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Review article

Breakfast: a review of associations with measures of dietary intake, physiology and biochemistry

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The present paper reviews the literature on breakfast to consider reported associations between breakfast and nutritional, physiological and biochemical variables. The contribution of breakfast to achieving nutrition targets for fat, carbohydrate and dietary fibre intakes is also examined as are the potential effects of fortified breakfast cereals on intakes of micronutrients and nutritional status. Breakfast consumption, particularly if the meal includes a breakfast cereal, is associated with lower intakes of fat and higher intakes of carbohydrate, dietary fibre and certain micronutrients. These findings may be relevant to population groups which could be at risk from low intakes of certain micronutrients, but further clarification of benefit is needed from studies of nutritional status. Associations between breakfast consumption and lower cholesterol levels have been reported, while lower body weights have been seen amongst breakfast eaters. It is concluded that breakfast consumption is a marker for an appropriate dietary pattern in terms of both macro- and micronutrients, particularly if breakfast cereals are included in the meal.

Breakfast: Micronutrients: Dietary fat

Much interest has focused on the role of breakfast in the diet, probably due to anecdotal evidence of its effects on nutrition and physiology. The result has been a plethora of studies aimed at making an objective assessment of such claims. The present paper examines studies reporting associations between breakfast and a number of important health-related issues: dietary intake, nutritional status, serum lipids, appetite and body weight. The case of breakfast cereals, which appear to be the most commonly-eaten food at breakfast, will be highlighted where it has been reported separately in the literature. The role of breakfast in the diet will be discussed in the context of dietary guidelines to reduce percentage energy from fat, increase carbohydrate and fibre intakes and ensure appropriate intakes of vitamins and minerals.

BREAKFAST CONSUMPTION

Reports on breakfast consumption indicate that children under 10 years old and adults over 65 years eat breakfast on a more regular basis than any other age group. Breakfast omission is most frequent in young adults and children aged between 13 and 16 years, 7 % of whom have nothing to eat before attending school (Gardner Merchant, 1996). Curry & Todd (1992) reported that only 62 % of 11–15-year-olds took breakfast every day and that 20 %

took it only once weekly, while Nicklas *et al.* (1993) found that 84 % of 10-year-olds ate breakfast (the value being lower in African–American girls than in white girls). Ortega *et al.* (1996) found that 95 % of 9–13-year-old Spanish children ate breakfast regularly, although a proportion of these took only a glass of milk. Ruxton *et al.* (1996) reported that 94 % of 7–8-year-old children ate breakfast five to seven times per week, while a study of 5–8-year-olds found a similar value (Box & Landman, 1994). The incidence of breakfast omission increases as children reach adolescence and girls miss breakfast more than boys, perhaps due to concerns about body weight (Morgan *et al.* 1986*a*). A lack of time available to eat breakfast before school may be another factor in breakfast omission since Ortega *et al.* (1996) found that children were more likely to eat a substantial breakfast during holidays than on school days. Reports on breakfast omission in adults vary depending on the country under consideration. In a review of the literature on breakfast, Dickie (1980) noted that 27 % of British men and women missed breakfast compared with 58 % of Japanese women. Chao & Vanderkooy (1989), in another review, reported that 29 % of Canadian adults omitted breakfast while Haines *et al.* (1996) suggested that the value for American adults had increased from 13 to 25 % between 1965 and 1991. Sommerville & O'Reagan (1993) found that 5 % of Irish subjects omitted breakfast. The lack of consistency in these values may be due to different definitions of what actually constitutes breakfast consumption; in many papers, this is not stated. Table 1 presents published studies which report breakfast consumption by age and nationality and gives the percentage of individuals consuming breakfast on a regular basis.

There is conflicting evidence on the link between breakfast consumption and social class. Chao & Vanderkooy (1989) reported that breakfast omission was more common in economically disadvantaged urban children than their more affluent counterparts, while Walker *et al.* (1982) found breakfast omission to be independent of social class in an adolescent South African population. Haines *et al.* (1996), using multivariate analysis on the National Food Consumption data, could explain little of the variance in breakfast

Table 1. *Percentage of individuals consuming breakfast on a regular basis by age and country*

Reference	Country	Age (years)	*n*	Breakfast consumption (%)
Box & Landman (1994)	England	5–8	935	95
Ruxton *et al.* (1996)	Scotland	7–8	136	94
Ortega *et al.* (1996)	Spain	9–13	742	95
Nicklas *et al.* (1993)	USA	10	568	84
Curry & Todd (1992)	Scotland	11–15	4079	62
Gardner Merchant (1996)	England	8–10	546	99
		11–12	319	98
		13–14	321	93
		14–15	241	93
Sommerville & O'Reagan (1993)	Republic	8–18	538	99
	of Ireland	18–80	675	95
Frost Anderson *et al.* (1995)	Norway	18	1564	77
Zabik (1987)	USA	5–12	5107	94
		13–17	3784	82
		25–34	5646	76
		⩾62	5490	91
Haines *et al.* (1996)	USA	18–29	Total	63
		30–39	*n* 10812	72
		40–49		79
		60+		86

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consumption patterns by accounting for education and employment. Ruxton *et al.* (1996) did not find an association between social class and breakfast omission in 7–8-year-olds but reported a lower consumption of breakfast cereals and lower energy and nutrient intakes at the breakfast meal in low- compared with high-social-class children.

BREAKFAST AND DIETARY INTAKES

Energy intakes

The contribution of breakfast to energy intake seems to vary depending on the age group and population under investigation. Livingstone (1991) reported a value of 6 % for Irish 5–9-year-olds, Magarey *et al.* (1987) reported 20 % for Australian 8-year-olds, while Ruxton *et al.* (1996) found a value of 14 % for Scottish 7–8-year-olds. Spyckerelle *et al.* (1992), who suggested that breakfast eating decreased with age, found that breakfast supplied 16 % of total energy in their 10–15-year-old French sample, a similar value to that reported for Spanish 9–13-year-olds (Ortega *et al.* 1996). A low value of 3 % of daily energy supplied by breakfast has been reported for 12–13-year-olds from a deprived area in London (Doyle *et al.* 1994), probably relating to the low uptake of breakfast in this group (about 66 % with only 20 % taking breakfast cereals regularly).

In adults, the contribution of breakfast to energy intakes is often reported to be lower than in children (Cade & Margetts, 1988) or at a similar level (Haines *et al.* 1996). Daily energy intakes appear to be unaffected when breakfast is not eaten (Zabik, 1987; Resnicow, 1991) possibly due to meal patterns where there is more use of snack foods in those who omit breakfast (Zabik, 1987).

Micronutrient intakes

Even if energy intakes can remain unaffected by breakfast omission, intakes of vitamins, minerals and trace elements normally provided by breakfast, are not compensated for during the rest of the day (Zabik, 1987; Nicklas *et al.* 1993). Morgan *et al.* (1981) reported that 5–12-year-olds who regularly omitted breakfast had lower daily intakes of vitamin B_6, Fe, Ca, Mg, vitamin A, Cu and Zn compared with children who consumed breakfast cereals on a regular basis. Nicklas *et al.* (1993) reported that 10-year-old children who regularly consumed breakfast were more likely to meet US micronutrient recommendations, while breakfast has been found to be a significant source of micronutrients such as Fe, thiamin and Ca in the diets of Australian pre-adolescent (Magarey *et al.* 1987) and adolescent (Magarey & Boulton, 1995) children.

These findings may be particularly relevant for socially disadvantaged children who are at risk of micronutrient deficiencies. Studies on the US School Breakfast Program have observed that children receiving regular school breakfasts demonstrated improved growth (Emmons *et al.* 1972) and increased daily micronutrient intakes (Hanes *et al.* 1984). Disadvantaged children in London who ate breakfast cereals more than four times per week had higher micronutrient intakes compared with those who ate cereals less often (Emmons *et al.* 1972). Unfortunately, the authors did not relate the blood biochemistry values collected during the study with breakfast intake to allow further interpretation of the dietary results.

Children (Department of Health, 1989), young women (Crawley, 1993) and elderly people (Morgan *et al.* 1986*c*) are often viewed as being susceptible to micronutrient deficiencies; thus the contribution of fortified breakfast cereals to vitamin and mineral intakes in these groups is particularly important. A number of studies, particularly in the

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US, have investigated micronutrient intakes in various age groups of subjects based on their usual type of breakfast. Albertson & Tobelmann (1993), in a study of 824 7–12-year-old children, observed that frequent consumers of breakfast cereals were more likely to meet US recommendations for micronutrients. Breakfast cereals contributed about 25 % of daily micronutrient intakes and their contribution to Zn intake was seen as particularly important since 75 % of children were found to have intakes below the US recommended daily allowance. Nicklas *et al.* (1995), from a 20-year epidemiological study, reported significant differences in overall daily micronutrient intakes in both young adults and 10-year-olds. Morgan and co-workers have published work on a number of population groups, ranging in age from 5 to 80 years (Morgan *et al.* 1981, 1986*a*, *b*, *c*; Morgan & Zabik, 1984; Zabik, 1987). The findings are fairly consistent and suggest that breakfast cereals have a strong beneficial effect on intakes of certain nutrients. Breakfasts which included a breakfast cereal were described as being more nutrient dense and lower in fat than other types of breakfast. Subjects with a regular intake of breakfast cereals were more likely to meet daily recommendations for micronutrients compared with those who omitted breakfast or who ate another type of breakfast. The finding of improved micronutrient intakes was seen as being particularly important for young women, some of whom were found to have 'excessively low' intakes of Fe, Ca, vitamin B_6, Zn, Mg and Cu (Morgan *et al.* 1986*b*).

In the UK and Ireland, authors have investigated the role of breakfast cereals as a source of micronutrients in a range of population groups. A high consumption of breakfast cereals has been related to higher intakes of a range of micronutrients in pre-school children (Payne & Belton, 1992), 7–8-year-olds (Ruxton *et al.* 1996), adolescents (Gibson & O'Sullivan, 1995) and adults (McNulty *et al.* 1994). Crawley (1993) looked at breakfast cereal consumption in 4760 16–17-year-olds and found that reference nutrient intakes (Department of Health, 1991) for micronutrients were more likely to be met when over 30 g was eaten daily. Mean daily intakes of breakfast cereals in the study were 32 g in males but only 18 g in females. An analysis of a sub-group of dieters from this survey (Crawley & Shergill-Bonner, 1995) found low intakes of micronutrients and a low consumption of breakfast cereals. Sommerville & O'Reagan (1993) investigated the role of breakfast cereals in 1213 Irish 8–80-year-olds. Subjects classed as 'cereal eaters' had higher daily intakes of a range of micronutrients and were more likely to have intakes which met British reference nutrient intakes (Department of Health, 1991). This was seen as especially important in terms of Fe, intakes of which were below reference nutrient intakes in most of the women studied. The authors concluded that fortified breakfast cereals played an important role in ensuring that certain groups in the population, particularly young women, met micronutrient recommendations. Table 2 presents data on the percentage contribution of breakfast and breakfast cereals to mean daily energy and nutrient intakes in adults and in children from infanthood to adolescence.

As in the case of all foods, improved intake does not necessarily imply improved nutritional status since many factors influence the bioavailability of vitamins and minerals. Data on reported nutrient intakes and actual biochemical status are valuable, but these are rarely compared in dietary surveys. Three notable UK exceptions are the studies of Gregory *et al.* (1990), Southon *et al.* (1994) and Gregory *et al.* (1995) who observed that few reported intakes of nutrients corresponded to plasma levels. Associations between breakfast intake and biochemical status were not reported in the UK studies but were reported in a French study (Hercberg *et al.* 1996) of 1008 subjects. Plasma levels of thiamin, riboflavin and β-carotene were found to be higher as percentage energy from

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Table 2. *Percentage contribution of breakfast* to mean daily energy and nutrient intakes by age*

Reference	Age (years)	Energy	Protein	CHO	Fibre	Ca	Fe	Thiamin	Riboflavin	Vit B_6	Vit B_{12}	Folate	Niacin
Livingstone (1991)	5–9	6											
Ruxton *et al.* (1996)	7–8	14	16	18	16	22	27	30	36	31	27	34	25
Magarey *et al.* (1987)	8	20											
Magarey & Boulton (1995)	11	18	19	21	21	29	23	32		16		22	
	13	18	17	21	20	28	24	34		17		24	
	15	17	17	20	20	28	26	35		17		25	
Andersson & Rossner (1996)	20–60	13											
Fricker *et al.* (1990)	35–40	13–15											
Mills & Tyler† (1992)	6–9 months	5	4	7			5	7	5			4	4
	9–12 months	8	6	12			13	14	9			6	8

CHO, carbohydrate; Vit, vitamin.

* Reported values for intake of energy and nutrients at breakfast expressed as a percentage of reported mean daily intakes.

† Percentage contribution from breakfast cereals only.

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breakfast increased. Further analysis of UK databases may provide additional evidence to support this finding.

There is stronger evidence relating to the impact of fortified breakfasts on both folic acid intake and folate status. Lack of folate during pregnancy has been related to a higher than average incidence of neural tube defects (NTD). A case–control study representing 56 049 pregnancies in Ireland (Kirke *et al.* 1993) reported that erythrocyte folate, plasma folate and vitamin B_{12} were lower in the eighty-four women with NTD babies compared with 266 controls. Risk of a NTD was nearly six times higher in women with the lowest *v.* the highest folate status. It is currently recommended that women consume 400 μg folic acid/d, peri-conceptually, to reduce the risk of a first-time NTD pregnancy (Department of Health, 1992), although it has been observed that, in practice, such an intake would be difficult to achieve using non-fortified foods (Wald & Bower, 1995). Studies to investigate the impact of fortified cereals on dietary intakes have revealed that they represent an available source of folic acid. National Food Consumption data (Olson *et al.* 1995) have revealed that breakfast cereals contribute 13 % of the folic acid in the diets of American women compared with 21 % from vegetables, 3 % from fruit, 8 % from bread and 8 % from orange juice. In addition, women with a high consumption of breakfast cereals have higher folic acid intakes. A 12-week intervention study to increase folate status (Cuskelly *et al.* 1996) investigated both blood values and dietary intakes. Women randomized to receive supplementation or fortified breakfast cereal had a greater erythrocyte folate than those who were given foods providing a natural source of folate or dietary advice alone. In an earlier study, Cuskelly *et al.* (1994) removed fortified breakfast cereals from the diets of healthy, non-pregnant women for 12 weeks and found that erythrocyte and plasma folate levels decreased significantly. These results suggest that fortified breakfast cereals make an important contribution to folate status. It would be beneficial to extend this type of research to investigate the impact of fortified foods on other biochemical indices, such as haemoglobin. It has been suggested that fortification should be extended to other foods such as wheat flour to assist more women to achieve the recommended intake of folic acid (Wald & Bower, 1995). Oakley *et al.* (1995) claim that extended fortification leading to increased folic acid intakes may decrease plasma homocysteine (a risk factor for cardiovascular disease) in the general population and reduce the incidence of NTD births by up to 75 %. Daly *et al.* (1995) suggest that extended fortification would help to prevent 48 % of NTD births.

Dietary fibre intakes

There is little information on the contribution of breakfast to dietary fibre intakes, a problem compounded by modifications in methods of analysis and the variety of terminology used. Cade & Margetts (1988) reported that breakfast cereals contributed 8 % of the fibre in the diets of 2402 middle-aged British adults, while Emmett *et al.* (1993) found that adults regularly consuming whole-grain or bran-enriched cereals were more likely to meet the UK recommendation for NSP of 18 g/d than those who did not eat this type of breakfast cereal. Crawley (1993) found that teenagers consuming a high-fibre breakfast cereal had significantly greater mean daily NSP intakes than the rest of the sample, while Hammond & Chapman (1994) reported higher daily fibre intakes in breakfast consumers compared with those omitting breakfast. Research on children is more specific. Magarey *et al.* (1987) found that breakfast supplied nearly a quarter of total dietary fibre in the diet of 8-year-olds, while Hackett *et al.* (1986) found this to be only 10 % in 11–12-year-olds. Albertson & Tobelmann (1993) reported that breakfast cereals contributed 18% of the dietary fibre in the diets of 7–12-year-olds. It is likely that the contribution of breakfast to dietary fibre intakes is greater in children than adults since children eat fewer fibre-containing foods.

Positive associations have been reported between breakfast consumption, or the type of breakfast consumed, and mean daily dietary fibre intakes. Hammond & Chapman (1994) found breakfast consumers to have higher daily fibre intakes than those who skipped breakfast in a group of young Canadian adults. Zabik (1987) demonstrated that daily crude-fibre intakes, in a sample of adults, were higher when breakfast cereals were eaten regularly. However, Crawley (1993) found that higher daily NSP intakes were only associated with those who particularly consumed higher fibre breakfast cereals. This was also the case in a study by Emmett *et al.* (1993). Subjects eating bran-enriched breakfast cereals had the highest intakes of NSP, while a regular intake of high-fibre breakfast cereals was associated with higher intakes of NSP from meals other than breakfast suggesting that consumption of high-fibre cereals is a marker of consumption of other high-fibre foods. The UK dietary reference value for NSP (18 g/d; Department of Health, 1991) was only met by those taking bran-enriched or whole-grain breakfast cereals daily, which highlights the importance of breakfast cereals in meeting this recommendation. However, such differences in dietary fibre intakes were not seen in 7–12-year-olds when breakfast habits were examined (Albertson & Tobelmann, 1993). The authors observed that, despite breakfast cereals being generally viewed as 'high in fibre', there was no significant difference between the dietary fibre intakes of children who ate breakfast cereals frequently and those who did not eat them at all. This probably suggests that the breakfast cereals consumed by the children in this study were low in fibre. Certainly, the need to encourage a reasonable intake of fibre at a fairly early age presents a challenge to manufacturers to produce appropriate, palatable, fibre-containing foods for children.

Fat intakes

Most studies on the nutritional significance of breakfast report that daily percentage energy from fat is lower when breakfast is consumed. Macdiarmid *et al.* (1997) found that a low consumption of breakfast was related to a higher fat intake. Stanton & Keast (1989), using data on 11 864 subjects from a national American nutrition survey (NHANES II) collected between 1976 and 1980, demonstrated an inverse relationship between fat intake and breakfast cereal consumption. Highest intakes of fat were seen in those who omitted breakfast altogether. Similar results have been reported by Morgan *et al.* (1986*b*, *c*), Zabik (1987) and Nicklas *et al.* (1995) based on data from different age groups. Albertson & Tobelmann (1993) and Ruxton *et al.* (1996) found differences in percentage energy from fat when young children who regularly consumed breakfast cereals were compared with those who consumed them less frequently or not at all. Data from teenagers (Crawley, 1993; Gibson & O'Sullivan, 1995) further support this finding.

It is likely that breakfast cereal consumption relates to a lower percentage energy from fat intakes, first, by replacing the traditional higher fat cooked breakfast with a low-fat food and, second, by increasing the overall energy received from both simple and complex carbohydrate. This latter effect was responsible for reductions in fat in an intervention study where breakfast cereals were given to students (Kirk *et al.* 1997). A further reason could be that breakfast cereal consumption is a marker for a high-carbohydrate diet and, since fat and carbohydrate intakes are reciprocally related (Gibney, 1990), this would result in lower fat intakes. Certainly, Gibson *et al.* (1992) demonstrated that breakfast cereal was

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one food which distinguished low-fat from high-fat diets in a large population survey (Gregory *et al.* 1990).

Yet, despite fat intakes being significantly lower when breakfast was eaten regularly, recommended levels, i.e. 30 % of energy in USA and 35 % of energy in UK, were not met by subjects in most of the studies reviewed. An exception to this was the study of Kirk *et al.* (1997), who reported a reduction in mean percentage energy from fat from 35 to 29 % following 12 weeks of supplementation with breakfast cereals. The argument is illustrated in Table 3, which presents published studies on a range of nationalities and age groups showing significant differences (in many cases) in percentage energy from fat between high and low consumers of breakfast cereals. This suggests that breakfast cereal consumption is a dietary manipulation which can help to achieve a lower fat intake.

BREAKFAST AND BIOCHEMICAL MEASURES

Serum lipids

The effect of breakfast eating or omission on serum lipids has been studied from both an experimental and an epidemiological standpoint. In a study of 198 9–19-year-olds (Resnicow, 1991), those who omitted breakfast had the highest serum cholesterol levels, followed by those mainly consuming a high-fat breakfast. Children taking breakfast cereals (particularly those high in dietary fibre) had the lowest serum cholesterol levels. These results may have been influenced by the fact that fat as a percentage of daily energy was higher in the diets of breakfast 'omitters'. Stanton & Keast (1989) classified 11 864 subjects as breakfast 'eaters' or 'omitters' and found that the 'omitters' had significantly higher serum cholesterol levels. A survey of 1008 subjects aged 2–97 years, revealed that high intakes of breakfast cereals were associated with lower serum cholesterol levels (Hercberg *et al.* 1996). Devaney & Fraker (1989) found that disadvantaged children participating in the US School Breakfast Program demonstrated lower serum cholesterol levels than a control group. It would be interesting to know, via follow-up of subjects,

Table 3. *Differences in mean daily percentage energy from fat between 'high' and 'low' consumers of breakfast cereals*

Reference	Age (years)	*n*	Percentage energy from fat: 'High' bk	Percentage energy from fat: 'Low' bk	Significance of difference
Ruxton *et al.* (1996)	7–8	136	36	40	$P < 0.001$
Morgan *et al.* (1986*a*)	1–4	2191	38	40	$P < 0.05$
	13–17	3784	39	42	$P < 0.05$
Morgan *et al.* (1981)	5–12	657	38	40	NS
Albertson & Tobelmann (1993)	7–12	824	37	38	$P < 0.01$
Doyle *et al.* (1994)	12–13	65	44	42	NS
Nicklas *et al.* (1995)	10	568	35	36	NS
	8–18	504	33	37	$P < 0.005$
Gibson & O'Sullivan (1995)	10–11	1727	36	39	$P < 0.05$
	14–15	978	36	40	$P < 0.05$
Crawley (1993)	16–17	4760	40	43	$P < 0.001$
Kirk *et al.* (1997)	18–23	48	29	35	$P < 0.05$
Morgan *et al.* (1986*c*)	50–61	4865	41	44	$P < 0.05$
Zabik (1987)	$\geqslant 62$	5490	38	43	$P < 0.05$

'High' bk, consumers deemed to have a high intake of breakfast cereals in referenced paper; 'Low' bk, consumers deemed to have a low intake of breakfast cereals in referenced paper.

whether or not lower cholesterol levels are maintained in breakfast consumers and whether this is related to a lower incidence of CHD. Laboratory-based breakfast studies have produced a succession of papers relating to the use of psyllium (an insoluble fibre) in breakfast cereals to reduce both total and LDL-cholesterol (Manley *et al.* 1993; Wolever *et al.* 1994). Results showed a significant effect of psyllium added to breakfast cereals, although sample sizes in the studies were small. Frape *et al.* (1994) noted that consumption of a high-fibre breakfast resulted in lower serum non-esterified fatty acid and triacylglycerol responses to a moderate-fat lunch. High circulating levels of these lipids are a risk factor for CHD and diabetes mellitus.

Glycaemia

Interest in possible negative effects of low blood glucose levels has prompted research into the role of breakfast in maintaining a measure of control over glycaemia. Benton & Sargent (1992) found lower levels of blood glucose in breakfast 'omitters', although this was not found by Cromer *et al.* (1990). Metzger *et al.* (1982) observed low blood glucose levels and high ketone levels in a group of pregnant women who had been asked to omit breakfast. The authors noted that if pregnant women are asked to fast before morning tests, raised ketones may constitute a possible risk to the unborn child. For this reason, the authors also criticized the practice of recommending carbohydrate restriction in obese pregnant women as a means of weight control. The effect of breakfast cereals on serum glucose concentrations is particularly relevant to diabetic patients, since advice is often given to avoid sugar-containing varieties. Wheeler *et al.* (1996) tested the effects of pre-sweetened *v.* unsweetened breakfast cereals on twenty-four insulin-dependent diabetic patients, and found that glycaemia was lower after the pre-sweetened breakfast. This can be explained by the fact that sucrose can lower the glycaemic index of starchy foods (Brand Miller & Lobbezoo, 1994). Addition of β-glucan (oat-bran fibre) to breakfast cereal has also been found to reduce the glycaemic response (Tappy *et al.* 1996).

BREAKFAST, APPETITE AND WEIGHT CONTROL

Weight control is often cited as a reason for omitting breakfast, yet studies suggest that breakfast consumers tend to be leaner (Gibson & O'Sullivan, 1995) and weight is inversely related to the number of eating occasions during the day (Summerbell *et al.* 1996). It may be that energy taken early in the day is used inefficiently and that larger breakfasts could be beneficial for weight reducers. This has been successfully investigated in lean individuals (Halberg, 1983) who were found to lose weight when extra energy was consumed at breakfast rather than at dinner. A similar protocol in obese women did not yield satisfactory results due to a small sample size and a lack of compliance with attempts to maintain isoenergetic intakes between those eating early and later in the day (Schlundt *et al.* 1992).

Other studies have considered whether high-fibre breakfasts can increase satiety and aid weight loss. Blundell & Burley (1987) reviewed the methodologies of such studies and reported that care should be taken when defining fibre, selecting the test diet or product, measuring satiety and estimating the amount of energy consumed by the subjects. They suggested that weight loss appeared to be more consistently associated with test diets containing methylcellulose or guar gum.

Burley *et al.* (1987) investigated the effect of a high- or low-fibre breakfast on satiety, hunger, desire to eat and actual food intake. Twenty normal-weight women were classified

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as high or low restrained eaters and sub-divided to receive either the high- or low-fibre breakfast. The high-fibre breakfast, despite being lower in energy, was related to greater fullness but there were no significant differences in hunger, desire to eat and energy intake between the high- and low-fibre groups. A further study by the same group (Burley *et al.* 1993) used cereal with added sugarbeet fibre in a blind trial to examine the effect of a high-fibre breakfast compared with a low-fibre breakfast on hunger and subsequent energy intake. It was found that consumption of the high-fibre breakfast was related to a lower energy intake at lunch which was not compensated for later in the day. Delargy *et al.* (1995) also investigated the effect of a high-fibre breakfast on hunger and energy intakes. In the first experiment, lunchtime energy intake was measured 3 h after equienergetic breakfasts which were either high or low in fibre. A low-energy juice breakfast was used as the control. Energy intake at lunch was lower after the high-fibre breakfast than after the control breakfast but there was no significant difference between the low- and high-fibre breakfasts, weakening the assertion that fibre was responsible for the reduced energy intake. The second experiment compared breakfasts with differing soluble : insoluble fibre ratios. Energy intakes at lunch were not significantly different between the four fibre groups although subjective ratings of hunger were lower after the high insoluble : soluble fibre breakfast. The findings of these studies suggest a short-term inhibition of hunger following a high-fibre breakfast, but greater statistical power and longer-term studies are needed to test whether the subjective reports of appetite suppression translate into reduced energy intakes.

NUTRITIONAL EFFECTS OF READY-TO-EAT BREAKFAST CEREALS

It could be argued from epidemiological evidence that many of the dietary patterns associated with breakfast consumption are due to inclusion of ready-to-eat breakfast cereals (RTEC) in that meal. Analysis of breakfast cereal consumption patterns as a separate variable supports this concept (Crawley, 1993; Gibson & O'Sullivan, 1995; Ruxton *et al.* 1996), although epidemiology cannot be viewed in isolation as proof of a 'cause-and-effect' mechanism.

An intervention study (Kirk *et al.* 1997) encouraged daily consumption of RTEC in a population of students with a low intake of breakfast cereals. After 12 weeks, compared with baseline and a control group, percentage energy from fat in the experimental group had decreased significantly from 35 to 29 %, while percentage energy from starch had increased from 26 to 31 %. Intakes of certain micronutrients in the experimental group were higher than baseline and in the control group (T. R. Kirk, unpublished results). Hobbiss & Mahdavi (1995) attempted to increase breakfast cereal intakes in forty-eight adults using 418·4 kJ (100 kcal) exchanges and reported a successful outcome via a lifestyle questionnaire. However, this study was highly subjective and did not report any data on nutrient intakes or amounts of breakfast cereals consumed. A school breakfast programme in Peru (Jacoby *et al.* 1996) led to improved intakes of energy, protein and Fe in the intervention group (*n* 233) compared with a control group (*n* 169).

What characterizes RTEC to explain the reported associations with dietary intakes and, possibly, biochemical factors? RTEC are high in carbohydrate and are usually fortified with a range of micronutrients including thiamin, riboflavin, vitamin B_6, vitamin B_{12}, vitamin D, folic acid, niacin and Fe (Rawitscher & Mayer, 1981; Nicklas *et al.* 1995). Table 4 presents data on the macro- and micronutrient compositions of a range of popular RTEC. Many varieties are high in dietary fibre due to the inclusion of wholegrains, bran or dried fruit (Toma & Curtis, 1989), although it has been suggested that products marketed

Table 4. *Average portion sizes and nutrient composition of ready-to-eat breakfast cereals per 100 g*

	Corn Flakes†	Rice Krispies†	All Bran†	Bran Flakes†	Fruit and Fibre†	Sugar Puffs‡	Weetabix‡
Average portion (g)*	40	30	50	40	40	40	40
Energy (kJ)	1550	1600	1150	1350	1500	1381	1500
Protein (g)	8	6	13	10	8	6	8
Carbohydrate (g)	82	85	46	65	67	84	71
Fat (g)	0·7	0·9	3·5	2·0	6·0	0·8	4·5
Fibre (g)	3·0	1·5	28·0	16·0	9·0	3·2	6
Vitamin D (μg)	4·2	4·2	3·1	4·2	0	0	0
Vitamin C (mg)	0	0	0	50	0	0	0
Thiamin (mg)	1·2	1·2	0·9	1·2	0·9	Tr	0·9
Riboflavin (mg)	1·3	1·3	1·0	1·3	1·0	0·03	1·5
Niacin (mg)	15	15	11·3	15·0	11·3	2·5	11·2
Vitamin B_6 (mg)	1·7	1·7	1·3	1·7	1·3	0·05	0·22
Folic acid (μg)	333	333	125	167	125	12	50
Vitamin B_{12} (μg)	0·85	0·85	0·65	0·85	0·65	0	0
Iron (mg)	7·9	7·9	8·8	11·7	8·8	2·1	7·4
Zinc (mg)	0·3	1·1	5·8	2·8	1·6	1·5	2·0
Calcium (mg)	5·0	10	60	40	40	14	35
Potassium (mg)	90	140	950	550	450	160	370
Sodium (mg)	1100	1100	900	800	600	140	290
Phosphorus (mg)	50	140	700	400	240	55	120
Magnesium (mg)	10	50	220	130	70	9	270

Tr, trace.
* Crawley (1988).
† Data from the Kellogg Company of Great Britain.
‡ Holland *et al.* (1991).

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for children tend to be low in fibre (Mitchell & Boustani, 1992). Na and sugars may be added to enhance palatability (Wang *et al.* 1992). The National Food Survey (Ministry of Agriculture, Fisheries and Food, 1995) found that breakfast cereals contributed 5 % to Na intakes (compared with 20 % from meat products), suggesting that breakfast cereals were not an important source of Na in the British diet. In the case of total sugars, breakfast cereals contribute 3 % of the total sugar intake of 5–12-year-old American children (Morgan *et al.* 1981), 3 % in English adolescents (Hackett *et al.* 1986) and adults (Ministry of Agriculture, Fisheries and Food, 1995) and 16 % in Scottish 7-year-olds (Ruxton *et al.* 1996). Criticism that sugar-containing breakfast cereals have a negative impact on dental health is not supported by controlled trials (Glass & Fleisch, 1974) or by longitudinal studies in which unlimited supplies of sweetened breakfast cereals were provided (Rowe *et al.* 1974). The addition of milk to breakfast cereals provides a further source of micronutrients and is acknowledged as a contributing factor to reported associations between breakfast cereals and nutrient intakes, particularly Ca and vitamin A.

CONCLUSIONS

This review has examined the role of breakfast in the diet with reference to nutritional, biochemical and physiological aspects. Evidence from a range of dietary surveys relates breakfast to higher intakes of certain micronutrients, particularly when a fortified breakfast cereal is eaten. Data on folate status show a clear contribution from fortified cereals and it would be interesting to extend this type of work to investigate the influence of breakfast on plasma levels of other micronutrients, such as Fe. Epidemiological evidence, supported by an intervention study, links breakfast consumption with lower fat intakes, probably due to the higher carbohydrate and low fat content of commonly-eaten breakfast foods, such as bread and breakfast cereals. Studies relating breakfast consumption to better lipid profiles appear to suggest a particular role for fibre, while effects of breakfast on appetite and weight control require further support from larger, longer-term studies to back up the epidemiological data.

Consumption of a cereal-based breakfast is clearly related to a range of positive dietary behaviours and possibly related to a beneficial biochemical status, suggesting that anecdotal beliefs about the benefits of breakfast may be justified.

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