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Brassicaceae: nutrient analysis and investigation of tolerability in people with Crohn's disease in a New Zealand study

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ABSTRACT

Background: Nutrition is an important environmental factor influencing symptoms of Crohn's disease, one of the two main expressions of inflammatory bowel disease. Varieties of Brassicaceae supply valuable nutrients. They are often avoided by people with Crohn's disease because of the adverse effects they are perceived to have on symptoms. The purpose of this study was to review the nutritional content of commonly eaten forms of Brassicaceae and identify from selected Brassicaceae those that exacerbate, ameliorate or make no difference to the symptoms of people with Crohn's Disease.

Methods: In this study commonly eaten Brassicaceae were identified and analysed for major nutrients, vitamins, minerals, phytochemicals and FODMAPs. An investigation on the tolerability of ten forms of Brassicaceae on people with Crohn's disease was also conducted. This was based on the responses of adult subjects in the 'Genes and Diet in Inflammatory Bowel Disease Study' based in Auckland, New Zealand.

Results: The nutrient analysis of the Brassicaceae showed their important contribution of fibre, vitamins, minerals, and phytochemicals, especially glucosinolates. Our study revealed that over 70% of respondents found that the consumption of broccoli, Chinese greens and rocket (arugula) made no difference to their Crohn's disease ($p=0.0001$).

Conclusions: Brassicaceae contain key nutrients which contribute significantly to a person's health through their fibre, vitamin, mineral and phytochemical content. Many people with Crohn's Disease can tolerate different forms of Brassicaceae. By identifying the particular varieties that can be consumed by people with Crohn's disease and encouraging them to eat them, their nutrition, immune status and anti-inflammatory and anti-cancer factors will be enhanced.

Key words: Brassicaceae: Key nutrients: Tolerability: Crohn's Disease

INTRODUCTION

Inflammatory Bowel Disease (IBD) is expressed through two main types - Crohn's disease (CD) and Ulcerative Colitis (UC). Both diseases are of a chronic and inflammatory nature. However CD usually affects the distal ileum and colon (although may occur in any part of the gastrointestinal tract (GI) tract), whereas UC arises in the colonic mucosa and may remain localized to the rectum. CD is characterized by symptoms that include diarrhea and abdominal pain, with abscesses, fistulas and sometimes bowel obstruction. UC's main sign is bloody diarrhea. In the long term, colon cancer also has a high association with UC [1].

Nutrition is an important environmental factor influencing symptoms, particularly with CD [2]. However, identifying the food groups and the necessary nutrients which enable people to stay in remission and keep well nourished, remains elusive. People with IBD typically show food intolerances, the exact nature of which differs among individuals [3]. Research which has been based on clinical work, where different nutrients like fats or refined sugar levels have been manipulated to help people with CD stay in remission, has been inconclusive to date. However, work in 2009 by Ferreira et al. [4], has shown that a high intake of total, saturated and monounsaturated fats and a higher n-6/n-3 polyunsaturated fatty acids (PUFA) ratio, was associated with a more active expression of the disease, mainly in people carrying a specific cytokine genotype. Treatment with a fibre rich, unrefined carbohydrate diet has been associated with a favourable outcome on the clinical course of CD [5]. Unfortunately no single nutrition recommendation can be made, i.e there is no 'one size fits all' solution. This has led individuals to avoid whole groups of food like dairy and gluten products, pip fruit, foods containing FODMAPS (Fermentable Oligo-, Di- and Mono-saccharides, and Polyols) [6] and vegetables, as they are perceived as exacerbating symptoms. This can have the consequence of people with CD often being malnourished.

Vegetables contribute many health benefits to people who consume them. The New Zealand (NZ) Nutrition Guidelines recommend three or more servings of vegetables and two of fruit be consumed each day [7]. The Brassicaceae (also known as Cruciferae), from the plant order Brassicales, are a significant group of vegetables. They are some of the oldest known cultivated plants, with evidence of their cultivation going back ten thousands of years [8]. They have been cultivated for human use in cooked or raw forms and as salads, condiments and also as oils. Cabbage, Brussel sprouts, cauliflower, broccoli, turnip, radish, rocket/arugula (as found in Mesclun mix), cress, collard greens, Pak Choi (i.e. Chinese cabbage), Choy Sum, as well as the spices (mustard, wasabi, capers, horseradish), and oils (mustard, rapeseed – known as canola) are the most well-known examples. Nasturtium and the fruit papaya are also part of the Brassicaceae family [9]. The common component of Brassicaceae is the secondary metabolite class of glucosinolates, which act as flavour complexes, natural pesticides and cancer inhibiting agents.

However, Brassicaceae are, as with many vegetables, important contributors of other critical nutrients – e.g. vitamins, minerals, phytochemicals and fibre [10]. Some people with CD find that certain Brassicaceae vegetables, e.g. cabbage, may exacerbate symptoms [11]. This leads to other varieties of Brassicaceae, and other important vegetables, being unnecessarily avoided in the diet. This contributes to the malnutrition observed in people with CD [12] and also makes them more vulnerable to their disease, because of their lack of exposure to vital immune boosting nutrients and anti-inflammatory and cancer inhibiting factors [13]. Because of the variety of Brassicaceae, it is important to identify, for people with CD, the key nutrients that this group contains and the different levels of these nutrients.

The aims of this study were therefore to review the nutritional content of commonly eaten forms of Brassicaceae; to identify the Brassicaceae typically consumed by people with CD, as reported by NZ adults from the 'Genes and Diet in Inflammatory Bowel Disease' Study, based in Auckland; and to identify which of these Brassicaceae are most likely to exacerbate, ameliorate or make no difference to the symptoms of people with CD from the Auckland Study.

METHODS

Brassicaceae Selection

The Brassicaceae plant family contains around 3,700 species, however only about 20 forms of these are commonly eaten. There are also a number of varieties, especially in cabbages and Chinese cabbages, mustards and radishes and these varieties are outlined in Clarke's plant classification for Brassicaceae [9]. The Brassicaceae analysed for tolerability were those recorded as being consumed by people with CD in the Auckland Study. These were extracted from the data base of the 'Genes and Diet in Inflammatory Bowel Disease' Study. These Brassicaceae were: broccoli, cabbage, cauliflower, Chinese greens, rocket (arugula), watercress, horseradish, mustard sauce, mustard powder and wasabi.

Nutrition Data

The New Zealand Food Composition Database 2008 [14] was used as the first source of food composition data. If the form of Brassicaceae was not available in the NZ Food Composition database, international data sets were then accessed. These included the United States Department of Agriculture (USDA) data bases [15] and Phenol-Explorer – an online data base on the polyphenol content in foods [16]. Glucosinolate information was also sourced from the British data on the dietary estimation of glucosinolates [17]. Data for the current study was based on the mean of their different results given for each vegetable. Data on free fructose content of common vegetables was sourced from Australian data published in 2007 [18].

The nutrition information from adults with CD in the Auckland Study was based on a secondary analysis of the dietary survey completed as part of this Auckland Study. This dietary questionnaire was designed on methods used by Joachim [19] and validated by a group of patients who had CD [2]. It included questions on whether foods listed made the person feel better or made them feel worse, so that information could be captured on the consumption of food in response to disease symptoms. Food lists which do not take account of this information fail to recognise that many foods are never consumed by CD sufferers because of their effect on the disease's clinical manifestations. In this questionnaire a series of food lists, with tick boxes were presented. Participants were required to nominate (on a 5 point scale) whether particular food items made their CD condition either: definitely worse, probably worse, had no effect, probably better, or definitely better. The questionnaires were reviewed for accuracy by a nutritionist or registered nurse when they were received and checked with subjects if their responses were unclear [2]. In the current study the five responses were classified into three categories: positive responses (probably better and definitely better) were regrouped as 'better' and negative responses (probably worse and definitely worse) were regrouped as worse and 'had no effect' were regrouped as 'no difference'. Percentages of the whole were calculated for each of these three categories.

Study Population

Only subjects from Auckland, the main North Island center were selected. These subjects were enlisted from gastroenterology clinics or by their response to advertising in the media. The Study population originally was 684 subjects (302 CD and 382 controls) [20]. Since then this study has recruited more subjects however, not all of them have completed the food questionnaire. Nutritional, clinical and/or genotype information from the Auckland based subjects were available for 409 adults with CD. All the selected participants were Caucasian. Other clinical data included age and the most recent Montreal classification of CD location [21] which was extracted from patient medical notes, supplied by the diagnosing gastroenterologist. Ethical approval was given by the New Zealand Multi-region Human Ethics committee (Ethic approval No: MEC04/12/11).

Statistical Analysis

The analyses for the Brassicaceae varieties in Figure 1 were carried out using R [22].

RESULTS

Major nutrients in Brassicaceae

The nutrients (major nutrient groups, vitamins, minerals and phytochemicals and FODMAPS) of forms of Brassicaceae commonly eaten are described. Ten forms of Brassicaceae were typically consumed by people with CD, from this Study. These ten forms were: broccoli, cabbage, cauliflower, Chinese greens, rocket (arugula), watercress, horseradish, wasabi, mustard sauce and mustard powder.

Tables 1-5 identify the nutrients in the forms of Brassicaceae commonly eaten. Brassicaceae nutrient content is affected by the particular variety, soil type, growing and storage conditions as well as cooking methods [23, 24, 25, 26]. This means that the data reported in the results did not reflect absolute values, but were based on representative samples of foods that were available. Table 1 shows the major nutrient groups (protein, total fat, available carbohydrates (CHO), fibre, total available sugars and starch) contained in Brassicaceae. It can be seen that they generally contain small amounts of protein (0.7-4.8g), very little fat (0.1- 0.69g with 4.01g for mustard prepared); low amounts of carbohydrate (0.2-6.94g for vegetables, with 11.29g for horseradish and 23.54g for wasabi); some fibre (1.0-3.8g, with wasabi 7.8g) and very little starch (0.1-0.63g) per 100grams. These results show that Brassicaceae can contribute protein and fibre to a person's diet. They are also all low in fat, except the mustard condiment. Brassicaceae are generally low in CHO and total sugars. The spices horseradish, mustard, wasabi, have a higher CHO content.

Table 1: Nutrients in Brassicaceae

	Protein g/100g	Total Fat g/100g	CHO g/100g	Fibre g/100g	Total Sugars g/100g	Starch g/100g
Boiled or cooked						
Broccoli	3.80	0.60	1.70	3.2	1.60	0.1
Brussel Sprouts	2.80	0.30	1.80	2.0	1.70	0.1
Cabbage Red	1.51	0.09	6.94	2.6	3.32	na
Cabbage Savoy	1.80	0.09	5.41	2.8	na	na
CabbageWhite-steamed	0.80	0.10	1.50	1.5	1.40	0.1
Cauliflower	1.90	0.20	2.70	2.0	2.60	0.1
Chinese Cabbage	2.30	0.10	1.20	1.0	1.20	T
Swede/Rutabaga	0.90	0.10	3.70	1.4	3.50	0.2
Turnip	0.70	0.30	2.30	1.5	2.20	0.1
Raw						
Broccoli	4.40	0.60	2.30	3.8	2.30	T
Cabbage red	1.70	0.30	3.40	2.8	3.40	T
Cabbage White	1.30	0.20	6.10	1.9	6.10	T
Cauliflower	2.20	0.30	3.80	2.2	3.30	0.5
Radish	1.00	0.50	2.60	1.3	2.60	0
Rocket/ Arugula	2.58	0.66	3.65	1.6	2.05	na
Wasabi	4.80	0.63	23.54	7.8	na	na
Watercress	2.80	0.40	0.20	1.4	0.10	0.1
Prepared						
Horse-radish	1.18	0.69	11.29	3.3	7.99	na
Mustard	4.37	4.01	5.33	3.3	0.86	na

na = no data available .T=trace

Vitamins and Minerals in Brassicaceae

Table 2 shows the vitamin content of Brassicaceae per 100g. Many varieties of Brassicaceae contain sufficient levels of Vitamins A, C, K and folate to meet the Recommended Dietary Intakes (RDI) [27]. Thiamin, vitamin B6, niacin and riboflavin are also available from these vegetables.

Table 3 shows the mineral content of commonly eaten Brassicaceae. These foods could contribute necessary minerals to help meet RDIs, particularly of potassium, iron and zinc. The table also illustrates that Brassicaceae are low in sodium, with the exception of the condiments mustard and horseradish. Trace amounts of selenium and iodine are present in many of the forms of Brassicaceae.

Table 2: Vitamins in Brassicaceae

	Total Vit A Equiv. µg/100g	Thiamin mg/100g	Riboflavin mg/100g	Total Niacin Equiv. mg/100g	Vit B6 mg/100g	Total Folate µg/100g	Vit C mg/100g	Vit K µg/100g
Boiled or cooked								
Broccoli	62	0.04	0.2	1.2	0.19	53	58	141.1
Brussel Sprouts	67	0.06	0.1	0.9	0.17	87	40	na
Cabbage Red	2	0.071	0.06	0.382	0.225	24	34.4	47.6
Cabbage Savoy	44	0.051	0.02	0.024	0.152	46	17	a
CabbageWhite-steamed	1	0.02	0.02	0.3	0.06	20	25	76
Cauliflower	1	0.06	0.09	0.9	0.2	40	55	13.8
Chinese Cabbage	290	0.05	0.04	0.6	0.08	33	19	76
Swede/Rutabaga		0.04	0.03	1	0.12	21	17	0.3
Turnip	3	0.03	0.04	0.6	0.06	8	17	0.1
Raw								
Broccoli	68	0.09	0.35	1.3	0.21	75	57	101.6
Cabbage Red	3	0.06	0.05	0.6	0.21	90	55	38.2
Cabbage White	2	0.05	0.04	0.3	0.1	44	21	na
Cauliflower	2	0.07	0.09	1	0.21	55	60	na
Radish	2	0.04	0.02	0.3	0.1	23	24	1.3
Rocket/Arugula	119	0.044	0.086	0.305	0.073	97	15	108.6
Wasabi	2	0.131	0.114	0.743	0.274	18	41.9	na
Watercress	824	0.12	0.04	0.8	0.19	80	75	250
Prepared								
Horseradish	0	0.008	0.024	0.386	0.073	57	24.9	1.3
Mustard	4	0.343	0.03	0.523	0.063	7	1.5	1.8

na = no data available

Table 3: Minerals in Brassicaceae

	Sodium mg/100g	Phosphus mg/100g	Zinc mg/100g	Potassium mg/100g	Ca mg/100g	Iron mg/100g	Se µg/100g	Iodine µg/100g
Boiled or cooked								
Broccoli	6	81	0.5	341	36	0.8	0.3	0.1
Brussel Sprouts	2	51	0.4	240	25	0.5	0.1	0.7
Cabbage Red	28	33	0.25	262	42	0.66	2.3	na
Cabbage Savoy	24	33	0.23	184	30	0.38	0.7	na
Cabbage White	8	25	0.2	179	19	0.4	0.1	0.1
Cauliflower	7	46	0.2	247	21	0.4	0.1	0.1
Chinese Cabbage	3	23	0.2	90	88	1.9	0.1	0.1
Swede/Rutabaga	12	18	0.1	176	30	0.4	0.2	0.4
Turnip	28	19	0.1	160	55	0.4	0.2	0.4
Raw								
Broccoli	5	104	0.7	487	42	1.2	0.3	0.2
Cabbage Red	32	32	0.3	300	53	0.6	0.1	0.1
Cabbage White	5	39	0.1	215	41	0.4	0.1	0.1
Cauliflower	8	53	0.3	340	25	0.4	0.1	0.2
Radish	56	26	0.4	229	42	1.8	0.3	0.7
Rocket/Arugua	27	52	0.47	369	160	1.46	0.3	na
Wasabi	17	80	1.62	568	128	1.03	na	na
Watercress	17	33	0.3	180	53	2.2	0.2	2.7
Prepared								
Horseradish	314	31	0.83	246	56	0.42	2.8	na
Mustard	1135	106	0.64	138	58	1.51	32.9	na

na =no data available

Phytochemicals in Brassicaceae

Table 4 is a compilation of the different phytochemicals available in Brassicaceae (mg/100gm). The flavinoids (Apigenin, Luteolin, Kaempferol, Myricetin, Quercetin, Cyanidin, Delphinidin and Pelargonidin) are well distributed among the different varieties of the commonly eaten Brassicaceae. Kaempferol is particularly high in raw rocket (arugula), with moderate amounts in raw turnip greens, raw Chinese cabbage and raw broccoli. Quercetin is high in raw watercress, raw rocket (arugula), and raw Chinese cabbage.

All Brassicaceae contain glucosinolates, although data were not available for all the commonly eaten Brassicaceae. Glucosinolates are particularly high in boiled and raw Brussel sprouts, boiled cabbage, raw broccoli, raw savoy and red cabbage, raw watercress, raw radish, raw swede (rutabaga) and raw turnip.

Total polyphenol content is particularly high for raw broccoli, raw Brussel sprouts, raw Chinese cabbage, and raw rocket (arugula). Polyphenol content was not available for boiled or cooked Brassicaceae except for dried horseradish. Chinese cabbage, rocket (arugula), turnip greens and watercress are the highest in beta-carotene content.

Table 4: Measurements of the Phytochemicals

	Apigenin mg/100g	Luteolin mg/100g	Kaempferol mg/100g	Myricetin mg/100g	Quercetn mg/100g	Cyanidn mg/100g	Delphinidin mg/100g	Pelargonidin mg/100g	Glucosino atess mg/100g	Total Polyphenols mg/100g	B-carotene mg/100g
Boiled or cooked											
Broccoli	0	0	1.38	0	0.21	0	0	0	37.2	na	0.369
Brussel Sprouts	na	na	na	na	na	na	na	na	135.9	na	0.400
Cabbage	0.01	0.02	0.01	0.03	0.01	na	na	na	78.6	na	0.048
Cauliflower	na	na	na	na	na	na	na	na	42.0	na	0.008
Chinese Cabbage	0.01	0.02	2.4	0.03	0.30	0.02	0.02	0.02	na	na	1.740
Turnip											0.016
Horseradish*	0	0.9	1.58	0	0.28	na	na	na	na	90	0.001
Raw											
Broccolli	0	8.6	4.01	0.01	2.51	0	0	0	61.7	198.55	0.410
Brussel Sprouts	0	0.34	0.95	0	0.3	na	na	na	233.8	220.75	0.450
Cabbage Green	na	na	0.02	na	0.02	na	na	na	na	88.63	na
Cabbage Red	0.1	0.1	0	0.02	0.38	72.86	0.1	0.02	50.6		0.670
Cabbage Savoy	0.23	0.06	0.26	0.03	0.12	na	na	na	115.2	119.9	0.600
Cabbage White	0.08	0.1	0.15	0	0.3	na	na	na	42.0	15.3	0.011
Cauliflower	0.03	0.07	0.38	0	0.66	na	na	na	46.4	81.74	0.009
Chinese Cabbage	0.65	0.2	8.32	0.03	5.58	na	na	na	45.6	193.45	2.681
Rocket/Arugula	0	0	72.45	na	6.95	0	na	na	na	136.4	1.424
Turnip Greens	0	0	11.87	0	0.73	na	na	na	na	93.5	6.952
Watercress	0.01	0.02	1.40	0.20	7.44	na	na	na	95.0		4.950
Radish	na	na	0.86	0	0	0	0	25.66	92.5	44.31	0.013
Swede/ Rutabaga	3.85	0	0.57	2.13	0.08	na	na	na	92.0	na	0.001
Turnip	na	na	na	na	na	na	na	na	84.6	54.5	0
Wasabi	na	na	na	na	na	na	na	na	na	na	0.021

na =no data available; *drie

Table 5: FODMAPS in Brassicaceae

	Carbohydrates By Difference+g/100g	Sugars Total g/100g	Sucrose g/100g	Glucose g/100g	Fructose g/100g	Lactse g/100g	Maltse g/100g	Galactose g/100g	Starch g/100g	Fibre Total g/100g
Boiled										
Broccoli	7.18	1.39	0.08	0.49	0.74	0	0	0	0	3.3
Brussels Sprouts	7.1	1.74	na	na	0.8*	na	na	na	na	2.6
Cabbage Red	6.94	3.32	0.71	1.42	1.2	0	0	0	0	2.6
Cabbage Savoy	5.41	Na	na	na	1.0*	na	na	na	na	2.8
Cabbage	5.51	2.79	0	1.62	1.16	0	0	0	0	1.9
Cauliflower	4.11	2.08	na	na	0.9*	na	na	na	na	2.3
Chinese Cabbage	1.78	0.83	na	na	na	na	na	na	na	1.0
Swede/Rutabaa	8.74	6.02	na	na	1.3*	na	na	na	na	1.8
Turnip	5.06	2.99	na	na	1.3*	na	na	na	na	2.0
Raw										
Broccoli	6.64	1.7	0.1	0.49	0.68	0.21	0.21	0	0	2.6
Cabbage Red	7.37	3.83	0.6	1.74	1.48	0	0	0	0	2.1
Cabbage	5.8	3.2	0.08	1.67	1.45	0	0.01	0	0	2.5
Rocket/Arugula	3.65	2.05	na	na	na	na	na	na	na	1.6
Radish	3.40	1.86	0.1	1.05	0.71	0	0	0	0	1.6
Watercress	1.29	0.2	na	na	na	na	na	na	na	0.5

* Nutrients were from material which was freeze dried not boiled.

+ Carbohydrates by difference - the carbohydrate content of the food calculated as the difference between the total weight of the food, minus protein, fat and water.

na =no data available,

FODMAPS in Brassicaceae

Table 5 shows the FODMAP content of common Brassicaceae. From the data available in this table, boiled swede (rutabaga) is the Brassicaceae containing the highest number of total sugars. Most of the other Brassicaceae contain less than 3g of total sugars/100g – except red cabbage both in raw and cooked forms and raw white cabbage. Total Fructose/100g has a range 0.68- 1.48 g across the different varieties of Brassicaceae. No data were available for Chinese cabbage or watercress. Galactose = 0 for cooked and raw forms of broccoli, red cabbage, cabbage and raw radish. Data for galactose were not available for the other common forms of Brassicaceae.

Tolerability to Brassicaceae

Figure 1 and Table 6 demonstrate the diversity of responses to these ten Brassicaceae consumed by participants in the Auckland Study. Figure 1 shows for each of the ten forms of Brassicaceae, the percentage of respondents where the form of Brassicaceae consumed made either no difference to their CD, made their symptoms worse or made their CD symptoms better. For six of the ten Brassicaceae there were significant differences between the levels of tolerance, ($p<0.0001$ for each Chi-square test) and $p=0.0017$ for mustard sauce. However, mustard powder, wasabi and horse radish did not show significant differences between groups, possibly because of the small sample sizes. For broccoli, Chinese greens and rocket (arugula), 71.09%, 71.98% and 79.17% of respondents respectively, found these Brassicaceae made no difference to their symptoms of CD. For cabbage, 47.88% found it made no difference, while for 49.09%, regular consumption made them feel worse. For cauliflower, 67.54% found it made no difference, while 23.98% reported that it made them feel worse.

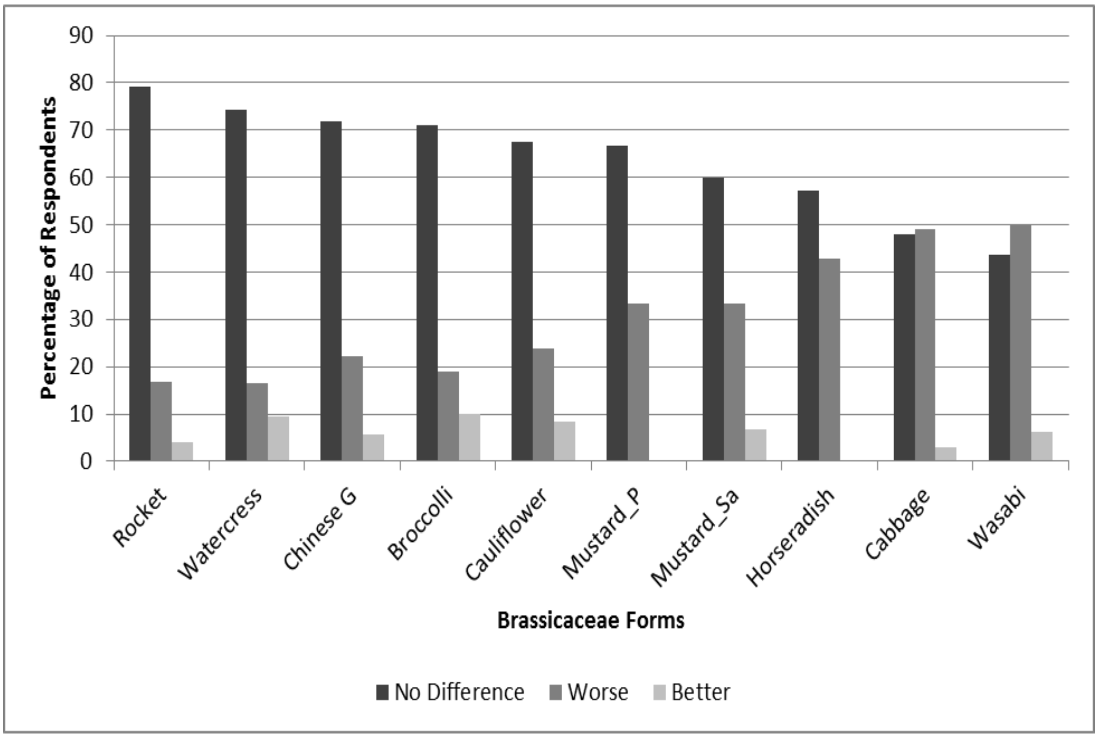

Figure I. Respondents tolerability to named Brassicaceae

Chinese G = Chinese Green; Mustard _Sa, = Mustard Sauce; Mustard_P,= Mustard Powder.

Table 6: Sample sizes of respondent's tolerability to named Brassicaceae

	Broccoli n (%)	Chinese Greens n (%)	Cabbage n (%)	Cauliflower n (%)	Rocket n (%)	Watercress n (%)	Horseradish n (%)	Mustard Powder n (%)	Mustard Sauce n (%)	Wasabi n (%)
No Diff	241 (71.1)	149 (72.0)	158 (47.9)	231 (67.5)	19 (79.2)	95 (74.2)	8 (57.1)	18 (66.7)	18 (60.0)	7 (43.8)
Better	34 (10.0)	12 (5.8)	10 (3.0)	29 (8.5)	1 (4.2)	12 (9.4)	0 (0.0)	0 (0.0)	2 (6.7)	1 (6.3)
Worse	64 (18.9)	46 (22.2)	162 (49.1)	82 (24.0)	4 (16.7)	21 (16.4)	6 (42.9)	9 (33.3)	10 (33.3)	8 (50.0)

DISCUSSION

Brassicaceae are an important family of the Brassicale order, which can contribute significantly to a person's health through their nutrient content. The following discussion shows how these nutrients boost immunity, enable bone health, and have anti-inflammatory and anti-cancer influences. As the analysis on tolerability in Figure I shows, many people with CD can tolerate different forms of Brassicaceae. By identifying, for people with CD, which particular varieties from the family of Brassicaceae, can be incorporated into their daily intake their nutritional intake can be improved, and their immune status and anti-inflammatory and anti-cancer factors enhanced.

Major nutrients in Brassicaceae

The Brassicaceae vegetables (Table 1), as opposed to the condiments are not energy dense and so can be eaten without concern for calories. Brassicaceae are also good sources of dietary fibre. They contain both soluble and insoluble fibre, in variable amounts (1.0-3.2 g/100g/3/4 cup in the cooked leafy varieties). Fibre interacts with other food in the gut and alters the way food is absorbed, for example, by reducing the activity of enzymes from the pancreas. Butyric acid from dietary fibre appears to be the preferred fuel source of the cells in the colonic mucosa [28]. Butyrate also has anti-inflammatory effects, and helps regulate apoptosis and immune function [29]. Dietary fibre also contains functional fibres [30]. Examples of these are arabinoxylans and cellulose (non-starch polysaccharides) and others termed 'resistant' e.g. oligosaccharides, beta-glucans, pectins and inulin. As a polysaccharide inulin produces short chain fatty acids as it is metabolised by the gut flora and this helps the absorption of magnesium, calcium and iron and increases the beneficial populations of *Bifidobacterium* and *Lactobacillus* [30].

Soluble fibre absorbs water and becomes gelatinous and viscous and contributes to the fermentation of food by bacteria in the colon, which for some may lead to bloating and gas production. However it is thought to reduce the risks of cardiac disease, and there is evidence that dietary fibre may reduce the risk of colorectal cancer [31], although some studies have not shown this [32]. Insoluble fibre increases the bulk of the stool and softens it, making it move more quickly through the gut thus lowering the risk of constipation (as long as plenty of water is consumed with it). Another advantage of consuming foods that are high in fibre is increased longevity. A nine year study of adults aged 50-71 years found those who consumed the highest amount of fibre had a 22% less risk of dying during this time [33].

Increased fibre intake has also been promoted as a way of managing weight, as it improves satiety [34]. Although people with CD are more likely to suffer from malnutrition, (with Hartman et al. [12] reporting that 85% of children and 65% of adults with CD have weight loss), nevertheless, for others over-consumption can be a problem. In the Blain et al. study [35], of 2065 people with CD, 62 (3%) of these people were described as obese, i.e. as having a BMI >25.0 at diagnosis and >30.0 during their disease. However, the consumption of Brassicaceae is unlikely to contribute to this issue and would certainly provide valuable vitamins and minerals. Whether malnourished or obese, lack of appropriate intake especially of vitamins and minerals can cause health issues, especially for those experiencing a chronic illness.

The study by Heaton et al. [5] has shown the benefits of fibre for people who have CD. In this study a group, involving 32 people with Crohn's disease, was treated with a high fibre diet and compared to another 32, a matched control group treated conventionally, over a period of just over 4 years. Those who had a fibre rich diet had considerably less time in hospital (111 days compared to the control group of 533 days) and only one required surgery compared to five in the control group. There was no evidence of obstruction.

Vitamins and Minerals in Brassicaceae

The results in Table 2 and 3 show the presence in Brassicaceae of many valuable vitamins and minerals that can contribute to being well nourished. Malnutrition in CD is often linked with vitamin and mineral deficiency, e.g. anaemia from iron, B12 and or folic acid deficiency. Hartman et al. also noted deficiencies in vitamin A, B, C, D and E in people with CD [12]. Brassicaceae vegetables contain meaningful amounts of minerals, vitamins and phytochemicals that are important for health. A daily intake of Brassicaceae could contribute significant levels of vitamin C, folate, vitamin A and vitamin K. However, these vegetables are often avoided by individuals with CD [11] and those advocating the FODMAP approach [36] also recommend their restriction.

If the appropriate Brassicaceae were eaten daily, e.g. 100grams or about 3/4 cup of cooked broccoli or cooked Brussel sprouts, they would meet or almost meet the NZ Recommended Dietary Intake (RDI) for these vitamins. RDI for Vitamin C for men and women aged 19<70years is 45 mg/day [27] and 100 grams of boiled broccoli contains 58 mg of vitamin C. Vitamin C is well known as an antioxidant and for its role in wound healing and aiding the absorption of iron [37]. Vitamin C cannot be synthesised by humans so needs to be ingested. Inflammation of the gut and the oxidative stress associated with CD shows the necessity for maintaining good levels of vitamin C in the diet [38]. Low plasma levels of vitamin C were found, by Imes et al. [39] to be reasonably frequent in people with CD whether their disease was active or inactive. Their study followed 137 people with CD attending outpatient clinics over six months. Low serum levels of vitamin C were thought to be due to low dietary intake and when this increased the vitamin C serum levels improved. Gastric juice has three times the concentration of vitamin C in the plasma [40]. Here it has also been shown to play an important part in stabilising mono-and triglutamate forms of methylfolate [41]. In the small intestine it enables the absorption of iron by keeping it in the reduced form Fe^{+2} [37]. Iron deficiency is reported to be common in people with CD [12, 42], and this is probably linked to low intakes of vitamin C.

Vitamin C doses higher than 1 gram a day may cause oxalate kidney stones [38]. This is uncommon and these stones are more often associated with low fluid intake, and a high intake of animal protein, oxalate containing foods, high intake of fructose, salt and carbonated drinks associated with the western lifestyle [43]. However, these stones are more common in people with CD [44]. Again this shows the need for appropriate professional nutrition advice and the safer option for CD sufferers of getting vitamin C from food sources like vegetables and especially Brassicaceae which are low in oxalates.

Brassicaceae also supply significant levels of folate. Folate is part of a coenzyme necessary for DNA formation, and thus needed to form all new cells. This is particularly relevant in the gut, where epithelial cells need to divide frequently, as too with erythrocytes and leukocytes. Low folate intakes lead to megablastic anaemia and if low in the first trimester of pregnancy may lead to neural tube defects [45]. Folate is found in food in the form of methyl-THF and formyl-THF, and its deficiency is generally linked to the diet [46]. Broccoli, Brussel sprouts and rocket (arugula) are particularly high in this vitamin (Table 2).

Folate deficiency has been associated with CD and Irritable Bowel Syndrome (IBS) [47], and is a common complication with CD activity [48]. In CD, low intake and malabsorption can both be factors. According to Steger et al. [49], in their study of 100 people with CD attending outpatient clinics, and 20 healthy controls, 25% of those with CD had faulty folate absorption and for nine of these (about 10%) serum folate levels did not improve with increased oral intakes. This malabsorption did not relate to the scope of CD or degree of activity. A common polymorphism of the *MTHFR* gene (677C→T) is associated with increased requirements. De Bree et al.[50] found that, in a random sample of 2051 people in a Dutch cohort aged 20–65 years, people with TT alleles had lower levels of folate in their plasma compared to people with CT and CC alleles at any level of intake of folate. According to Mahmud et al. [51], comparing 174 people with established IBD, with 273 healthy controls there is also an association with this polymorphism and IBD. With respect to those with CD, 16.8% were homozygous for the C677T variant, whereas only 7.3% of the healthy controls were. This was thought to explain the greater number of complications relating to thrombosis or embolisms found in people with IBD. If people with CD are being treated with Sulfasalazine, they may also be folate deficient as this drug is known to interfere with the absorption of folic acid [52].

Vitamin A is especially important for people with CD. This is because vitamin A deficiency leads to susceptibilty to infection and loss of immune tolerance, with increased vulnerability to food allergies and autoimmune diseases [53], which can exacerbate CD symptoms. Table 2 illustrates the total vitamin A equivalent in the different Brassicaceae varieties, and Table 4 shows the beta-carotene content of Brassicaceae. Beta- carotene is the most recognised plant source of dietary pro-vitamin A. Beta-carotene, the most prevalent of the carotenoids is particularly abundant in the Brassicaceae (Table 4), most notably in cooked broccoli, Brussel spouts, and Chinese cabbage, and raw red and savoy cabbage, Chinese cabbage, rocket (arugula), turnip greens and watercress.

Vitamin A has a number of important roles in the body. One of the most significant roles of vitamin A is maintaining vision [54]. It is essential for the cornea, conjunctival membranes and the retina of the eye. Uveitis (inflammation of the interior of the eye) can be an early sign of Crohn’s disease and could be related to vitamin A deficiency. Vitamin A is also essential to form healthy epithelium which lining organs like the lungs, gastrointestinal and urinary tracts and it is a key vitamin for mucous production. Where vitamin A is deficient these tissues become flattened, dry and keratinized [54]. Other significant roles for vitamin A are in reproduction, bone growth, healthy skin and immunity. All these features are pertinent to CD.

The immune system, both the innate and adaptive systems (through animal models [55]), has been shown to need adequate vitamin A to function properly. In the innate system, vitamin A deficiency leads to inactivity in the neutrophil microbiocidal response, macrophage led phagocytosis and natural killer cell activity. There is also an increase in movement of bacteria across the mucosa. With the adaptive immune response, T cells and B cells are shown to become abnormal. Vitamin A deficiency is also associated with excess production of type 1 cytokine and a reduction of type 2 cytokine activities. All this leads to impaired epithelial barrier function and can lead to inflammation [55]. Inflammation if already present can also be exacerbated by vitamin A [54], so an inflammation cycle is set up. In children, vitamin A deficiency can result in diarrhoea and respiratory infections and decreased bone growth and slower growth rates [45]. These are also clinical manifestations of CD in children.

In its role as an antioxidant, vitamin A is part of the antioxidant family, which includes ascorbic acid, and carotene, lycopene, cryptoxanthin, vitamin D, E and K. The role of antioxidants in the body is to counter the damage done by reactive oxygen species (ROS). These are thought to play a part in the development of pathogenesis of CD [56]. During inflammation the neutrophils move through the intestinal wall and create ROS [57]. These cause damage in tissues especially the epithelium [58]. When inflammation is chronic as in CD, the increase in ROS can engulf the defences of the antioxidant system adding to the oxidative stress. When the ingestion of antioxidant micronutrients is low this can lead to an exacerbation of this process. Thus it is important to encourage people with CD to eat vegetables containing these vital nutrients, e.g. Brassicaceae. As the analysis of the Auckland Study has shown (Figure 1), over 70% of this group who have CD, can tolerate the Brassicaceae broccoli, Chinese greens and rocket (arugula) without their symptoms of CD deteriorating.

However, even if vitamin A in the form of beta-carotene is taken in the daily recommended amount, if the person carries one of the common polymorphisms (rs12934922 or rs7501331) in the gene encoding for beta-carotene, their metabolism of this vitamin may be impaired. According to Leung et al. [59], up to 45% of healthy individuals from the UK may carry one of these two polymorphisms of the *BCMO1* gene (on chromosome 16q23.2) which impedes the conversion of beta-carotene to retinol as compared to normal converters. *BCMO1* is highly active in the mucosa of the intestine, particularly in the enterocytes of the jejunum. Carriers of the lipoprotein lipase *X447* allele also have reduced plasma beta-carotene levels [60]. People with CD need to be advised appropriately about their vitamin A intake so their nutrition can be tailored effectively. Too much vitamin A can cause nausea, anorexia, muscle weakness as well as other maladies and a regular chronic dose of preformed vitamin A of 1500 RAE has been linked to hip fractures and osteoporosis [61]. Thus, giving correct information about this vitamin is important. Vegetables are a much safer source of vitamin A than supplements or ingesting regular animal sources such as liver.

Vitamin K is a term used to describe a number of compounds which prevent haemorrhaging. They include K1 (phylloquinone) made by plants and the main food source, K2 (the main one is Menaquione-9) produced by the gut bacteria and K3,

(2-methyl-1,4napthoquinine) a synthetic version. The predominant source from plants is the green leafy vegetables, which include collards, spinach, salad greens and the Brassicaceae broccoli, cabbage and Brussel sprouts [62]. The availability of K1 once ingested, varies. K1 absorption is higher if added to vegetable oils [63]. Phylloquinone, the main food source once ingested is taken up by the lymphatic system from the digestive tract. This may be diminished where malabsorption is present, such as with CD [64]. K2 is produced by the gut bacteria mainly by *Bacteroides fragilis, Escherichia coli, Archnia, Propionibacterium* and *Eubacterium* groups [62]. Although production of this vitamin K can be quite large and is above what the daily food intakes are, this amount is probably reduced in those people with CD because of their associated reduced numbers of gut bacteria.

Vitamin K deficiency is rare but is implicated in antibiotic use [62], and with anticoagulant medication [65]. Antibiotics which have been linked to vitamin K deficiency are: Clindamycin, erythromycin, aminoglycosides, penicillin and cephalosporin. Antibiotics are one of the treatment options for CD [66], and also their high use in early childhood is associated with later onset of CD [67]. Vitamin K deficiency has also been associated with long term parental nutrition and now is more likely to be considered for adult formulas, although it has been part of paediatric formulations [68]. Parental nutrition is part of treatment options for CD. Low fat intake and any faults in lipid absorption also decrease vitamin K absorption.

Vitamin K is required for the blood to clot and is needed by all four clotting factors [69]. Vitamin K intake has been related to bone fractures and low intake has been associated with an increase in hip fractures [70]. The daily adequate intake for vitamin K in NZ is not very high (Men 70 μg, women 60 μg, for adults, 19-50 years) [27], and easily met by a serving of broccoli or rocket (arugula) daily (Table 2). Low intake of vitamin K as well as low intake of calcium by people with CD may well be associated with their high bone fracture rate. Bernstein reports for people with IBD 'The overall relative risk of fractures is 40% greater than that in the general population and increases with age' [71].

The major minerals like sodium, phosphorous, potassium and calcium are available in Brassicaceae (Table 3). One of the benefits of Brassicaceae is that in their vegetable form they are low in sodium, so do not adversely affect blood pressure. If dairy foods are not part of the diet calcium provided by Brassicaceae would help contribute to peoples' daily requirements if Chinese cabbage or rocket were consumed. The estimated average requirements for calcium in NZ are 840mg for adults aged 10-50 years [27]. Lack of calcium intake by people with CD increases their risk of bone demineralisation and osteoporosis. These are well known complications of this condition.

Another mineral which is in significant amounts in Brassicaceae is potassium. The NZ nutrient reference values describe adequate intake (per day) as 2800mg for women and 3800mg for men aged 19-50 years [27]. A daily serve of most Brassicaceae vegetables will contribute substantially to this. Potassium has an important metabolic role in the body [72]. All the cells and subsequently tissues and organ systems of the body need it. It has a key function in protein synthesis and the metabolism of carbohydrates. It is essential for normal body growth and muscle development. It enables the maintenance of the acid-base balance. Diarrhoea is common symptom in people with CD and this can be accompanied by acid base disorders reflecting an interruption in potassium levels [73]. A lack of potassium has a critical role in high blood pressure and cardiovascular risk [74]**.** Vegetables like Brassicaceae are considered good sources of potassium because they are also a low source of sodium.

Interruption of potassium homeostasis can also be caused by overactive potassium channels [75]. In a study by Simms et al. [76], the SNP (rs2306801) of a gene involved in potassium channels *KCNN4*, and expressed in the intestines, was also found to be associated with CD (P=0.0008, OR=0.76, 95% CI: 0.65-0.89) in NZ and Australian populations.

Phytochemicals in Brassicaceae

Brasssicaceae have a wide range of phytochemicals as shown in Table 4, a compilation from a number of phytochemical data bases. These latter compounds produced by plants are also described as allyl sulfides, antioxidants, anthocyanins, carotenoids, catechins chlorophyll, flavones, flavonoids, glucosinolates, isoflavones, isothiocyanates, phytosterols and polyphenols [77].

Flavonoids, a major group of phytochemicals containing 5000 phenolic compounds, are the main class of phytochemicals found in the Brassicaceae [78]. The phytochemicals in Brassicaceae come mainly from the subclasses flavones (e.g. apigenin and luteolin), flavonols (e.g. kaempferol, myricetin and quercetin) and anthocyanins (e.g. cyanidin, delphinidin and pelargonidin). The beta-carotenes influence has been reviewed in the context of vitamin A.

Flavones such as apigenin and luteolin have been shown to inhibit the growth of cancer cells [79]. They have also been shown when tested on rat hepatocytes to inhibit the activity of the 5-Aminosalicylic acid (5-ASA) a drug used for the treatment of CD [80]. In a study by Pan et al. [81], apigenin had an anti-inflammatory response by inactivating *NF-kB*. In another study, luteolin influenced *NF-kB* signaling, inhibiting *TNF*-α and *IL-8* production, a key inflammatory cytokine in IBD [82].

Kaempferol, myricetin and quercetin are the most common flavonols and quercetin has been the most studied. It is well absorbed in the small intestine by the activity of bacterial enzymes especially if it is bound to glucose [83]. Studies on quercetin show it to be an effective antioxidant [84]. Kaempferol, myricetin and quercetin also inhibited the activity of the drug 5-Aminosalicylic acid [80]. However, quercetin has also been shown with murine studies on epithelial cells, to inhibit tumor necrosis factor α (TNF)-induced pro-inflammatory gene expression in the small intestine [85].

Anthocyanins, which give the blue, purple and red colour to plants, are present in red cabbage and red radish, as shown in Table 4. Passamonti et al. describe them as unique as they are absorbed in entirety as glycosides [86]. The structure of anthocyanins in phenolic models, imply strong antioxidant activity, through electron donation or hydrogen atom transfer [87]. An example of this activity has been associated with improved night vision. A study on dark adaption and visual fatigue showed significant improvements [88]. However studies associated with increased anthocyanin intake and vision improvement have been hard to replicate, as the doses and length of time involved differ between studies [89]. Increased anthocyanin intake has also been associated with the cell cycle and apoptosis and averting DNA damage [90]. In a murine model for IBD, anthocyanin extract from blueberries stopped weight loss and improved the score for diarrhoea. This anthocyanin extract also modulated *IL-10* and the levels of *IL-12*, *TNF-α* and *IFN-γ* were reduced [91]. Phytochemicals especially those in Brassicaceae can be seen to be valuable nutrients. Their application and usefulness to people with Crohn’s disease and their role in the amelioration of their disease symptoms needs further research.

Brassicaceae are unique in that they, of the entire plant kingdom, almost exclusively contain the phytochemicals known as glucosinolates (GLS); Table 4. These have been intensely researched because of their links with cancer reduction. Two hundred different GLS have been reported [9]. GLS are high in sulphur and, as anionic products, can be hydrolyzed by the plant enzyme myrosinase (an endogenous thioglucosidase) into a number of biologically active compounds e.g. thiocyanates, isothiocyanates and nitriles. In *Homo sapiens*, these act as flavor complexes, natural pesticides and cancer inhibiting agents [92]. The isothiocyanates and indole products (from the nitriles) are thought to modulate the development of cancer cells by their influence on target enzymes, affecting cell death and impeding the cell cycle [93].

Each plant species of the Brassicaceae family may contain up to four different classes of GLS [94]. The most common glucosinolates are: glucobrassicin (found in broccoli, Brussels sprouts, cabbage and cauliflower), glucoraphanin (Broccoli sprouts, broccoli, Brussels sprouts, cabbage), gluconasturtiin (watercress), glucotropaeolin (cabbage, garden cress, Indian cress) and sinigrin (cabbage, horseradish and mustard) [95]. The concentration of these and their products can vary widely in the different species in this order by the following factors: their genetics, stage of development, growing techniques and conditions, storage, handling and methods used in food preparation. For example if they are grown in a more acid pH substrate nitriles are formed, but at a more physiological pH, isothiocyanates are the predominant product [96].

For GLS to be beneficial, they have to be broken down into their biologically active parts by the endogenous plant enzyme myrosinase, which is temperature sensitive. This means that, if in any part of the process from production to consumption, Brassicaceae are over exposed to heat, the enzyme will be inactivated and the benefits of the break down products of GLS are not available. The content of GLS in Brassicaceae is also affected by heat. This means post-harvest storage temperatures need to be less than 4 degree C with relatively high humidity [24] to prevent GLS content loss happening. Cooking at high temperatures e.g. boiling, also limits the availability of GLS. Steaming for 2 minutes has been reported as the best method to retain the GLS content of Brassicaceae [23]. Stir- frying for 3-5 minutes is also recommended [25]. Microwaving of broccoli florets decreased GLS content by 74% [26].

Once ingested, GLS in raw Brassicaceae vegetables are broken down into their biologically active products by the endogenous plant myrosinases, while in the small intestine. Where the endogenous myrosinanses have been inactivated, they are broken down by the bacterial myrosinases in the gut microflora when they reach the large intestine [96]. The *Bifidobacteria, Enterococcus, Escherichia, Bacteroides, Peptostreptococcus* species are thought to be involved with this process [97]. Recent molecular diversity studies have indicated that the composition of gut microflora diversity in individuals with IBD is reduced [98]. Their gut microbiome contains smaller numbers of microbiota, an oversupply of some species and a less divergent range of species [99]. This may mean the lowered availability of these beneficial Brassicaceae products for people with CD who can eat Brassicaceae. However if Brassicaceae are not ingested at all, the benefits of the immune and anti-inflammatory factors via these bacteria products is lost completely.

GLS have been shown to decrease inflammatory activity [100]. An example of this is Phenethylisothiocynanate (PEITC) a well-known GLS precursor, rich sources of which can be found in the seeds of *Barbarea verna*, the Brassicaceae commonly known as Land cress. PEITC has been shown when given orally as PEO (PEITC essential oil, > 95% natural PEITC from *Barbarea verna*) to decrease chronic and acute inflammation in colitis in an experimental mammalian model system. It appears to do this by suppressing *STAT1* transcription and thus *IL-6* signalling which is linked with IBD and consequently enables inhibition of proflammatory cytokines [100].

GLS components are increasingly being identified as interacting with significant genotypes. Common variations (polymorphisms) in these genes can affect the function of the enzymes they influence. The isothiocyanates (ITC) and indole-3 carbonyl are thought to be the major bioactive constituents involved in this. ITC are substrates for several glutathione transferases enzymes, (formerly known as glutathione S-transferases) e.g. glutathione transferease MUl-1 (*GSTM1)* and glutathione transferease *GSTT1* (*GSTTI*) [101]. Polymorphisms of *NADPH–quinone oxidoreductase (NQO1)* are also affected by ITCs [102]. A third example of a gene affected by Brassicaceae intake is the polymorphism of *Cytochrome P-450* (*CYP1A2)* [103].

FODMAPS in Brassicaceae

Some members of the Brassicaceae family (broccoli, Brussel sprouts, cabbage and cauliflower) are also described as foods containing FODMAPs. These are foods containing specific types of sugars and reported to be particularly high in **F**ermentable **O**ligo, **D**i- and **M**ono-saccharides, and **P**olyols. The Brassicaceae, Brussel sprouts, cabbage and cauliflower are described as containing the Oligosaccharides fructans and/or galactans [6]. Fructans are polymers of fructose molecules and galactans are chains of the sugar galactose. By decreasing the consumption of foods that contain FODMAPs, those prescribed to follow this eating pattern are advised that these signs and symptoms of CD will decrease in the short term [36]. Sugars in humans are absorbed mainly in the small intestine as the monosaccharides glucose, fructose and galactose. Enzymes are responsible for splitting the larger sugars oligo- & di- saccharides into these monosaccharides in preparation for absorption. These enzymes are produced in the brush border mucosal cells of the small intestine.

Inflammation of the gut wall as in CD causes a transitory loss of mucosal cells so the sugars cannot be absorbed. The unabsorbed sugars then move onto the large intestine where bacteria interact with them. The effect here is to form toxic metabolites (e.g. butan2-3 diol, ketones, acids and aldehydes) as a result of the anaerobic digestion of these carbohydrates. This alters the signaling mechanisms of the bacteria and their growth patterns and hence the balance of bacteria colonies in the gut [104]**.** This results in gas, pain and diarrhoea. With a normal gut wall, flatulence and diarrhoea are common too if doses of oral fructose over 50g are given [105]. Polyols like Sorbitol are sugar alcohols and cannot be absorbed by the body as there is no carrier for them. So if these are ingested in larger quantities they will cause the same issues [104]. Table 5, shows the total Fructose/100g for cooked broccoli, Brussel sprouts, cabbage and cauliflower were 0.74g, 0.8g, 1.16g, and 0.9g respectively. For raw broccoli, Brussel sprouts, and raw white cabbage these were 0.68g, and 1.45g respectively. Galactose values were zero for raw/cooked broccoli and cabbage. Values were not available for the other Brassicaceae. This means for example, using the USDA analysis, that if a cup of chopped boiled broccoli was eaten (164g), about 1.2g of fructose would be ingested. If a cup of raw broccoli was eaten (93 g), this would amount to less than 0.6g of fructose. If a cup of boiled cabbage is eaten (146g), 1.69 g of fructose is ingested, while if 1 cup of raw cabbage is eaten (79g), 1.1 g of fructose would be taken in. These values are minimal, well below the 50g limit, which upsets the normal gut. The FODMAP content of Brassicaceae is very low.

Tolerability to Brassicaceae

The results of the tolerability study (Figure 1) revealed that over 70% of respondents found that the consumption of broccoli, Chinese greens and rocket (arugula) made no difference to their symptoms of Crohn's disease (p=0.0001). This means that people with Crohn's disease may be unnecessarily avoiding these foods, and consequently are missing out on key nutrients found in Brassicaceae, which would boost their nutrition and immunity and promote anti-inflammatory and anti-cancer functions. The reaction to cabbage is less clear cut, with 47.88% finding it made no difference to their symptoms of Crohn's disease, and 49.09% finding the regular consumption of cabbage made their symptoms worse.

It is interesting to speculate what it is about cabbage that gives these results. It would be of interest to know if it is related to the different types of glucosinolates present in cabbage. Glucobrassicin, neoglucobrassicin, 4-methoxy glucobrassicin and glucoiberin are the most prevalent in cabbage [106]. Whereas in broccoli for example, glucoraphanin, glucobrassicin, gluconapin, and progoitrin are the most abundant [23]. Glucoraphanin is particularly abundant in broccoli, with a relative abundance of 55%. In cabbage it is glucobrassicin which is the predominant glucosinolate. Glucoraphanin is a sulforophane whereas glucobrassicin is an indole. The difference in their chemical composition may mean they are metabolized differently in the gut, particularly in people with Crohn's disease with glucobrassicin being more inflammatory. Different tolerability to individual glucosinolates could be another area worth exploring in people with Crohn's disease.

CONCLUSIONS
Brassicaceae are an important family of the Brassicale order, which can contribute significantly to a person's health through their fibre, vitamin, mineral and phytochemical content. These nutrients boost immunity, enable bone health, and have anti-inflammatory and anti-cancer influences through their effects on genetic pathways. Many people with CD can tolerate different forms of Brassicaceae. This makes it important to identify, for people with CD, which particular varieties from the family of Brassicaceae, can be incorporated into their daily intake. By so doing, the nutritional intake of people with CD can be improved, and their immune status and anti-inflammatory and anti-cancer factors enhanced.

Abbreviations
Crohn's disease (CD), carbohydrates (CHO), inflammatory bowel disease (IBD),
Isothiocyanates (ITC), Fermentable, Oligo, Di and Mono-saccharides and Polyols (FODMAPS), Gastrointestinal (GI), Glucosinolates (GLS), Matrix gla protein (MGP), polyunsaturated fatty acids (PUFA), New Zealand (NZ), reactive oxygen species, (ROS), Recommended Dietary Intake (RDI), ulcerative colitis (UC), United Kingdom (UK), United States Agricultural Service (USDA).

Competing Interests
The authors declare they have no competing interests.

Authors' Contributions
The authors' contributions are as follows. B Campbell and L Fergusson had a role in concept and design. Dug Yeo performed the statistical analysis. Christopher M Triggs and Alan G Fraser provided data from the 'Genes and Diet in Inflammatory Bowel Disease' study. B. Campbell wrote the manuscript. All authors gave final approval of the version to be published.

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