrasound in Medicine* 1999, **18**(10):673-682

- 345 27. Haber GB, Heaton KW, Murphy D, Burroughs LF. **Depletion and disruption of**  
346 **dietary fibre. Effects on satiety, plasma-glucose, and serum-insulin.** *Lancet* 1977,  
347 **2(8040):679-82.**
- 348 28. Schenk S, Davidson CJ, Zderic TW, Byerley LO, Coyle EF. **Different glyceimic**  
349 **indexes of breakfast cereals are not due to glucose entry into blood but to glucose**  
350 **removal by tissue.** *Am J Clin Nutr* 2003, **78(4):742-748.**
- 351 29. Calbet JA, MacLean DA. **Role of caloric content on gastric emptying in humans.** *J*  
352 *Physiol* 1997, **498**( Pt 2):553-559.
- 353 30. Bergmann JF, Chassany O, Petit A, Triki R, Caulin C, Segrestaa JM. **Correlation**  
354 **between echographic gastric emptying and appetite: influence of psyllium.** *Gut*  
355 1992, **33(8):1042-1043.**
- 356
- 357
- 358
- 359
- 360
- 361
- 362
- 363
- 364
- 365
- 366
- 367
- 368
- 369

370 **Table 1.** Nutrient composition of the test product portions.

371

	Sour Milk	Frebaco	Kellogg's	Kellogg's
		Oat Flakes	All-Bran Regular Flakes	Cornflakes
	300 g	50g	50g	50g
Total energy (kcal)	135	185	163	185
Total protein (g)	12	6	5	3.5
Total fat (g)	1.5	2	1	0.35
Total Carbohydrate (g)	18	35.5	33.5	42
Sugar (g)	15	0.75	11	4
Total Fibre (g)		4	7.5	1.5
$\beta$ -glucan (g)		0.5		

372

373

374

375

376

377

378

379

380

381

382

383

384

385 **Table 2.** Postprandial blood glucose areas under the curve after ingestion of meals consisting  
 386 of Frebaco Wholemeal Oat Flakes, Kellogg’s All-Bran Flakes or Kellogg’s Corn Flakes in  
 387 twelve healthy subjects <sup>1</sup>. Significant differences of postprandial blood glucose AUCs were  
 388 evaluated with Wilcoxon t-test. There were no significant differences between the AUCs.  
 389

Area under the curve	Wholemeal Oat Flakes <i>mmol * min/ L</i>	All-Bran Flakes <i>mmol * min/ L</i>	Corn Flakes <i>mmol * min/ L</i>
0 – 5 min	0.3 ± 0.1	1.3 ± 0.1	0.3 ± 0.1
0 - 25 min	21.2 ± 2.8	19.3 ± 1.4	19.3 ± 3.4
0 – 45 min	58.9 ± 7.1	53.8 ± 3.9	59.2 ± 10.2
0 - 65 min	83.0 ± 12.4	76.9 ± 7.7	93.8 ± 16.9
0 - 85 min	97.8 ± 16.3	88.7 ± 9.9	116.8 ± 21.8
0-105 min	110.1 ± 18.9	96.0 ± 10.4	124.4 ± 26.4
0 - 125 min	120.6 ± 21.5	106.8 ± 12.9	143.0 ± 26.3

390

391 <sup>1</sup> Mean ± SEM; n= 12

392

393

394

395

396

397

398

399

400 **Table 3.** Satiety area under the curve after ingestion of meals consisting of Frebaco  
 401 Wholemeal Oat Flakes, Kellogg’s All-Bran Flakes or Kellogg’s Corn Flakes in twelve  
 402 healthy subjects <sup>1</sup>. Significant differences of postprandial blood glucose AUCs were evaluated  
 403 with Wilcoxon t-test. There were no significant differences between the AUCs.  
 404

Area under the curve	Wholemeal Oat Flakes <i>cm<sup>2</sup></i>	All-Bran Flakes <i>cm<sup>2</sup></i>	Corn Flakes <i>cm<sup>2</sup></i>
0 – 5 min	14.0 ± 2.1	16.4 ± 2.4	12.5 ± 2.5
0 - 25 min	128.1 ± 18.7	148.5 ± 19.4	112.9 ± 21.1
0 – 45 min	244.0 ± 34.7	275.6 ± 34.2	206.2 ± 38.0
0 - 65 min	359.8 ± 45.8	386.4 ± 46.9	289.4 ± 52.6
0 - 85 min	459.8 ± 56.6	466.6 ± 56.1	363.5 ± 65.8
0-105 min	542.3 ± 66.1	544.9 ± 64.9	418.1 ± 75.0
0 - 125 min	602.4 ± 74.6	600.8 ± 12.9	454.6 ± 80.1

405  
 406 <sup>1</sup> Mean ± SEM; n= 12

407  
 408  
 409  
 410  
 411  
 412  
 413  
 414

415 **Figure 1.** Means ( $\pm$  SEM) incremental blood glucose concentrations in twelve healthy subjects  
416 after ingestion meals consisting of sour milk with Kellogg's All-Bran Flakes (■), Kellogg's  
417 Corn Flakes (◆) or Frebaco Wholemeal Oat Flakes (▲). Significant differences evaluated with  
418 Wilcoxon t-test. \* Kellogg's All-Bran Flakes significantly different from response compared to  
419 Kellogg's Corn Flakes ( $p < 0.05$ ). Z Kellogg's All-Bran Flakes significantly different from  
420 response to Frebaco Wholemeal Oat Flakes ( $p < 0.05$ ).

421  
422 **Figure 2.** Gastric emptying of sour milk with Kellogg's All-Bran Flakes, Frebaco Wholemeal  
423 Oat Flakes or Kellogg's Corn Flakes, estimated as gastric emptying rate (GER), in twelve  
424 healthy subjects. The median, minimum (Min), and maximum (Max) values and the values of  
425 the first (q1) and the third (q3) quartiles are shown. Significant differences were evaluated with  
426 Wilcoxon t-test. Kellogg's All-Bran Flakes significantly different from response to Frebaco  
427 Wholemeal Oat Flakes ( $p < 0.05$ )

428  
429 **Figure 3.** Means ( $\pm$  SEM) incremental satiety scores in twelve healthy subjects after ingestion  
430 meals consisting of sour milk with Kellogg's All-Bran Flakes (■), Kellogg's Corn Flakes (◆) or  
431 Frebaco Wholemeal Oat Flakes (▲). Significant differences evaluated with Wilcoxon t-test.  
432 There were no significant differences between the mean incremental satiety scores.

433  
434  
435

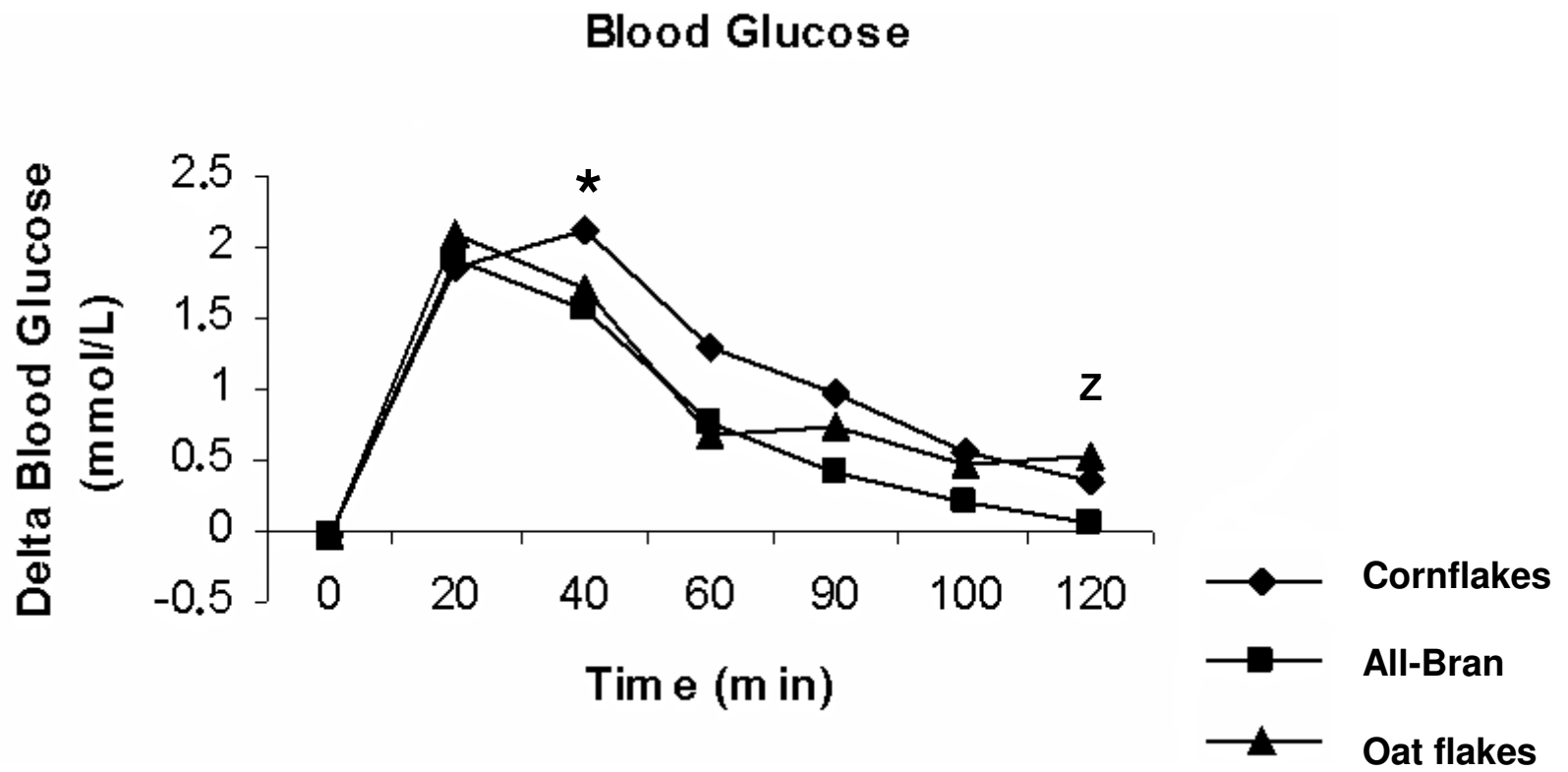


Figure 1

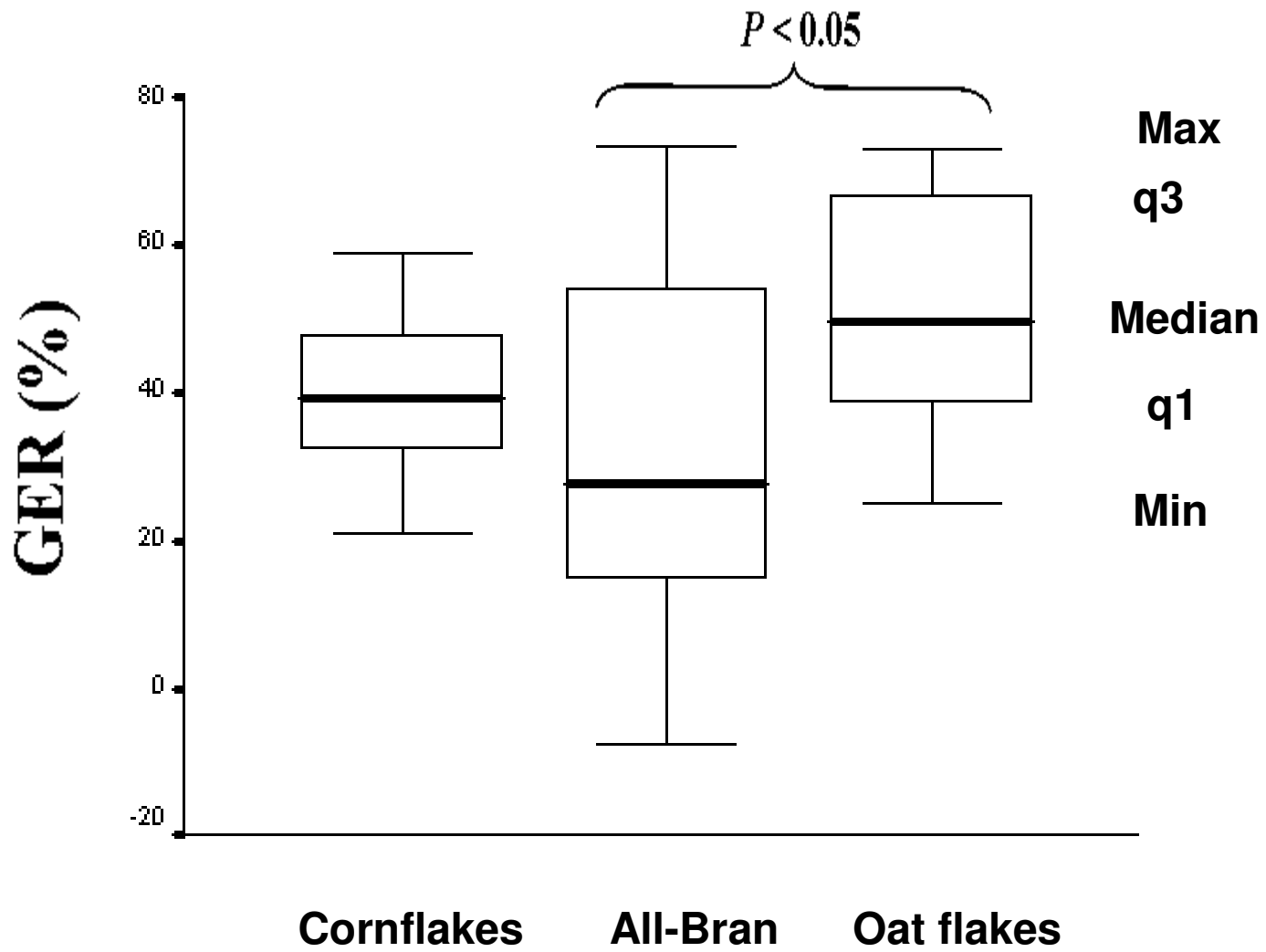


Figure 2

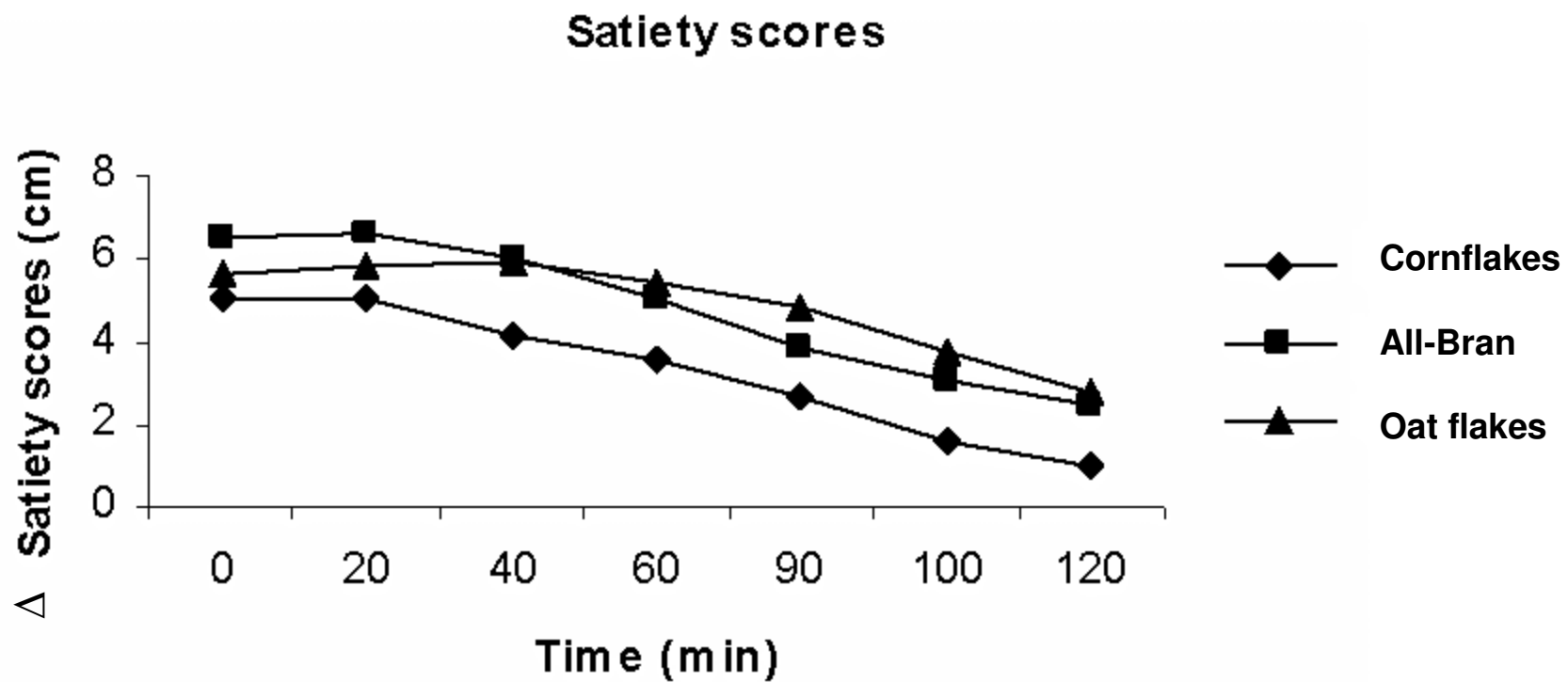


Figure 3