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# Evaluating the $\leq 10:1$ wholegrain criterion in identifying nutrient quality and health implications of UK breads and breakfast cereals

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Shortened title: Wholegrain criteria and nutrient quality

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- Ethical standards disclosure: No human subjects.

1 **Abstract**

2

3 Objective: To evaluate the nutrient quality of breads and breakfast cereals identified using the  
4 wholegrain definition of  $\leq 10:1$  carbohydrate:fibre ratio.

5

6 Design: Following a cross-sectional study design, nutritional information was systematically  
7 gathered from food labels of breads and breakfast cereals that met the  $\leq 10:1$   
8 carbohydrate:fibre criterion. The median nutrient content was compared with the UK Food  
9 Standards Agency nutrient profiling standards and the association between carbohydrate:fibre  
10 ratio and other nutrients were analysed. Subgroup analyses were undertaken for products with  
11 and without fruit, nuts and/or seeds.

12

13 Setting: Products from four major supermarket stores in the UK.

14

15 Subjects: 162 breads and 266 breakfast cereals.

16

17 Results: Breads which met the  $\leq 10:1$  criterion typically contained medium fat, low saturated  
18 fat, low sugar and medium sodium. Breakfast cereals typically contained medium fat, low  
19 saturated fat, high sugar and low sodium. In both groups, as the carbohydrate:fibre ratio  
20 decreased, fat content increased (bread:  $p=0.029$ ,  $r=-0.171$ ; breakfast cereal:  $p=0.033$ ,  $r=-$   
21  $0.131$ ) and, in breakfast cereals, as the ratio increased, sugar content increased ( $p<0.0005$ ,  
22  $r=0.381$ ). Breakfast cereals with fruit, nuts and/or seeds contained, per 100 g, more energy  
23 ( $p=0.002$ ), fat, saturated fat and sugar (all  $p<0.0005$ ) while seeded breads had more energy,  
24 fat and saturated fat (all  $p<0.0005$ ).

25

26 Conclusions: Overall, breads and breakfast cereals meeting the  $\leq 10:1$  criterion have good  
27 nutritional quality, suggesting that the criterion could be useful in public health and/or food  
28 labelling. The utility of applying the 10:1 criterion to products containing fruit, nuts and/or  
29 seeds is less clear and requires further research.

## 30 **Introduction**

31

32 The term “whole grain” typically refers to the entire edible grain from cereals and related  
33 plants <sup>(1)</sup>. Food containing whole grains can include the full grain or be reconstituted so the  
34 components of the grain are recombined to a similar proportion to that of the original grain  
35 <sup>(2)</sup>. Many studies suggest that foods high in wholegrain ingredients may reduce the risk of  
36 chronic diseases such as cardiovascular disease (CVD), type 2 and gestational diabetes and  
37 some cancers, including gastrointestinal and breast cancer <sup>(2,3,4,5,6)</sup>. Foods high in whole grains  
38 can replace more processed, higher glycaemic index cereals such as white bread and hence  
39 maintain satiation and prolong gastric emptying which may reduce obesity risk <sup>(7)</sup>. These  
40 effects are potentially due to substances in the germ and bran of the grain, which work  
41 synergistically, including insoluble and soluble fibre, phytosterols and antioxidants such as  
42 lignans, polyphenols and flavonoids <sup>(8)</sup>. However, some of the health benefits of whole grains  
43 may also be attributed to their role as a proxy for a diet high in other nutrients. For example,  
44 Venn and Mann <sup>(9)</sup> demonstrated uncertainty about whether the impact of unrefined grain  
45 intake on reducing diabetes-related mortality is due to wholegrain foods or other lifestyle  
46 factors. Thus, the mechanism by which whole grains are beneficial is still partially unclear.  
47 Furthermore, much of the research into whole grains is sponsored by companies that  
48 manufacture cereal-based products <sup>(2,10,11)</sup>. Whilst not all of these companies are interested in  
49 wholegrain goods, this funding may influence both the focus of cereal-based studies and the  
50 findings that are published. In addition, there is little consistency in how authors define  
51 wholegrain foods <sup>(12)</sup>. These factors influence conclusions that can be drawn from the  
52 literature <sup>(12,13)</sup>. Despite this, there is a general consensus from authoritative organisations that  
53 increasing intake of whole grains can reduce the risk of many important public health  
54 problems <sup>(14,15,16)</sup>.

55

56 Unlike the US, Australia, Denmark and Canada, the UK does not have a quantified  
57 recommendation for intake of whole grains <sup>(17)</sup>. The only recommendation is in The Eatwell  
58 Guide which advises that “starchy food should make up about a third of the food” eaten in a  
59 day and wherever possible, wholegrain options should be chosen <sup>(14)</sup>. However, intake of  
60 whole grains remains low. Comparison of data from the UK National Diet and Nutrition  
61 Survey (NDNS) with the US recommendation of at least three 16 g servings of whole grains

62 per day shows that 45% of UK adults ate less than one serving and 18% consumed no whole  
63 grains during the 4-day collection period <sup>(17)</sup>. With obesity and diabetes increasing <sup>(18)</sup> and  
64 low intakes of whole grains, a public health initiative to substitute foods containing whole  
65 grains for those containing significant amounts of refined grains might improve health, save  
66 resources and reduce total and CVD-related mortality <sup>(19)</sup>.

67

68 However, it is difficult to promote whole grains when there is little standardisation in  
69 defining “wholegrain” foods. In Europe, a food must have  $\geq 51\%$  wholegrain ingredients by  
70 wet weight in order to make a health claim <sup>(20)</sup>. However, other nutrients are not specified in  
71 relation to this which means that products making this claim can also have very high levels of  
72 sugar or fat. The UK Institute of Grocery Delivery <sup>(1)</sup> recommend that a food should have at  
73 least 8 g of wholegrain ingredients per serving to be called whole grain. However, as with the  
74 USA and Canadian Whole Grain Stamps <sup>(21)</sup>, this recommendation is non-binding. Non-  
75 statutory labelling is predominately decided by industry representatives <sup>(1)</sup> which raises the  
76 concern that they may focus on commercial rather than health purposes and thus may be  
77 potentially misleading <sup>(22, 23)</sup>.

78

79 In 2015 the UK Scientific Advisory Committee on Nutrition (SACN) recommended that a  
80 standardised definition of “whole grain” and wholegrain foods should be developed as this  
81 would facilitate recommended portion sizes for wholegrain foods and support public health  
82 messages about the importance of dietary fibre <sup>(24)</sup>. Similarly, the US Dietary Guidelines  
83 Technical Advisory Committee have declared “a call to action” to develop a definition of  
84 wholegrain foods that can be internationally implemented <sup>(12)</sup>. This would benefit public  
85 health directly by providing consumers with consistent and useful information and indirectly  
86 by facilitating research into whole grains <sup>(12,25)</sup>.

87

88 Mozaffarian *et al.* recently compared five different criteria to see which represented the healthiest  
89 American wholegrain-based foods <sup>(23)</sup>. They found that foods with a  $\leq 10:1$  carbohydrate:fibre ratio  
90 contained the least sugar, sodium and trans-fats. No similar studies have been undertaken outside  
91 the USA but this criterion could be considered in other countries.

92

93 The  $\leq 10:1$  criterion is based on the recommendation of the American Heart Association <sup>(26)</sup> as it is  
94 approximately the carbohydrate:fibre ratio in whole-wheat flour <sup>(23)</sup>. This ratio acts as a benchmark  
95 to represent the “balance of whole grain versus sugars and refined grains”, hence indicating overall  
96 carbohydrate quality <sup>(23)</sup>. However, there is no clarification that the fibre content must come from  
97 wholegrain ingredients.

98

99 The aim of this cross-sectional study was to evaluate *the nutritional quality of breads and*  
100 *breakfast cereals identified using the wholegrain definition of  $\leq 10:1$  carbohydrate:fibre ratio*  
101 *and, therefore, to examine the utility of this criterion by considering the health implications*  
102 *of foods that it defines.*

103

104 The term “utility” in this context is used to describe a variety of factors. These include, but  
105 are not limited to: how easily the criterion can be used; how healthy the foods that meet it  
106 are; whether it can be used to promote healthier choices; and whether it is representative of  
107 wholegrain foods. Even though the word “healthy” is used in this article, the authors  
108 acknowledge that it is subjective and can have various meanings; this is discussed further in  
109 the paper’s limitations.

## 110 **Method**

### 111 *Data collection*

112 The NDNS was used to establish which cereal-based foods are most commonly eaten in the  
113 UK. It was determined that breads and breakfast cereals constitute 49% of UK cereal intake  
114 <sup>(27)</sup>. Using these foods to evaluate the use of the criterion was appropriate as they make a  
115 major contribution to cereal intake. The remaining 51% included foods like pasta, rice and  
116 sweet items. However, other commonly consumed foods containing whole grains, such as  
117 pasta, varied considerably in the form of products available, e.g. being sold dry or fresh,  
118 which confounded analysis so they were not included in this study. Hence, all the products in  
119 this research were breads or breakfast cereals with a carbohydrate:fibre ratio  $\leq 10:1$ . Products  
120 with a ratio  $>10:1$  were not studied. Sweet breads (e.g. malt loaf), gluten-free foods and  
121 foods marketed for infants and toddlers were excluded due to typically having a different  
122 composition.

123

124 Nutritional information was obtained online from four major supermarkets to make the  
125 results generalizable as 79% of the UK buy food from one or more of these shops <sup>(28)</sup>. Their  
126 websites were accessed in order of their market share: Tesco, Asda, Sainsbury's and  
127 Morrison's <sup>(28)</sup>. A generic search was made using the terms "bread" and "breakfast cereal"  
128 and then searches were conducted for more unusual products that the NDNS included such as  
129 "roti" or "English muffins". Out of all the breads and breakfast cereals across the  
130 supermarkets that met the search terms, a total of 162 breads and 266 breakfast cereals met  
131 the criterion and were included in the study. The nutritional information for each product was  
132 documented as g/100 g and kJ/100 g for comparison. Data included portion size,  
133 carbohydrate, fibre, energy, fat, saturated fat, sugar, sodium and ingredients. These nutrients  
134 were included because they were used to assess a food's nutrient quality <sup>(29)</sup>. Carbohydrate to  
135 fibre ratio was calculated.

136

### 137 *Data analysis*

138 Nutritional data were assessed for statistical distribution and, as the data were non-  
139 parametric, the median and quartiles of energy and each nutrient were calculated for breads,  
140 breakfast cereals and subgroups (listed below). The data for fat, saturated fat, sugar and

141 sodium were categorised according to the Food Standards Agency (FSA) definitions of  
142 “high”, “medium” and “low” levels of each nutrient per 100 g as used in UK nutrient  
143 profiling <sup>(29)</sup> (Table 1). Therefore, conclusions were drawn about amounts of nutrients in the  
144 foods meeting the criterion. Sodium is referred to throughout this paper but was multiplied by  
145 2.5 for conversion to salt (based on 1 g of salt containing 390 mg sodium) for comparison  
146 with the FSA definitions <sup>(30)</sup>.

147

148 The association between the carbohydrate:fibre ratio and the amount of energy, fat, saturated  
149 fat, sugar and sodium was examined in breads and breakfast cereals using a Spearman rank  
150 correlation.

151

152 Subgroup analyses were undertaken using independent samples median tests as it was  
153 observed that some of the products containing fruit, nuts and/or seeds also contained  
154 substantial quantities of refined carbohydrate and fewer wholegrain ingredients. The analyses  
155 compared breads containing seeds with breads that did not and breakfast cereals containing  
156 fruit, nuts and/or seeds with those that did not.

157

158 Most of the analyses for breakfast cereals were based on the dry products. However, it was  
159 recognised that breakfast cereals are often consumed with milk. As milk contains  
160 carbohydrate but negligible fibre <sup>(31)</sup>, a separate analysis was completed in which the  
161 carbohydrate in a portion of semi-skimmed milk (125 ml) <sup>(31,32)</sup> was added to the  
162 carbohydrate content of a portion of each breakfast cereal (specified by the manufacturer) to  
163 assess how milk affects the carbohydrate:fibre ratio. This was conducted for breakfast cereals  
164 containing fruit, nuts and/ or seeds and those that did not. The breakfast cereals that exceeded  
165 this ratio once milk was added were still included in the research as the carbohydrate:fibre  
166 ratio of the dry product was the main focus.

167

168 All tests were completed using SPSS version 22.0 (IBM Corporation, New York USA) and  
169  $p < 0.05$  was accepted as statistically significant.

170



## 171 **Results**

### 172 *Comparisons of nutrient content with FSA categories*

173 The nutrient content per 100 g for 162 breads and 266 breakfast cereals with  $\leq 10:1$   
174 carbohydrate:fibre ratio classified using the FSA <sup>(29)</sup> high, medium or low categories are  
175 presented in Table 2. For bread, the content of saturated fat, sugar and sodium based on  
176 median values were consistent enough for generalisations to be made, i.e. that typically they  
177 contained low saturated fat, low sugar and medium sodium. There was more variation in the  
178 fat content, but, based on median values, they contained a medium amount of fat.

179 For breakfast cereals, the median values indicated medium fat, low saturated fat, high sugar  
180 and low sodium content. However, for all the nutrients, the values at the 25<sup>th</sup>, median and/or  
181 75<sup>th</sup> quartiles corresponded to different FSA categories, indicating that the amounts of  
182 nutrients in breakfast cereals are more widely distributed (Table 2).

183

### 184 *Relationships between carbohydrate:fibre ratio and energy and nutrient content*

185 A significant positive correlation was found between the ratio and sugar content for breakfast  
186 cereals ( $p < 0.0005$ ,  $r = 0.381$ ) indicating that as carbohydrate increases and/or fibre decreases,  
187 sugar content increases. A significant negative correlation was found for both breads and  
188 breakfast cereals between the ratio and fat (breads:  $p = 0.029$ ,  $r = -0.171$ ; breakfast cereals:  
189  $p = 0.033$ ,  $r = -0.131$ ). This indicates that as carbohydrate decreases and/or fibre increases, fat  
190 content increases.

191 For breads, there were no significant relationships between the ratio and the content of  
192 energy, saturated fat, sugar or sodium. For breakfast cereals there were no significant  
193 relationships between the ratio and energy, saturated fat or sodium.

194

### 195 *Subgroup analyses*

196 There were significant differences in the median amounts of nutrients in breads with and  
197 without seeds (Table 3). Most importantly, seeded breads have significantly higher energy,  
198 fat and saturated fat (all  $p < 0.0005$ ).

199 There were also significant differences in the median amounts of nutrients in the breakfast  
200 cereals containing fruit, nuts and/or seeds and those without (Table 3). The products

201 containing fruit, nuts and/or seeds had significantly higher energy ( $p=0.002$ ) and fat,  
202 saturated fat and sugar (all  $p<0.0005$ ).

203 Without distinguishing between breakfast cereals that did and did not contain fruit, nuts  
204 and/or seeds, when the nutritional information of a portion of semi-skimmed milk was added  
205 to each breakfast cereal portion, 90 (34%) exceeded the  $\leq 10:1$  ratio.

206

## 207 **Discussion**

208 This study aimed to evaluate *the nutritional quality of breads and breakfast cereals identified*  
209 *using the wholegrain definition of  $\leq 10:1$  carbohydrate:fibre ratio* in order to contribute to  
210 understanding of the utility of the criterion in promoting nutritional health. The FSA  
211 categories for fat, saturated fat, sugar and salt were chosen for comparison as they are an  
212 accepted method of nutrient profiling in the UK <sup>(33)</sup> and highly relevant to public health.

213

### 214 *Evaluation of the criterion in relation to breads meeting the $\leq 10:1$ ratio*

215 The median nutrient content for wholegrain breads identified using the  $\leq 10:1$  ratio suggests  
216 they have good nutritional quality, an important indication of the utility of this criterion. The  
217 low saturated fat and sugar content supports current public health guidance as limiting  
218 saturated fat and sugar intake is recommended to reduce the risk of common long-term  
219 conditions in the UK, notably CVD and diabetes <sup>(14)</sup>. This is one reason why wholegrain  
220 bread is recommended as a carbohydrate source in guidelines across Europe <sup>(14,34)</sup>. The  
221 medium content of fat is not concerning as only 16% is saturated. The remaining unsaturated  
222 fats may promote a healthier blood lipid profile, improving cardiovascular health <sup>(35)</sup>, again  
223 suggesting these breads have good nutritional quality. The medium sodium content is  
224 unsurprising as bread is the largest single contributor of sodium in the UK diet <sup>(36)</sup>. This is a  
225 well-established concern <sup>(37)</sup>. Most breads have a high salt content, not just those meeting the  
226 criterion, but this is decreasing in UK bread following a voluntary salt-reduction programme  
227 <sup>(36)</sup>.

228 Studies of wholegrain breads tend to examine health benefits or micronutrient  
229 supplementation rather than overall nutritional content as in the present study. In addition, no  
230 published studies have examined the  $\leq 10:1$  criterion in UK breads. Results of this study  
231 cannot be compared to the findings of Mozaffarian *et al.* <sup>(23)</sup> as their study did not distinguish  
232 between the nutritional composition of breads and other products meeting the criterion.  
233 However, when compared to wholegrain breads in the UK food tables, The Composition of  
234 Foods <sup>(31)</sup>, the breads that met the criterion were higher in fat, saturated fat, sugar and sodium,  
235 suggesting that they are, overall, less healthy. Nevertheless, this comparison is limited as the  
236 food tables have a smaller sample size and analysis methods may differ. Overall, the  
237 nutritional composition of breads meeting the criterion appears to correspond with healthy  
238 eating recommendations <sup>(14)</sup> which indicates the utility of using this criterion.

239 Regardless of the relatively good nutritional profile and health implications, it is important to  
240 consider that, due to the inclusion criterion of the  $\leq 10:1$  carbohydrate:fibre ratio, many of the  
241 breads contained seeds. While people who eat seeds may have better health (including lower  
242 triglyceride levels and increased insulin sensitivity)<sup>(38)</sup>, seeds contain a different type of fibre  
243 from whole grains, which some argue has fewer biological benefits<sup>(39)</sup>. This fibre lowers the  
244 ratio without contributing whole grains. In addition, the seeded breads have a different  
245 nutritional composition with more energy, fat and saturated fat (Table 3). While eating  
246 seeded rather than un-seeded breads is unlikely to have a major impact in isolation on  
247 someone's body weight, it may be a less desirable choice for overweight or obese people who  
248 are trying to reduce their energy intake. Thirty-seven percent of the breads examined  
249 contained seeds and, based on the food labelling, it is not possible to determine which would  
250 meet the  $\leq 10:1$  criterion by virtue of their wholegrain content alone, i.e. if the seeds were  
251 excluded. This is a limitation of the criterion as a  $\leq 10:1$  carbohydrate:fibre ratio does not  
252 guarantee a product contains adequate wholegrain ingredients and, as a result, foods meeting  
253 the criterion may have a different nutritional profile.

254 In breads, there was an inverse relationship between the carbohydrate:fibre ratio and fat  
255 content. This may relate to the relative mutual displacement of the macronutrients in terms of  
256 fat and unrefined carbohydrate or it may be because the seeded breads have more fat and  
257 fibre (Table 3) due to the contribution from seeds<sup>(40)</sup>. The difference in fibre between breads  
258 with and without seeds was not statistically significant, but this may be because of inadequate  
259 sample size. In fact, it disagrees with evidence that higher fibre diets are usually associated  
260 with a lower fat intake<sup>(23)</sup>, though this may be because the negative association relates to  
261 wholegrain foods alone, not the total diet. Nonetheless, more research is needed to see if this  
262 is representative of breads and other wholegrain products. This correlation suggests that, to  
263 promote lower fat wholegrain options, products with a higher ratio should be chosen;  
264 however, foods with a higher ratio provide fewer wholegrain benefits due to having less fibre  
265<sup>(8)</sup>.

266 Even though breads meeting the criterion have a relatively good nutritional profile, the  
267 criterion does not account for the negative change to overall nutritional profile due to adding  
268 high fat or sugar ingredients such as butter or jam. This is supported by recommendations in  
269 international guidelines<sup>(41)</sup> and recent Public Health England recommendations<sup>(14)</sup> to avoid  
270 adding fats to starchy foods to prevent excess weight gain. Nonetheless, a small serving of  
271 butter or jam may not affect health benefits significantly whereas a larger serving could. This

272 is pertinent because bread is normally eaten in a mixed meal which can affect its nutritional  
273 properties, such as glycaemic index <sup>(42)</sup>, sometimes detracting from potential health benefits  
274 of the wholegrain ingredients. Clearly, the utility of the wholegrain criterion is limited by its  
275 inability to account for this.

276

#### 277 *Evaluation of the criterion in relation to breakfast cereals meeting the <10:1 ratio*

278 There is no other research looking at this criterion in relation to UK breakfast cereals. There  
279 is literature that looks at the nutritional composition of wholegrain breakfast cereals, albeit  
280 defining whole grains differently, and these are considered here to assist the evaluation. The  
281 breakfast cereals meeting the criterion have low amounts of saturated fat and sodium (Table  
282 2) which could contribute beneficially to the diet as the average intake of these nutrients in  
283 the UK exceeds recommendations, contributing to poorer heart health <sup>(27)</sup>. This is supported  
284 by a systematic review by Williams <sup>(43)</sup> who found that those who eat wholegrain breakfast  
285 cereals have a lower CVD and hypertension risk, partly due to reduced sodium intake. The  
286 NDNS <sup>(27)</sup> has also shown that breakfast cereals, on average, only contribute 1-2% of total  
287 dietary sodium. This indicates that the saturated fat and sodium content of these breakfast  
288 cereals corresponds with healthy eating recommendations <sup>(29)</sup>. As with breads meeting this  
289 criterion, the medium fat content is not of concern as only 18% is saturated. The remaining  
290 unsaturated fats contribute positively to the nutritional profile and may contribute to  
291 improved cardiovascular outcomes <sup>(44)</sup>.

292 Research has shown that, in all age groups, in the UK and internationally, breakfast cereal  
293 consumption is associated with reduced overall fat intake <sup>(27,45)</sup>, suggesting that the medium  
294 fat content of the breakfast cereals is unlikely to contribute to increased fat intake.

295 However, some breakfast cereals have a high sugar content which is detrimental to their  
296 overall nutritional profile <sup>(46)</sup>. Even though it is well-established that some breakfast cereals  
297 are high in sugar, there is no evidence that those who eat them have a higher overall sugar  
298 intake or are more likely to be overweight <sup>(43,47)</sup>. This study showed the higher the  
299 carbohydrate:fibre ratio, the higher the sugar content. This may be due to added sugar, listed  
300 as an ingredient in 77% of the breakfast cereals, which contributes to the carbohydrate but not  
301 the fibre content. This is supported by Williams <sup>(43)</sup> who has discussed the presence of sugar  
302 in breakfast cereals. However, there are many lower sugar breakfast cereals as the sugar  
303 content of these products varied from 0.3 g to 31.4 g/100g. It could be argued that to make

304 the criterion a better tool, it should only be applied to breakfast cereals that have a  $\leq 10:1$  ratio  
305 and a medium or low amount of sugar (i.e.  $< 15\text{g}/100\text{g}$ ). Alternatively, promoting a lower  
306 criterion could exclude high sugar cereals while providing more fibre as suggested by  
307 Mozaffarian et al<sup>(23)</sup>. Furthermore, the UK food tables show that the carbohydrate:fibre ratio  
308 of wholemeal flour is typically 6.5:1-7:1<sup>(31)</sup> which is lower than the  $\leq 10:1$  ratio suggested by  
309 the American Heart Association<sup>(16)</sup>. This may be further justification for a lower ratio to be  
310 used in order to exclude foods with significant amounts of added sugars. Alternatively, for  
311 breakfast cereals, carbohydrate:fibre:sugar ratio could be considered to provide a better  
312 indication of the overall carbohydrate composition and sugar content.

313 As with bread meeting this criterion, in these breakfast cereals, as the carbohydrate:fibre ratio  
314 decreases, fat content increases. This may be due to nuts and seeds which have high fibre and  
315 fat content<sup>(40)</sup> and was reflected in the results from this study where breakfast cereals with  
316 fruit, nuts and/or seeds contained more energy, fat, saturated fat and sugar (Table 3).  
317 Therefore, even though the fruit, nuts and/or seeds can provide benefit through their  
318 contribution to micronutrient and phytosterol intake<sup>(48,49)</sup>, the breakfast cereals containing  
319 fruit, nuts and/or seeds had a poorer nutritional profile and, considering some may not have  
320 met with  $\leq 10:1$  criterion without the addition of fruit, nuts and/or seeds, they may have less  
321 wholegrain benefits and hence less bioactive properties. Nonetheless, consuming breakfast  
322 cereals with fruit, nuts and/or seeds would still be a good way of increasing the general  
323 population's fibre intake which is an important public health message<sup>(27)</sup>. However, if  
324 consumers assumed all foods with a  $\leq 10:1$  carbohydrate:fibre ratio contain whole grains, they  
325 could be misled and choose products high in fruit, nuts and/or seeds but low in actual  
326 wholegrain ingredients, especially as some ice-creams and fruit juices (both without whole  
327 grains) meet this ratio. Another example is a supermarket own brand porridge pot where the  
328 plain porridge did not meet the criterion but the same product with fruit, nuts and/or seeds  
329 did. Confusion could be avoided by using clear front-of-pack labelling showing if there is  
330 adequate fibre *from whole grains* to meet the criterion. This would also help consumers  
331 identify products that are better for their health. Mozaffarian et al<sup>(23)</sup> also supported  
332 codifying the  $\leq 10:1$  ratio to use it on front-of-pack labelling.

333 Furthermore, consideration needs to be given to the type of cereal. As whole wheat typically  
334 has a low carbohydrate:fibre ratio (e.g. wholemeal wheat flour, code 11-889 = 6.9)<sup>(31)</sup>, this  
335 criterion is likely to favour wheat-based foods, along with those with added fibre and rye  
336 flour (rye flour, code 11-897 = 5.2)<sup>(31)</sup>. However, despite oats having a higher

337 carbohydrate:fibre ratio (porridge oats, code 11-788 = 9.1)<sup>(31)</sup> research shows that, due to the  
338 presence of beta-glucans and avenanthramides amongst other bioactive components, there are  
339 more consistent results for the health benefits associated with their consumption<sup>(50)</sup>. Clearly  
340 identifying the source of the whole grains as well as the carbohydrate:fibre ratio may enable  
341 consumers to better understand the overall nutritional value of the food.

342 Adding other ingredients to breakfast cereals post-purchase alters the carbohydrate:fibre  
343 ratio, as with breads. Adding milk can alter the nutritional profile: 34% of products originally  
344 meeting the criterion do not meet it after milk is added. The original premise of the criterion  
345 is to capture the balance of whole grains in relation to sugars and refined grains<sup>(20)</sup> but adding  
346 milk detracts from this as lactose in milk increases the ratio. This may look like a drawback  
347 of the criterion. However, adding milk helps meet calcium, protein and vitamin B  
348 requirements<sup>(51)</sup>. Lactose also enhances calcium and magnesium absorption while having a  
349 low glycaemic index and carcinogenicity<sup>(52)</sup>. Therefore, even though adding milk to  
350 wholegrain breakfast cereals can result in the meal exceeding the  $\leq 10:1$  ratio, it can be argued  
351 that the nutrition that milk provides is more important, especially as it does not detract from  
352 the benefits of wholegrain ingredients. Adding other ingredients, such as sugar, is different  
353 and could detract from the wholegrain ingredients<sup>(7)</sup>. While this is a limitation of the  
354 criterion, it may not be worth altering it for this reason. Instead, a separate public health  
355 campaign that encourages reducing sugar intake, such as Change4Life's Sugar Smart<sup>(53)</sup>,  
356 could mitigate this.

357

### 358 *Limitations*

359 This study included only breads and breakfast cereals. Other grain-based foods could be  
360 assessed such as pasta and foods aimed at children aged less than 4 years and evaluating these  
361 would contribute to a more comprehensive evaluation of how widely the criterion could be  
362 applied. Furthermore, foods from other retailers could have been included as 21% of the UK  
363 population do not shop at the supermarkets surveyed<sup>(28)</sup> so there may be products that were  
364 not analysed. There are also nutritional components that affect health that are not included on  
365 food packaging which could have extended the evaluation, for example, trans-fats or the  
366 extent of processing. In addition, the effect of portion size when discussing nutritional  
367 content of foods has not been considered. Looking at nutrients per 100 g enables medians to  
368 be calculated and compared with the FSA standards but this does not account for the portion

369 someone might eat. The FSA standards themselves were designed to inform consumers rather  
370 than assess food products and have limitations as a tool <sup>(54)</sup>.

371 In an attempt to discuss the possible health implications of foods meeting this criterion, some  
372 inevitable generalisations may have been made regarding the effects of the nutritional  
373 composition of wholegrain ingredients or foods on health - these associations are not always  
374 straightforward or predictable <sup>(55)</sup>. Another significant limitation is the unavoidable  
375 subjectivity when judging health quality. While the authors may consider a medium amount  
376 of fat, saturated fat, sugar or sodium to represent a relatively healthy food, others may  
377 disagree. This indicates the importance of considering the whole diet rather than single  
378 components in isolation.

379

#### 380 *Future recommendations*

381 As this is the first study of its kind, more research is needed before steps can be taken  
382 towards using this criterion. It would be useful to repeat the research comparing it with  
383 similar products with a >10:1 ratio. This would also provide an opportunity to compare the  
384 price of foods that meet the criterion with those that do not to explore the cost of foods that  
385 meet this criterion and how this could affect sales and intake. The research could also be  
386 completed while comparing the nutritional content of the foods to a different nutrient  
387 profiling model. This would improve understanding of how useful the criterion is in  
388 identifying healthier foods. An investigation into the contribution of fruit, nuts and seeds to  
389 products meeting the criterion would also be useful so decisions can be made about whether  
390 products with fruit, nuts and seeds should be included. In addition, more research could be  
391 conducted to determine if a different ratio (for example,  $\leq 7:1$ ) should be used to promote  
392 products with less fat or sugar. This could help meet other public health goals. However, a  
393 disadvantage of using a criterion other than  $\leq 10:1$  is that it may be more difficult for  
394 consumers to work out from food labels if a product meets the wholegrain criterion. It is also  
395 important to explore whether consumers would understand how to identify wholegrain foods  
396 using this criterion and if not, how it could be adapted. Nonetheless, this  $\leq 10:1$  criterion has  
397 potential as a standardised definition for wholegrain foods.

398

399

400



401 *Conclusions*

402 This study furthers understanding of the  $\leq 10:1$  carbohydrate:fibre wholegrain criterion and its  
403 potential implementation by reporting that foods meeting the  $\leq 10:1$  criterion are relatively  
404 healthy when assessed using the FSA nutrient profiling standards as a benchmark; the main  
405 exception being the sugar content of breakfast cereals. The utility of the criterion is its  
406 potential to offer a standardised approach to the classification of wholegrain breads and  
407 breakfast cereals which relates to their nutrient content and thus potentially contributing to  
408 efforts to increase wholegrain intake <sup>(20,21,56)</sup>.

**Table 1:** Food Standard Agency nutrient profiling categories for **high**, *medium* and *low* amounts of nutrients per 100g respectively including salt re-calculated as sodium as described in the method <sup>(25)</sup>.

<b>Level</b>	<b>Fat (g/100g)</b>	<b>Saturated Fat (g/100g)</b>	<b>Sugar (g/100g)</b>	<b>Sodium (g/100g)</b>
<b>Low</b>	<u>&lt;3.0</u>	<u>&lt;1.5</u>	<u>&lt;5.0</u>	<u>&lt;0.1</u>
<b>Medium</b>	<i>3.0-20.0</i>	<i>1.5-5.0</i>	<i>5-15.0</i>	<i>0.1-0.6</i>
<b>High</b>	<b>&gt;20.0</b>	<b>&gt;5</b>	<b>&gt;15.0</b>	<b>&gt;0.6</b>

**Table 2:** Energy and nutrient content per 100g of breads and breakfast cereals meeting the  $\leq 10:1$  wholegrain criterion. Values classified as **high**, *medium* and **low** amounts of nutrients per 100g respectively, following Food Standards Agency nutrient profiling categories <sup>(29)</sup>.

Food Group	Carbohydrate (g/100g)	Fibre (g/100g)	Carbohydrate: Fibre ratio	Energy (kJ/ 100g)	Fat (g/100g)	Saturated Fat (g/100g)	Sugar (g/100g)	Sodium (g/100g)
<b>Breads (n=162)</b>								
25 <sup>th</sup> Quartile	37.00	5.38	5.29	981.00	<u>2.40</u>	<u>0.40</u>	<u>2.60</u>	0.88
Median	39.75	6.45	6.18	1032.50	3.50	<u>0.56</u>	<u>3.20</u>	0.93
75 <sup>th</sup> Quartile	43.25	7.10	7.79	1159.25	6.75	<u>1.03</u>	<u>4.20</u>	1.00
<b>Breakfast Cereals (n=266)</b>								
25 <sup>th</sup> Quartile	60.08	7.70	6.75	1518.75	<u>2.50</u>	<u>0.60</u>	13.75	<u>0.03</u>
Median	66.00	8.50	7.57	1572.50	6.20	<u>1.10</u>	<b>18.40</b>	<u>0.13</u>
75 <sup>th</sup> Quartile	69.68	9.70	8.86	1682.50	9.50	1.85	<b>22.13</b>	0.45

**Table 3:** Median content of carbohydrate, fibre, carbohydrate: fibre ratio, sugar, sodium, energy, fat and saturated fat for breads with seeds, breads without seeds, breakfast cereals with and without fruit, nuts and/or seeds

<b>Subgroups</b>	<b>Carbohydrate (g/100g)</b>	<b>Fibre (g/100g)</b>	<b>Carbohydrate: Fibre ratio</b>	<b>Energy (kJ/100g)</b>	<b>Fat (g/100g)</b>	<b>Saturated fat (g/100g)</b>	<b>Sugar (g/100g)</b>	<b>Sodium (g/100g)</b>
<b>Breads</b>								
<b>Bread containing seeds (n=60)</b>	38.40	6.70	5.76	1165.00	7.30*	0.90	3.20	0.37
<b>Bread not containing seeds (n=102)</b>	40.50	6.35	6.12	1005.00	2.60*	0.40	3.20	0.94
<b>P value†</b>	0.026	0.323	0.212	<0.0005	<0.0005	<0.0005	0.996	0.883
<b>Breakfast cereals</b>								
<b>Breakfast cereals containing fruit, nuts ± seeds (n=138)</b>	64.45	7.58	7.66	1601.50	7.55	1.20	20.05	0.10
<b>Breakfast cereals without fruit, nuts ± seeds (n =128)</b>	68.50	8.80	7.66	1564.50	3.70	0.85	16.00	0.24
<b>P value‡</b>	0.001	0.093	0.713	0.002	<0.0005	<0.0005	<0.0005	<0.0005

\* The only difference in Food Standards Agency categories<sup>(29)</sup> between subgroups is in fat content with seeded and non-seeded breads: seeded breads having medium fat and non-seeded breads having low fat.

†P values obtained by comparing nutrients in breads with seeds and without seeds using the independent samples median test.

‡P values obtained by comparing nutrients in breakfast cereals containing fruit, nuts and seeds with those that did not using the independent samples median test.

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