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A review of associations between Crohn's disease and consumption of sugars

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Objectives: To critically review the available literature reporting associations between the onset of Crohn's disease and intakes of sugars or sugar-containing foods. To evaluate published evidence on the use of dietary manipulation of sugars in the treatment of Crohn's disease.
Design: All publications from refereed journals which reported intakes of sugars and sugar-containing foods in the context of Crohn's disease onset or treatment were selected.
Conclusion: Evidence suggesting a relationship between sugars and onset of Crohn's disease was inconsistent and subject to important methodological limitations. There was a clear lack of distinction between reporting of current, as opposed to, retrospective intakes. There appeared to be no clinical advantage to the use of reduced sugar diets in Crohn's disease treatment.
Sponsorship: The Sugar Bureau.
Descriptors: Crohn's disease; aetiology; treatment; sugars

Introduction

Crohn's disease (CD) can affect any part of the gastrointestinal tract and is characterised by chronic inflammation of the bowel wall often associated with granulomas and deep fissuring ulceration. There can be long periods of remission interspersed with relapse when patients experience abdominal pain, diarrhoea, weight loss and anaemia. Traditional treatment of active disease includes pharmaceutical or surgical intervention. Enteral feeds and steroids are effective in producing remission, while long term remission has been maintained by exclusion diets. CD can occur at any age and is more prevalent in industrialised societies than in the developing world. For example, the average UK incidence is 8–14 patients per 100 000.

The aetiology of CD is unknown, although possible determinants include genetic factors, immune mechanisms and bacterial or viral agents. For many years, the influence of diet has been considered and, as early as 1969, Burkitt postulated that 'refined foods' could cause a wide spectrum of colonic diseases. The idea of specific macronutrients acting as an aetiological factor in CD was not raised until the mid-seventies when Miller *et al* (1976) and Martini & Brandes (1976) in Germany investigated observations that adolescent CD sufferers had eaten large quantities of sweets before diagnosis. In Britain, James (1977) was the first to consider diet as a possible cause of CD when he investigated foods eaten on an empty stomach, finding that patients ate cornflakes at breakfast more often than controls. Later studies have not confirmed these findings.

This paper critically reviews the evidence for and against the hypothesis that refined foods, particularly sugars, are related to the onset of CD and draws on studies where a shift from refined to unrefined diets has been tested as a means of inducing remission in CD patients.

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Section 1

Past diet and present Crohn's disease

This section will consider studies which have attempted to identify early dietary behaviours which relate to the onset of CD. The recalled diets were mainly those followed just prior to the start of symptoms, although diets consumed over a number of months before symptoms arose were also considered. All studies included a control group which was asked, in the main, to recall the diet eaten at the time corresponding to the matched patient's onset of symptoms. In a small number of studies, controls were asked only to recall current habitual intake. Significant differences in the intake of sugars or consumption of particular foods were investigated between patient and control groups. A summary of the methods and findings of the 14 studies examining intake of sugars and refined foods as one aetiological factor in CD is presented in Tables 1a and 1b. A number of terminologies relating to sugar were used by the authors, for example refined, added, total, and these have been retained in the descriptions of studies. In the discussion of these papers, the expression 'sugars' is used as an umbrella term.

Evidence

Seven authors focused on the relationship between onset of CD and intakes of sugars and refined foods. Martini & Brandes (1976) used a postal questionnaire to examine intakes of confectionery, preserves, biscuits and cakes 1–3 y prior to the onset of disease in a group of 63 CD patients. A control group, matched for age, sex and social class, was asked to recall current rather than retrospective diet, which would have made the results more comparable. Martini and Brandes validated their postal questionnaire by comparing results from 15 patients with results from a dietary history. Bingham (1987) has criticised the use of qualitative dietary assessment techniques, such as the diet

Table 1a Published studies relating retrospective intake of selected sugar-containing foods to incidence of Crohn's disease

Author, year	*CD n =*	*Control n =*	*Length of diagnosis*	*Diet recalled*	*Dietary assessment*	*Significant difference in intakes*
Martini, 1976	63	63[a]	mean 4.5 y	Pre-disease	Postal questionnaire	+
Rawcliffe, 1978	100	100	?	Pre-symptoms	Interview recall	0
Silkoff, 1980	27	27	mean 8 y	At onset of symptoms	Questionnaire	+
Katschinski, 1988	104	153	?	10 y previously	Postal questionnaire	+
Mayberry, 1980	120	120	mean 10.1 y	Pre-symptoms	Postal questionnaire	+
Gilat, 1987	302	998	6 months–15 y	Pre-disease	Interview recall	0
Mayberry, 1981	32	32	< 1 y	Pre-symptoms	Postal questionnaire	+

[a]Current diets studied in controls.
? = No details given.

Table 1b Published studies relating retrospective intake of total dietary sugars to incidence of Crohn's disease

Author, year	*CD n =*	*Control n =*	*Length of diagnosis*	*Diet recalled*	*Dietary assessment*	*Significant difference in intakes*
Jarnerot, 1983	15	15	< 6 months	Pre-disease	Diet history	0
	15	15	7–36 months	Pre-disease		+
Persson, 1992	152	305	Up to 4 y	5 y previously	Postal questionnaire	+
Kasper, 1979[b]	35	70[a]	1–2 y	Pre-disease	7 d recall	+
Thornton, 1979	30	30[a]	< 3 months	Pre-disease	Diet history	+
Tragnone, 1995	51	102	Recent	Up to six months pre-disease	Food frequency questionnaire	+
Reif, 1997	33	59	Recent	Up to 1 y	Quantified diet history	0
Matsui, 1990	50	50[a]	?	Pre-disease	Interview recall	+

[a]Current diets studied in controls.
[b]This study investigated current intakes, subjects claimed sugar intake had been established prior to diagnosis.
? = No details given.

history, as validation tools since they cannot be considered a 'gold standard'. Daily intakes of refined sugars were calculated to be 177 g in CD patients prior to the onset of disease, while current daily intakes in the control group were significantly lower at 74 g. Intakes of refined foods were reported to be higher in the CD group. Reported mean daily energy intakes were 3900 kcal in the CD group and 3200 kcal in the controls, giving percentage energy from sugars as 17% and 9% respectively. The energy values appear high, suggesting overestimation of intakes, while the sugar intake in the CD group is similar to that of the British population (16% of energy; Gibson, 1996).

Rawcliffe & Truelove (1978) interviewed 100 men with CD to investigate whether their pre-disease addition of sugar to drinks and breakfast cereals was higher than average. No indication was given of the length of time which had elapsed between the study and the onset of disease. The 100 controls were asked to estimate their past diet in a similar fashion to the CD group. No significant differences were found between the diets of CD patients and controls.

A questionnaire was used by Silkoff *et al* (1980) to quantify the intakes of table sugar, preserves, confectionery, beverages, fruit and milk by 27 CD patients who had been diagnosed for a mean of 8 y. Questions were aimed at the period of time before symptoms began. Compared with controls, who also retrospectively assessed their diet, mean intakes of total refined sugars were significantly higher in CD patients (207 g/d in controls *vs* 314 g/d in patients). However, when added sugars were compared, there were no significant differences. The reported intakes of total refined sugars in both groups appear unusually high since the energy contribution from sugars can be calculated as 776 kcal for controls and 1178 kcal for patients. Energy intakes were not given but, if the estimated average requirement for men of 2550 kcal (Department of Health, 1991) were used as an example, the resulting percentage energy from total refined sugar would be 30 and 46% in the control and CD groups respectively, which seems abnormally high. Interestingly, despite the patients' claims that sugar intakes had not changed since the onset of symptoms, current intakes of sugars were found to be lower than the intakes recalled for the period before symptoms appeared.

Katschinski *et al* (1988) examined diet as part of a study looking at the relationships between smoking and CD in 104 patients matched with 153 age- and sex-matched controls. The postal questionnaire attempted to quantify intakes of confectionery and sugar added to drinks and cereals. The period of time recalled was up to 10 y prior to the study for both patients and controls, although it was not stated when patients were diagnosed. When the estimated added sugar intakes were expressed as five 40 g increments, significantly more controls fell into the 'zero' category, while more CD patients were in the 40–79 g and 80–119 g categories.

Mayberry *et al* (1980) used a postal questionnaire to investigate current intakes of sugar, milk and breakfast cereals in a group of 120 patients with CD who had been diagnosed for a mean of 10 y (sd 7.2 y). The controls, who were matched for age and sex were also asked to estimate current intakes of added sugars. CD patients were asked if they had altered their use of sugar since the onset of the disease, while controls were asked to recall any changes in their sugar usage over a similar time period. Results showed that significantly fewer CD patients had reduced their sugar intakes over time compared with controls (27 *vs* 46%). The authors concluded that it was unlikely that sugar played a primary role in the development of CD but suggested that sugar restriction may favourably influence

the disease course. This idea is explored later in this review.

A multi-centred study from nine countries, published by Gilat *et al* (1987), examined intakes of commercial desserts, carbonated drinks and sweetened cow's milk in 302 CD patients. All subjects interviewed were less than 25 y old and had been diagnosed at least six months previously. Controls were matched for age and sex. Both groups were asked to recall their dietary intakes at the age of 10 y or earlier. The questions about addition of sugar to cow's milk related to infancy. No significant differences were found in the intakes of desserts and sweetened beverages or in the addition of sugar to cow's milk between the patients and controls. However, the authors expressed doubt about the quality of the data, stating that 'it could not be independently ascertained whether these dietary habits antedated or followed disease'.

Mayberry *et al* (1981) used a postal questionnaire to focus on the addition of sugar to drinks and the frequency of consumption of sugar-containing foods such as cakes, confectionery, honey and soft drinks. The 32 CD patients, who had been diagnosed within 12 months of the study, were age- and sex-matched with healthy controls. Patients were asked to recall both current dietary intakes and those prior to the onset of symptoms, which had been present for an unspecified 'considerable period' of time. Controls recalled their diets in a similarly retrospective fashion. The weekly addition of sugar to drinks and cereals, estimated from the questionnaire, was significantly higher in the CD group compared with the controls (336 g *vs* 168 g per week). In addition, CD patients ate significantly more food items containing sugar per day during the time prior to the onset of their symptoms; three items compared with one item in the control group. A 5 d food diary was undertaken by an additional set of 16 patients and 16 controls to provide further information on current intakes of sugars. While the reported daily intakes of added sugars from the postal questionnaire were significantly different between patients and controls (45 g in CD *vs* 18 g in controls), this was not the case when data from the 5 d diary was examined (16 g in CD *vs* 5 g in controls). The authors conceded that the control group's sugar intakes appeared much lower than the 48 g of daily added sugars reported by the National Food Survey at that time, suggesting under-reporting of food data. Mayberry *et al* patients also claimed to have reduced their intake of sugars since diagnosis but this assertion was not supported by the data.

Seven studies considered the relationships between total diet and onset of CD. Using a structured dietary history questionnaire, Jarnerot *et al* (1983) asked 30 CD patients, who had been diagnosed within the previous 3 y, to recall habitual pre-illness diet. Patients were age- and sex-matched with controls who also recalled retrospective diet. For comparison, pre-illness diet was recorded in 30 patients with ulcerative colitis (UC) and 30 patients with irritable bowel syndrome who had been diagnosed less than 3 y before the study. The mean intake of refined sugars was significantly higher in the CD group compared with the controls (88.9 g *vs* 64.3 g per day). Intakes of refined sugars were also higher in the CD group compared with the other patients studied. However, when length of disease was considered, the 15 CD patients who were diagnosed within six months of the study reported daily intakes of sugars which were similar to the controls (69.9 g). This suggests that perception of past sugars intake is influenced by the intervening time between the dietary habits under consideration and the actual recall occasion. In addition, the use of control patients with other illnesses that might influence dietary habits is open to criticism.

UC patients were also used as controls in a study by Persson *et al* (1992). A postal questionnaire was used to assess pre-illness diet and intake of 'fast foods' in 152 CD patients and 145 patients with UC who had been diagnosed up to 4 y prior to the study. A further group of 305 healthy controls was also asked to recall retrospective diet by the same method. Energy and nutrient intakes were estimated by combining the frequency of foods eaten with standard portions sizes. Using the resulting estimates of sucrose intakes, subjects were split into 'high' and 'low' consumption groups, namely >55 g per day *vs* <29 g per day. More patients with CD were found to be in the 'high' group and the relative risk associated with having a sucrose intake in excess of 55 g per day was 2.6 (CI = 1.4–5.0). Using energy intake data from the British adults survey (MAFF, 1994), this cut-off would correspond to a percentage energy from sucrose of only 8% per day. Mean intakes of non-milk extrinsic sugars in the UK are 15% (Gibson, 1996) suggesting that the majority of the British population exceeds Persson *et al* 'safe limit' of 55 g of sugar per day, yet the incidence of CD in the UK is only 8–14 per 100 000. This suggests that sugar cannot be directly toxic but does not exclude a potential trigger effect in susceptible individuals.

A strength of studies where total diet is assessed, rather than the intake of selected foods, is that the subjects' response is less likely to be affected by interview bias. However, making specific requests for information can still bias responses. Kasper & Sommer (1979) in a German study of current total diet in 35 CD patients and age-, sex-, social class-matched controls, included a question about patients' usage of sugar prior to developing symptoms. This involved a recall of consumption patterns related to sugar-containing foods up to two years in the past. Estimated intakes of added sugar were significantly higher in the CD group (156 g *vs* 91 g) and the patients claimed that their sugar usage had 'become a habit many years before onset of the initial symptoms'. As in the case of other studies, mean daily energy intake was high in both groups; 2928 kcal in the controls and 3439 kcal in the CD patients. This would give a percentage energy from added sugars of 11% in the controls and 17% in the CD patients.

Studies using a shorter duration of recall may produce more reliable data but this requires the recruitment of patients who are recently diagnosed. Thornton *et al* (1979) used the diet history method to investigate pre-illness intake in 30 CD patients who had been diagnosed within the previous three months. Symptoms were reported to have occurred for a mean of 5 months prior to diagnosis and patients were asked to consider their dietary intakes leading up to this time. Controls ($n = 30$) were matched for age, sex, social class and reported pre-illness height and weight. They were asked only to recall their current dietary intakes—retrospective intakes would have been better. Significant differences in estimated daily total sugars intake were found (122 g/d in CD *vs* 65 g/d in controls). Percentage energy from total sugars can be calculated from these data as 18% in the CD group and 11% in the control group, which seems low since results for *added* sugars are similar to this in other papers (see Kasper & Sommer, 1979).

Tragnone *et al* (1995) reduced recall bias by studying patients at the time of their diagnosis. A group of 51 newly diagnosed CD patients were asked to recall their pre-illness

diet while 102 age- and sex-matched controls reported dietary intakes from a period between 6 and 12 months prior to the study. A food frequency questionnaire, administered by interview and combined with standard portion data, was used as the dietary assessment tool. Intakes of carbohydrate, starch, energy and refined sugars were significantly higher in the CD group compared with controls (100.2 g per day *vs* 81.4 g per day for refined sugar). However, when reported daily energy intakes are taken into account, (2483 kcal and 2049 kcal in the CD and control groups respectively), percentage energy from refined sugar works out as 15% in both groups. The authors report a relative risk of 3.5 for intakes of sugars above 100 g per day, which relates to the mean daily UK intake (Gibson, 1996). As in the case of Persson *et al* relative risk data, it is difficult to accept that more than half of the UK population have a higher than average risk of CD based on their sugar consumption when the incidence of the disease is so low.

Another study which recruited CD and UC patients at diagnosis was carried out by Reif *et al* (1997) who assessed pre-illness diet using a dietary history questionnaire and photos of portion sizes. Patients were no more than 12 months from the onset of symptoms and the dietary assessment was made by a dietitian. Patients were asked to report current diet and then state whether intakes of each food had changed within the last five years. The changes were then quantified and used to estimate pre-illness dietary intakes. Two controls were matched for age, sex and social class to each of the patients recruited; one from an outpatient clinic and another from the general population. Dietary intakes in the control groups were assessed by telephone interview. No details were given for mean intakes of energy and nutrients to enable comparisons between patients and controls. Instead, intakes of nutrients and food groups were divided by thirds of consumption and odds ratios calculated for each third. Linear trends were calculated and significant positive associations were found in the combined CD/UC patient group ($n = 87$) for sucrose ($P = 0.03$), total fat ($P = 0.02$), animal fat ($P = 0.02$) and vegetable fat ($P = 0.04$) when compared with general population controls. When food groups were considered, a significant positive association was found with soft drinks compared with the outpatient clinic controls ($P = 0.01$) but not with the general population controls ($P = 0.31$). These associations were not significant when the CD group ($n = 33$) was considered alone.

Matsui *et al* (1990) interviewed 50 CD patients to assess their pre-illness diet. It is not clear whether the 50 healthy controls, who were matched for age, sex and social class, were asked to recall past diet or report current intakes. No information was given either on the length of diagnosis or on the mean time for which symptoms were experienced. CD patients were found to consume significantly higher intakes of carbohydrate (343 g *vs* 302 g per day) and sugars (39.9 g *vs* 27.5 g per day) compared with controls.

Critique

Investigating past dietary habits is a technique often employed by epidemiologists to relate the appearance of a disease to specific nutrients or foods. The technique is beset by methodological problems. While an analysis of methods to determine validity of assessment tools is beyond the scope of this review, it is worth mentioning areas where errors can arise. In the case of recall of past dietary intakes, these include incomplete recollection of the types of foods eaten and imprecise estimation of portion sizes. It is accepted that the nature of retrospective dietary assessment precludes the use of weighed inventories. Nevertheless, it is of concern that most studies reported here estimated intakes of macronutrients and specific foods to the nearest gram using imprecise tools such as postal questionnaires, which can only classify individuals into broad groups (Bingham, 1987). Estimates of error are particularly important where clinical differences are small and only just statistically significant. For example, in the cases of Mayberry *et al* (1981), Jarnerot *et al* (1983), Matsui *et al* (1990), Persson *et al* (1992) and Tragnone *et al* (1995), differences in reported sugars intake between CD patients and controls varied by only 12 g to 25 g per day.

Apart from methodological problems which affect most estimates of retrospective diet, the key criticism of the studies described here is the length of time between the pre-illness diet and its recall. Certainly, Jarnerot *et al* (1983) acknowledged that it was 'almost impossible for patients to remember in any detail their dietary habits from several years earlier', while Archer & Harvey (1978) claimed that 'few people can recall with confidence what they regularly ate several years previously'. Despite this, of the 11 studies which reported length of time since diagnosis, only two interviewed newly diagnosed patients. Of the remainder, two interviewed patients who had been diagnosed up to 2 y before the study commenced, four studies involved patients who had been diagnosed six months to 5 y prior to interview and three reported that patients had been diagnosed up to 10 y previously. Few studies reported the duration of symptoms occurring prior to diagnosis. This is important as it would increase the retrospective element of the assessment if pre-illness, rather than just pre-diagnosis, diet was of interest. Onset of symptoms is also important if it is accepted that the abdominal pain, weight loss and diarrhoea characterising CD might influence what is eaten during the period leading up to diagnosis.

Another source of bias originates from patient awareness of the study's aim which can lead to under- or over-reporting of dietary behaviour. Therefore, care is required to avoid focusing on the consumption of specific foods, especially during face-to-face interviews. Only four of the studies presented ensured that subjects were unaware of the hypothesis, while seven focused on questions relating to intake of sugars. Three did not state whether subjects were aware. Taking these methodological considerations into account, it must be questioned whether estimates of retrospective diet are an acceptably rigorous source of information when relating past behaviours to present illness. A further point relates to whether subjects recalling retrospective diet have the ability to separate present eating patterns from those in the distant past. Jarnerot *et al* (1983) believed that the patients in their study were reporting present diet, using this theory to explain why sugar intakes in newly diagnosed patients differed from intakes of patients diagnosed more than 6 months before the study. Gilat *et al* (1987) also expressed concern about the validity of their retrospective dietary data. Differences in current diet between patients and controls are presented later in this review.

Eleven of the studies found differences in the intakes of sugars and refined foods between patients and controls but it is difficult to accept that patients with a disease which could prejudice current dietary intakes would be able to quantify intakes of specific foods eaten up to 10 y prior to the study. However, if a relationship between CD and

intakes of sugars or refined foods does exist, it may be possible to see trends in CD incidence and per capita sugar consumption data.

Intakes of sugars vary considerably across countries and daily intakes of healthy adults are reported to be 64.3 g in Sweden (Jarnerot *et al*, 1983); 65 g in Britain (Thornton *et al*, 1979); 81.4 g in Italy (Tragnone *et al*, 1995); 91 g (Kasper & Sommer, 1979) and 74 g (Martini & Brandes, 1976) in Germany; 27.5 g in Japan (Matsui *et al*, 1990) and 207 g in Israel (Silkoff *et al*, 1980). Amongst CD sufferers, daily intakes of sugars are 88.9 g in Sweden (Jarnerot *et al*, 1983); 122 g in Britain (Thornton *et al*, 1979); 100.2 g in Italy (Tragnone *et al*, 1995); 156 g (Kasper & Sommer, 1979) and 177 g (Martini & Brandes, 1976) in Germany; 39.9 g in Japan (Matsui *et al*, 1990) and 314 g in Israel (Silkoff *et al*, 1980). If intakes of sugars are of primary importance in CD onset, the incidence in Israel should be substantially greater than any of the other countries considered. Sonnenberg (1988) conducted an epidemiological analysis correlating the per capita consumption of refined sugars with the incidence and mortality of CD from different countries. No significant correlations was found between refined sugar consumption and the incidence or time trends of Crohn's disease. Correlation of recent data relating to incidence of CD in Northern Europe (eight countries for which data on both sugar intakes and CD incidence were available are Iceland, Norway, Denmark, Ireland, UK, Netherlands, Germany and France) (Shivananda *et al*, 1996) and per capita sugar consumption (Woodward & Walker, 1994) reveals no significant association (Figure 1). However, it is acknowledged that this type of comparison can be flawed by the age of the data, namely should CD incidence be related to sugar consumption data from the *same* year or to data from 5–10 y before?

Silkoff *et al* (1980) have remarked that, while the incidence of CD in the UK has been rising, intakes of sugar have remained fairly stable. This point was supported by Mayberry *et al* (1981) who added that 'it is of note that the rise in incidence of CD in Great Britain does not correspond with any marked change in sugar consumption in the last 50 y'. Therefore, it would appear that the available epidemiological data do not lend support to a relationship between the onset of CD and intakes of sugars. However, to avoid discounting the findings from the retrospective studies unfairly, it is necessary to explore two further questions: (1) Are there differences in contemporary dietary intakes between CD patients and the general population which could explain the trends towards higher intakes of sugars seen in the recall data? (2) Is it reasonable to assume that, if sugars and refined foods are important factors in CD, improvements in symptoms or outcome will result from avoidance of these types of foods? These questions are addressed below.

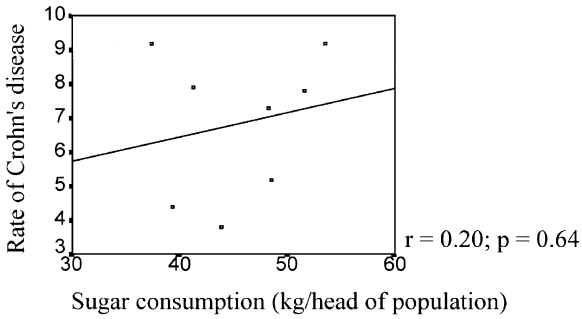

Figure 1 Rates of Crohn's disease corrected for age and sex in eight Northern European countries (Shivanandaet *al*. 1996) *vs* per capita sugar consumption (Woodward & Walker, 1994).

Section 2

Current diet in patients with Crohn's disease

This section will present the methods and findings of 13 published studies which have investigated current intake of sugars in CD patients and will provide an assessment of their methodological quality. The studies are summarised

Table 2a Published studies examining current intake of selected sugar-containing foods in patients with Crohn's disease and controls

Author, year	*CD n =*	*Controls n =*	*Activity specified?*	*Treatment specified?*	*Dietary assessment*	*Sig. difference in intakes*
Mayberry, 1978	100	100	No	No	Interview re: sugar at breakfast	+
Graham, 1978	68	74	No	No	Interview re: sugar at breakfast	+
Silkoff, 1980	27	27	No	No	Interview re: milk, fruit, sweet foods and sugar	+
Mayberry, 1980	120	120	No	No	Postal questionnaire re: sugar only	+
Mayberry, 1981	32	32	No	No	Postal questionnaire re: sweet foods	+
Penny, 1983	70	58	Yes	No	Self-filled questionnaire re: sweet foods only	+
Porro, 1985	109	250	No	Yes	Interview re: refined CHO and vegetables	+
Katschinski, 1988	104	153	No	No	Postal questionnaire re: sugar only	+

CHO = carbohydrates.
Sig. = significant.

Table 2b Published studies examining current total sugar intake in patients with Crohn's disease and controls

Author, year	*CD n =*	*Controls n =*	*Activity specified?*	*Treatment specified?*	*Dietary assessment*	*Sig. difference in intakes*
Martini, 1976	63	63	No	No	Postal questionnaire	+
Kasper, 1979	35	70	No	No	7 d recall	+
Kasper, 1980	23	23	Yes	No	Diet history	+
Mayberry, 1981	16	16	No	No	5 d weighed intake	0
Brauer, 1983	23	65	Yes	No	48-h recall	0
Jarnerot, 1983[a]	30	30	No	No	Food frequency questionnaire	+

[a] This study was originally designed to investigate retrospective sugar intakes but authors believed subjects reported current intakes.
Sig. = significant.

in Tables 2a and 2b. Six of these have examined current intakes alongside retrospective intakes in the same groups of patients and controls. The retrospective element has already been presented in Section 1.

The majority of studies reviewed suggest that CD patients eat a diet which is higher in sugar than controls. However, little attention has been paid to either the activity of the disease or the type of treatment given, both of which may affect nutritional intakes. Detailed examination of the methods used reveals flaws which lessen the robustness of the results. Many studies were open in design and only one was conducted on a double blind basis. Control groups were often other patients or hospital employees, who may have been exposed to more nutritional information than the general public. The methodologies used to assess dietary intake and the types of nutrients reported varied considerably making comparisons difficult.

Evidence

Three different assessments of sugar intake were used in the 13 studies:

I. Use of added sugar to cereals and drinks.
II. Consumption of sweet foods combined with amount of sugar added to foods.
III. Total dietary intake.

For the purpose of this review, studies will be grouped according to their method of assessment for sugar intake. As a few studies used two methods of dietary assessment, they feature in more than one category.

Methodology type I

Following early interest in the possible role of breakfast in CD incidence, Mayberry *et al* (1978) suggested that CD patients ate more sugar than controls based upon data showing that significantly more patients than controls added sugar to their breakfast cereals ($P < 0.05$) and to their beverages ($P < 0.001$). Daily added sugar was examined by both Graham *et al* (1978) and Mayberry *et al* (1980) as a proxy for total sugar intake. Both studies reported similar intakes and found that CD patients added more sugar to foods than controls. However, the disease activity or treatment were not considered and the control groups selected by the authors were other patients or hospital staff. Graham *et al* (1978) interviewed subjects and reported that CD patients consumed 10 teaspoons of sugar per day compared with seven teaspoons in the control group ($P < 0.0009$). Using a postal questionnaire, Mayberry *et al* (1980) found that patients added 10.6 teaspoons per day whereas controls added six teaspoons per day ($P < 0.001$).

Methodology type II

In addition to measuring the daily amount of added sugar, six published studies questioned patients about their daily intake of sweet foods and confectionery. All found that CD patients ate significantly more sweet foods than controls recruited from other patient groups or hospital staff. Only one study by Thomas *et al* (1993) considered disease activity and treatment.

In Israel, Silkoff *et al* (1980) questioned CD patients and matched controls about their intakes of added sugar and sweet foods during the previous week. Although the study did not claim to be blind, subjects may not have been aware of the nutrient being studied as questions about milk and fruit intakes were included in the interview. Total daily sugar intake was estimated from reported consumption of these foods and was found to be significantly higher in CD patients (269 g in patients *vs* 192 g in controls; $P < 0.02$). The amount of added sugar taken by patients was 35 g compared with 16 g in controls and there was no correlation between total and added sugar intakes.

Mayberry *et al* (1981), conducted a two part study to compare current sugar consumption in CD patients and matched controls, using a postal questionnaire. Weekly intake of sugar was assessed from a combination of added sugar and the number of sugar containing foods and drinks. The study was not reported to be blind. Daily estimates of added sugar were significantly greater in the Crohn's patients than in controls (45 g compared with 18 g; $P < 0.05$) and patients ate significantly more sugar-containing foods, having a median of two items per day compared with one item per day in controls ($P < 0.02$).

Penny *et al* (1983) related sugar consumption to changes in taste acuity in patients with inflammatory bowel disease. This is one of the few studies to measure disease activity in CD patients but the results show only a comparison with taste sensitivity and not with sugar intake. Patients with CD, matched controls and patients with UC were asked to complete a questionnaire on their daily intake of added sugar and sugar-containing foods. CD patients were found to eat significantly more sugar-containing foods than controls (3.37 items per day compared with 2.15 items per day; $P < 0.001$) and added more sugar to foods (65.1 g compared with 29.2 g; $P < 0.01$). CD patients also ate significantly more sugar-containing foods and added more sugar to foods than UC patients. Taste sensitivity was found not to relate to sugar consumption.

Porro & Panza (1985) reported a positive correlation between refined carbohydrate intake and the risk of both CD and UC when examining the relationship between smoking habits and inflammatory bowel disease. However, there are no details in this short report regarding disease activity, diet methodology, figures for sugar intake or refined carbohydrate intake.

Katschinski *et al* (1988) used a postal questionnaire to enquire about smoking habits, added sugar intake and confectionery consumption in patients with CD and matched controls from a General Practitioner's list. Sugar intake was not quantified but expressed in 40 g increments. Significantly more controls than patients ate less than 40 g of added sugar per day and more patients than controls were found to add between 40 g and 119 g of sugar per day. CD patients were also found more likely to report high levels of confectionery consumption.

Intakes of confectionery were also studied by Thomas *et al* (1993) using a food frequency questionnaire. Children with CD in remission were found to have a greater intake of confectionery than their healthy siblings ($P < 0.05$), although there were no significant differences in intakes of added sugar. This study is discussed in greater detail below.

Methodology type III

In six studies, less 'food focused' dietary assessments were used, namely recall of total daily intakes. This would have helped to conceal the study's purpose and provided more robust data. The most notable study, by Brauer *et al* (1983), was double-blind and used a randomly selected control group—most others have chosen hospital patients as controls or have not provided details about their control group.

In this study, dietitians used a 48 h recall combined with food portion models to estimate total dietary intake in CD patients and controls. Average intakes of energy, total sugar, protein, fat, carbohydrate, starch and fibre were estimated in female patients with CD, UC and irritable bowel syndrome and compared with intakes from female controls ($n = 65$) living in the same residential area. Disease activity was assessed in CD patients only ($n = 23$) and the majority were found to have quiescent disease, though nutrient intakes did not correlate with disease activity. Treatment type was not reported. There were no significant differences between the CD patients and healthy controls for any of the above nutrients. Mean energy intakes were 1851 kcal in the CD patients and 1836 kcal in the controls, while mean total daily sugar intakes were 121 g (24% of energy) in CD patients and 101 g (20% of energy) in the controls.

In a single blind study, Martini & Brandes (1976) obtained current dietary histories from patients with CD and matched controls using a postal questionnaire and also asked about retrospective intakes (see Section 1). Treatment and disease activity were not reported in the patient group. Total daily energy intake was 3200 kcal in both groups, which seems a high value. Patients were found to eat significantly more sweet foods (sugar, preserves, candies and chocolate) than controls (482 g per week *vs* 285 g per week; $P < 0.005$). Estimated daily sugar intakes were 116 g in patients and 74 g in controls, giving a percentage energy sugar of 14% in patients and 9% in controls. As in the case of other studies, the figure for patients appears more similar to the UK national average (Gibson, 1996) while the figure for controls seems rather low.

Kasper & Sommer (1979) examined total diet in CD patients using a 7 d recall to assess any effects of preference for sweet foods on intakes of other macronutrients. Information on disease activity or treatment was not reported. CD patients were found to have a significantly higher sugar consumption (156 g in patients compared with 91 g in matched controls; $P < 0.001$). The patients ate significantly more energy, starch and dietary fibre but similar amounts of fat and protein. Energy intakes appeared rather high in both groups—3439 kcal in patients and 2928 kcal in controls—which suggests an overestimation by the 7 d recall method.

In 1980, Kasper & Sommer investigated whether abnormalities in taste could account for the reported increase in consumption of sweet foods by CD patients. Average daily sugar consumption was estimated using a dietary history in patients and matched controls. Disease activity was reported and 15 out of the 23 patients were found to have quiescent disease. Daily sugar intakes in the patient group (140 g $\pm$ 50 g) were deemed to be high by the authors, but no corresponding values were given for the control group. Differences in taste threshold were not found between patients and controls and there were no significant associations between taste threshold and either disease activity or daily sugar intakes.

Mayberry *et al* (1981) asked 16 patients with CD (seven of whom had completed an initial questionnaire on current intake of sweet foods) to weigh all food and drink over 5 d. This is one of the few studies using prospective dietary assessment in CD patients. Disease activity and treatment were not reported. No significant differences in average daily intakes of energy, carbohydrate, total sugars, added sugar, protein, fat and fibre were found between patients and controls. The median energy intake in patients was 2380 kcal and 2868 kcal in the controls, while intakes of total sugars were 118 g (20% of energy) in patients and 104 g (14% of energy) in controls. The estimated intakes of added sugars seem low at 16 g (2.5% of energy) in patients and 5 g (0.7% of energy) in controls. The authors suggested that the low reported levels of added sugar may have been due to modification of intakes during the weighed inventory.

The only study found which examined nutritional intake in CD patients during relapse and remission following specific treatment was conducted by Thomas *et al* (1993), but sugar intakes were sadly not reported. Nevertheless, the study is a good example of how dietary intakes are affected by disease state and treatment. A 5 d weighed dietary intake was completed for 17 children during relapse and compared with matched controls, showing that children with active CD had significantly lower intakes of energy, protein, iron, copper, zinc, folic acid and vitamin C than controls. Children in the CD group were then randomised to one of two treatments for four weeks: steroids with a normal diet or elemental feed only. Energy intakes were reassessed at the end of the study and at week 13, when those on the elemental feed had returned to a normal diet and the steroid dose had been reduced. By week four, energy intakes had increased in both treatment groups, particularly in the steroid group, although, by week 13, energy intakes in the elemental group had returned to pre-treatment levels.

Critique

Eleven of the 13 published studies reviewed suggested that sugar intakes were significantly higher in CD patients than in controls. The studies by Mayberry *et al* (1981) and Brauer *et al* (1983), which used more rigorous methods of dietary assessment, found no significant differences in sugar intakes. The use of varying techniques to estimate dietary intake and possible differences in disease activity (which was not reported in the majority of studies) may have contributed to the inconsistency in results. Mayberry *et al* (1980) and Graham *et al* (1978) used the amount of sugar added to beverages and cereals as a proxy measure of sugar consumption, while a combination of added sugar and frequency of sugar-containing foods was used by Silkoff *et al* (1980), Mayberry *et al* (1981) and Penny *et al* (1983). Katschinski *et al* (1988) used a combination of added sugar and confectionery consumption. It is doubtful whether these types of methods offer an accurate reflection of daily sugar intakes.

The six studies which examined total dietary intakes also used varying assessment techniques; namely dietary history, 7 d recall, postal questionnaire, 5 d weighed inventory, 48 h recall. Many of the studies reported energy intakes which appear unrealistically high and, as in the case of the retrospective evidence, this resulted in sugar intakes as a percentage of energy appearing lower than expected. Table 3a and 3b presents a summary of intakes of energy and sugars from the studies reviewed in Section 1 and Section 2 which have reported such data. It may be that the dietary assessment tools which relied on standard portion sizes, such as the postal questionnaires, recalls and dietary histories over-estimated energy intakes. However, a proper consideration of this cannot be made without data on height, weight and physical activity levels.

A major criticism of the studies reviewed is the lack of attention paid to disease activity and treatment in the patient groups. The majority of CD patients experience

Table 3a Intakes of energy and sugars from published studies of retrospective diets in patients with Crohn's disease compared with controls

	CD patients			*Controls*		
Author, year	*Energy (kcal)*	*Sugars (g)*	*Sugars % energy*	*Energy (kcal)*	*Sugars (g)*	*Sugars % energy*[a]
Jarnerot, 1983	n/a	89		n/a	64	
Thornton, 1979	2483	122	18	2287	65	11
Tragnone, 1995	2483	100	15	2049	81	15

[a]Calculated for the purposes of this review.
n/a = data not reported.

Table 3b Intakes of energy and sugars from published studies of current diets in patients with Crohn's disease compared with controls

	CD patients			*Controls*		
Author, year	*Energy (kcal)*	*Sugars (g)*	*Sugars % energy*	*Energy (kcal)*	*Sugars (g)*	*Sugars % energy*[a]
Martini, 1976	3200	116	14	3200	74	9
Kasper, 1979	3439	156	17	2928	91	11
Mayberry, 1981	2380	118	20	2868	104	14
Brauer, 1983	1851	121	24	1836	101	20

[a]Calculated for the purposes of this review.

periods of relapse and remission, influencing appetite, activity and well-being. The presence of abdominal pain and diarrhoea may well affect appetite and, if patients are receiving high doses of steroids as their medical treatment, increased appetite is likely. Only four out of the 13 reviewed studies measured disease activity. Kasper & Sommer (1980) and Penny *et al* (1983) related this to taste acuity rather than sugar consumption, while Brauer *et al* (1983) recorded the majority of patients as having quiescent disease which may explain the similarity of sugar intake with the general population. The only study to relate dietary intake to disease activity and treatment was Thomas *et al* (1993), although sugar intakes were not reported. However, the study did confirm that high doses of steroids produced a massive increase in appetite, in some cases doubling calorie intake between relapse and the fourth week of treatment.

Therefore, findings that CD patients consume more sugar than the general population may be a consequence of active disease, pharmacological treatment or past dietary advice. Anecdotally, many physicians advise their CD patients follow a low fibre diet based on the rationale that such a diet is less likely to produce symptoms. Such a diet may indeed contain a greater proportion of sugars. Other explanations to explain higher intakes of sugars in CD patients could be that sugar-containing foods are found more palatable, especially when appetite is poor or that sugar-containing foods are given to patients as 'treats'. The findings of Thomas *et al* (1993) that children with CD had a greater intake of confectionery than their healthy siblings would seem to add weight to this suggestion. The idea that a greater consumption of sugars in CD patients may be a result, rather than a cause, of the disease is perhaps supported by the most carefully designed study reviewed (Brauer *et al*, 1983) which found similar intakes of energy and sugars CD patients in remission compared with randomly selected controls.

Section 3

Dietary intervention and Crohn's disease outcome

Therapeutic trials of reduced sugar intakes

Interest in the possible role of sucrose in the pathogenesis of CD has lead to publication of a number of trials of low sugar diets. All but one of the five trials reviewed encouraged patients to follow a high fibre diet as well as reducing sucrose intake (Table 4). The sole study of sucrose avoidance (Brandes *et al*, 1981) involved 20 patients, five with active disease, for a period of 18 months. Here, 10 patients were asked to follow a low carbohydrate diet with sugar excluded, whilst the other ten ate a high carbohydrate diet

Table 4 Published studies of the efficacy of low sugar diets in producing remission in active Crohn's disease

Author, year	*Study patients n =*	*Control patients n =*	*Test diet*	*Control diet*	*Outcome*
Heaton, 1979	32	32	Low sugar, low fibre diet.	No dietary advice given. Retrospective assessment.	• Fewer hospital admissions in study patients. • Drug treatment still required.
Brandes, 1981	10	10	Sugar free diet. All drugs withdrawn.	Sugar rich diet. All drugs withdrawn.	• Patients with high disease activity improved on test diet. • No difference seen when patients were in remission.
Brandes, 1982	20	No control group	Sugar free, high fibre diet. All drugs withdrawn.		• 16/20 remained in remission after 20 months. • 4 relapsed at around 7 months.
Ritchie, 1987	190	162	Low sucrose, high fibre diet.	Low fibre, unrestricted sucrose	• No significant difference between groups.
Alun-Jones, 1985	10	10	Low sugar, high fibre diet. All drugs withdrawn.	Exclusion diet. All drugs withdrawn.	• All on test diet relapsed by 6 months. • Exclusion diet significantly better.

which was referred to as 'sugar rich'. No benefits of sucrose avoidance were found in the patients with inactive CD but four out of five patients with active disease remained well throughout the course of the study compared with none out of four on the 'sucrose rich diet'. Since a full dietary analysis was not reported, it is unclear whether patients complied with the low sucrose recommendation or, indeed, changed their diets in other ways. The difference between the two groups did not reach statistical significance.

In the sucrose and fibre trials, it is difficult to separate the possible effects of sucrose avoidance from those of increasing fibre intake. Nevertheless the two earlier trials (Heaton *et al*, 1979; Brandes *et al*, 1982) claimed benefits for the low sucrose group. In Brandes' 1982 study, 16 out of 20 patients remained well for an average of 19.6 months and only four relapsed, which appears to be a good result. Likewise Heaton *et al* (1979) reported significantly fewer hospital admissions in the diet group. Sadly neither of these studies is scientifically robust. Brandes had no control group whose progress could be compared with those on the dietary treatment and, although Heaton *et al* did have a control group, their study was not a double-blind randomised prospective trial, but obtained control data retrospectively from the notes of 32 other patients.

Of the two randomised prospective studies of low sucrose, high fibre diets, none has demonstrated any significant benefits. The large multi-centre British study conducted by Ritchie *et al* (1987) recruited 190 patients to the active disease group and 162 controls. Physicians assessing the progress of the patients were unaware of their treatment group. No significant benefits of the low sucrose, high fibre diet were seen. In the other, smaller, prospective randomised double blind study (Alun-Jones *et al*, 1985), a low sucrose, high fibre diet was used as a control diet to assess the efficacy of an exclusion diet in the management of CD. All of the 10 patients randomised to the low sucrose, high fibre diet had relapsed by six months whereas seven out of 10 in the exclusion diet remained well ($P < 0.05$). These carefully designed trials suggest that it is unlikely that sucrose avoidance is of benefit in CD treatment. However, the effect of sucrose provocation has yet to be examined in a properly designed trial.

Therapeutic trials of elimination diets

Evidence from food intolerance trials also suggests that sucrose consumption is unlikely to relate to symptoms in CD. Interest in maintaining remission following elemental feeding prompted investigation into the use of elimination diets. The majority of Crohn's patients who achieve remission with an elemental feed relapse after a short period of time if they revert to their normal diet without support from drug treatment. The identification of food intolerances as a means to prolong remission was first suggested by Alun Jones (1995), who reported that two-thirds of patients following restricted diets remained well for two years. Sugar was tested during this food introduction regimen but was not identified as a food intolerance in any of the 64 patients who undertook this treatment. Other workers have confirmed this finding. Pearson *et al* (1993) found that none of the 20 patients who completed their food testing trial identified sugar as a food intolerance, while Giaffer *et al* (1991) reported sugar intolerance in only two out of 20 patients who had followed an elimination diet. In a recent prospective study (Riordan *et al*, 1993), treatment with an exclusion diet produced a significantly longer remission than a normal diet plus prednisolone. Sugar was found to trigger relapse in only two patients out of 40, suggesting that it is unlikely to induce symptoms in the majority of patients.

Conclusions

This paper aimed to examine associations between sugars and Crohn's disease by reviewing evidence from epidemiology, intervention trials and dietary assessment studies. Epidemiology revealed no relationship between national sugar consumption data and the incidence or mortality relating to Crohn's disease. Intervention trials of low sugar diets did not reveal a significant advantage to this type of treatment, suggesting that active disease is not influenced, in the main, by sugar consumption. However, most dietary studies found that Crohn's disease patients consumed greater intakes of sugars and sugar-containing foods than controls. Efforts to relate this to the onset of disease were hampered by the flawed dietary assessment methodologies used in these studies, which often asked patients to recall diets eaten years prior to the study. In most cases, mean intakes of sugar in patients were similar to what would be expected for the general population, suggesting mis-reporting of food intakes in controls and possibly even in patients. Studies where there was a shorter time lag between onset of disease and dietary investigation found few differences in sugar intakes between controls and patients. This may suggest that the duration of disease influences recall. Certainly a few authors raised the possibility that long-standing patients were reporting current rather than retrospective intakes. The available published evidence shows differences in dietary habits between Crohn's patients and controls but fails to answer convincingly whether or not high intakes of sugar actually relate to Crohn's disease onset. While a dedicated prospective trial would be desirable to examine more fully whether dietary components relate to Crohn's disease onset, it is acknowledged that the relatively low incidence of the disease would render this option untenable. It is hoped, instead, that evidence from national prospective surveys, which use a weighed method of dietary assessment, may yield an answer.

References

Alun Jones V, Dickinson RJ, Workman E, Wilson AJ, Freeman AH & Hunter JO (1985): Crohn's disease: maintenance of remission by diet. *Lancet* **ii**, 177–180.

Archer LNJ & Harvey RF (1978): Breakfast and Crohn's disease. Part II. *Br. Med. J.* **ii**, 540.

Bingham SA (1987): The dietary assessment of individuals; methods, accuracy, new techniques and recommendations. *Nutrition Abstracts and Reviews* (Series A) **57**, 705–742.

Brandes JW & Lorenz-Meyer H (1981): Sugar free diet: a new perspective in the treatment of Crohn's disease? Randomized, control study. *Z. Gastroenterol.* **19**, 1–12.

Brandes JW, Korst HA & Littman KP (1982): Sugar-free diet as long-term or interval treatment in the remission phase of Crohn's disease—a prospective study. *Leber Magen Darm.* **12**, 225–228.

Brauer PM, Gee MI, Grace M & Thomson AB (1983): Diet of women with Crohn's and other gastrointestinal diseases. *J. Am. Diet. Assoc.* **82**, 659–664.

Burkitt DP (1969): Related disease—related cause? *Lancet* **ii**, 1229.

Department of Health (1991): *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*. Report on Health and Social Subjects, 41. London: HMSO.

Giaffer MH, Cann P & Holdsworth CD (1991): Long-term effects of elemental and exclusion diets for Crohn's Disease. *Aliment. Pharmacol. Ther.* **5**, 115–125.

Gibson SA (1996): Are diets high in non-milk extrinsic sugars conducive to obesity? An analysis from the Dietary and Nutritional Survey of British Adults. *J. Hum. Nutr. Diet.* **9**, 283–292.

Gilat T, Hacohen D, Lilos P & Langman MJS (1987): Childhood factors in Ulcerative Colitis and Crohn's disease. An international co-operative study. *Scand. J. Gastroenterol.* **22**, 1009–1024.

Graham WB, Torrance B & Taylor TV (1978): *Br. Med. J.* **2**, 768.

Heaton KW, Thornton JR & Emmett PM (1979): Treatment of Crohn's disease with an unrefined carbohydrate, fibre-rich diet. *Br. Med. J.* **2**, 764–766.

James AH (1977): Breakfast and Crohn's disease. *Br. Med. J.* **1**, 943–945.

Jarnerot G, Jarnmark I & Nilsson K (1983): Consumption of refined sugar by patients with Crohn's disease, Ulcerative Colitis or Irritable bowel syndrome. *Scand. J. Gastroenterol.* **18**, 999–1002.

Kasper H & Sommer H (1979): Dietary fibre and nutrient intake in Crohn's disease. *Am. J. Clin. Nutr.* **32**, 1898–1901.

Kasper H & Sommer H (1980): Taste thresholds in patients with Crohn's disease. *J. Hum. Nutr.* **34**, 455–456.

Katschinski B, Logan RFA, Edmond M & Langman MJS (1988): Smoking and sugar intake are separate but interactive risk factors in Crohn's disease. *Gut* **29**, 1202–1206.

MAFF (1994): The Dietary and Nutritional Survey of British Adults—Further Analysis. London: HMSO.

Martini GA & Brandes JW (1976): Increased consumption of refined carbohydrates in patients with Crohn's disease. *Klinische Wochenschrift* **54**, 367–371.

Matsui T, Iida M, Fujishima M, Imai K & Yao T (1990): Increased sugar consumption in Japanese patients with Crohn's disease. *Gastroenterologia Japonica* **25**, 271.

Mayberry JF, Rhodes J & Newcombe RG (1978): Breakfast and dietary aspects of Crohn's disease. *Br. Med. J.* **2**, 1401.

Mayberry JF, Rhodes J & Newcombe RG (1980): Increased sugar consumption in Crohn's disease. *Digestion* **20**, 323–326.

Mayberry JF, Rhodes J, Allan R, Newcombe RG, Regan GM, Chamberlain LM & Wragg KG (1981): Diet in Crohn's disease. Two studies of current and previous habits in newly diagnosed patients. *Dig. Dis. Sci.* **26**, 444–448.

Middleton SJ, Rucker JT, Kirby GA, Riordan AM & Hunter JO (1995): Long-chain triglycerides reduce the efficacy of enteral feeds in patients with active Crohn's disease. *Clinical Nutrition* **14**, 229–236.

Miller B, Fervers F, Rohbeck R & Strohmeyer G (1976): Sugar consumption in patients with Crohn's disease (German). *Verh. Dtsch. Ges. Inn. Med.* **82** (Part 1), 922–924.

Pearson M, Teahon K, Levi AJ & Bjarnason I (1993): Food intolerance in Crohn's disease. *Gut* **34**, 783–787.

Penny WJ, Mayberry JF, Aggett PJ, Gilbert JO, Newcombe RG & Rhodes J (1983): Relationship between trace elements, sugar consumption, and taste in Crohn's disease. *Gut* **24**, 288–292.

Persson PG, Ahlbom A & Hellers G (1992): Diet and Inflammatory Bowel Disease: a case-control study. *Epidemiology* **3**, 47–52.

Porro GB & Panza E (1985): Smoking, sugar and inflammatory bowel disease. *Br. Med. J.* **291**, 971–972.

Rawcliffe PM & Truelove SC (1978): Breakfast and Crohn's disease-1. *Br. Med. J.* **2**, 539–540.

Reif S, Klein I, Lubin F, Farbstein M, Hallak A & Gilat T (1997): Pre-illness dietary factors in inflammatory bowel disease. *Gut* **40**, 754–760.

Riordan AM, Hunter JO, Cowan RE, Crampton JR, Davidson AR, Dickinson RJ, Dronfield MW, Fellows IW, Hishon S, Kerrigan GNW, Kennedy HJ, McGouran RCM, Neale G & Saunders JHB (1993): Treatment of active Crohn's disease by exclusion diet: East Anglian Multicentre Controlled Trial. *Lancet* **342**, 1131–1134.

Ritchie JK, Wadsworth J, Lennard-Jones JE & Rogers E (1987): Controlled multicentre therapeutic trial of an unrefined carbohydrate, fibre-rich diet in Crohn's disease. *Br. Med. J. Clin. Res.* **295**, 517–520.

Shivananda S, Lennard-Jones J, Logan R, Fear N, Price A, Carpenter L & van Blankenstein M and the EC-IBD Study group (1996): Incidence of inflammatory bowel disease across Europe: is there a difference between north and south? Results of the European collaborative study on inflammatory bowel disease (EC-IBD). *Gut* **39**, 690–697.

Silkoff K, Hallak A, Yegena L, Rozen P, Mayberry JF, Rhodes J & Newcombe RG (1980): Consumption of refined carbohydrate by patients with Crohn's disease in Tel-Aviv-Yafo. *Postgrad. Med. J.* **56 (662)**, 842–846.

Sonnenberg A (1988): Geographic and temporal variations of sugar and margarine consumption in relation to Crohn's disease. *Digestion* **41**, 161–171.

Thomas AG, Taylor F & Miller V (1993): Dietary intake and nutritional treatment in childhood Crohn's disease. *J. Pediatr. Gastroenterol. Nutr.* **17**, 75–81.

Thornton JR, Emmett PM & Heaton KW (1979): Diet and Crohn's disease: characteristics of the pre-illness diet. *Br. Med. J.* **2**, 762–764.

Tragnone A, Valpiani D, Miglio F, Elmi G, Bazzocchi G, Pipitone E & Lanfranchi G (1995): Dietary habits as risk factors for inflammatory bowel disease. *Eur. J. Gastroenterol Hepatol.* **7**, 47–51.

Woodward M & Walker ARP (1994): Sugar consumption and dental caries: evidence from 90 countries. *Br. Dent. J.* **176**, 297–302.