Dietary Fibre: Clinical Perspectives

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Curriculum vitae

Dr Vorster (neé Martins) was born in Volksrust (Tvl) where she also completed her schooling. She attended the Potchefstroom University for Christian Higher Education from 1961 and obtained a DSc degree in 1987 in Physiology with the thesis: Physiological effects of dietary fibre with special reference to the plasma coagulation factors. Esté has been in teaching professions since 1965 and was appointed Associate Professor in 1989. She is married to Ignatius (a lawyer) and they have two children, Jan and Hattie.

Summary

A high-fibre, low-fat diet is one of the environmental factors which protect against degenerative Western diseases. In recommending this diet to all patients, the general practitioner can play an important role in preventive medicine, ensuring a healthier population. The diet is characterised by an increased intake of unrefined plant foods, such as wholegrains, wholewheat bread, fruit, vegetables and legumes.

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Diet; Dietary Fibre; Fats; Physician, Family.

Introduction

Epidemiological evidence that a high fibre, low fat or so-called prudent diet may possibly protect against degenerative Western diseases such as coronary heart disease, type 2 diabetes mellitus, gall stones, constipation, diverticular disease, obesity, and some forms of cancer[1] has stimulated intensive research during the past two decades on the physiological and biochemical impact and effects of dietary fibre.[2] Today it is recognised that dietary fibre protects against constipation related diseases and improves, through a number of mechanisms, several of the risk markers (factors) of other Western diseases such as hyperlipoproteinaemia, hyperfibrinogenaemia and glucose intolerance[3]. Dietary fibre not only protects against Western diseases, but may also be used in the treatment of these diseases. Increased dietary fibre intake improves for example glycaemic control of diabetic patients.[4]

To "convert" patients to high fibre, low fat diets, the general practitioner should know and understand what dietary fibre is (definition and classification), how it works (mechanism of action) and how to increase dietary fibre intake (sources and characteristics of high fibre diets).

The concept of dietary fibre: definition and classification

Englyst and Cummings[5] point out that except for lignin (which is present only in negligible amounts in edible plant foods) all dietary fibres are plant polysaccharides and are therefore termed non-starch polysaccharides (NSP). NSP are further classified into structural NSP (primary cell wall NSP which may be either cellulose or non-cellulose substances such as the pectins, glucans and hemicelluloses) and non-structural NSP (secondary cell wall substances such as storage polysaccharides or gums).

Therefore, a large variety of different dietary fibre components are found in our daily food. These components may be either water soluble or water insoluble. The physical properties and the physiological and biochemical effects of soluble and insoluble fibre components after ingestion differ markedly. Recent literature[2,5] indicates that the insoluble fibres (mainly cellulose) are responsible for water binding in the gut and stimulation of peristaltic movements. Intake will result in more frequent and softer stools, less straining during defecation and the prevention of constipation and constipation-

related diseases. These include diverticular disease, appendicitis, hiatus hernia, varicose veins, and haemorrhoids. Soluble or gel-forming dietary fibre components (glucans, pectins, gums, etc) act similar to a chromatographic gel filtration system in the small gut and will influence the tempo of digestion and absorption of a number of nutrients and bile acids, thereby affecting several metabolic diseases.

Both types of dietary fibre are resistant to digestion by human enzymes in the small gut, but are partially fermented (together with other substrates which escape digestion) by bacterial enzymes in the large gut. The short chain fatty acids, acetate, butyrate and propionate are some of the fermentation products which are either metabolised by colonic epithelium cells (eg butyrate) or quickly absorbed and transported to the liver where they may contribute to some of the metabolic effects of dietary fibre.

How does dietary fibre work? (Mechanism of action)

The prudent or high-fibre, high-carbohydrate, low-fat diet which is currently recommended by various authoritative bodies to prevent diet-related degenerative diseases,[6] differs in more ways than just fibre content from our present-day Western or affluent diet. The total amount of fat and carbohydrate, the fatty acid profile, the ratio of animal to plant protein and the levels and ratios of several vitamins and minerals will differ.[7] These differences will of course contribute to the changed metabolism observed during the ingestion of the prudent diet. There is, however, enough and convincing evidence that dietary fibre *per se* influences metabolism favourably. Supplementation of the Western diet of experimental subjects[8] or animals[9]

More dietary fibre will result in more frequent and softer stools, less straining and prevent constipation-related diseases

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with various dietary fibre isolates or concentrates has demonstrated the independent beneficial effects of dietary fibre on metabolism.

Dietary fibre may have acute or immediate effects, such as the prevention of constipation or the flattening of the glucose and insulin response curve when fibre is mixed with carbohydrate during a carbohydrate tolerance test.[8] Longterm or chronic effects such as lowering of serum low-density lipoprotein cholesterol become apparent only after a regular ingestion of soluble dietary fibre components over a longer period. The mechanisms through which dietary fibre ingestion changes metabolism are illustrated in figure 1. The figure indicates that dietary fibre changes the digestion and absorption of nutrients from the small intestine. The factors which influence this effect of dietary fibre are summarised

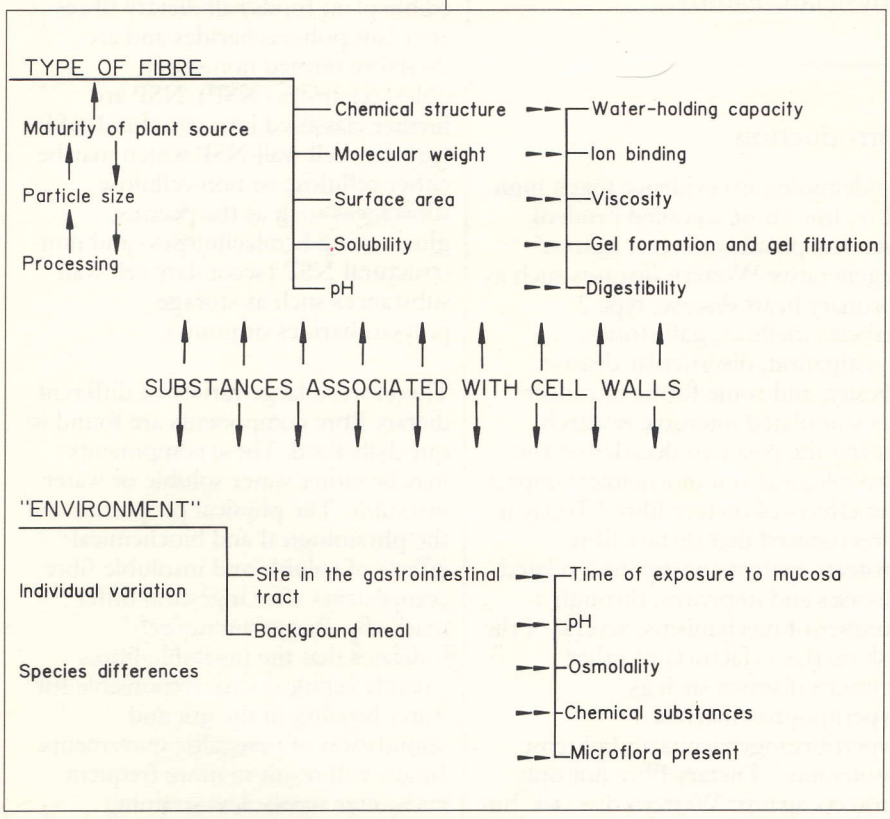

Figure 1. Relation between gut and metabolic effects of dietary fibre (Adapted from Vorster[10]

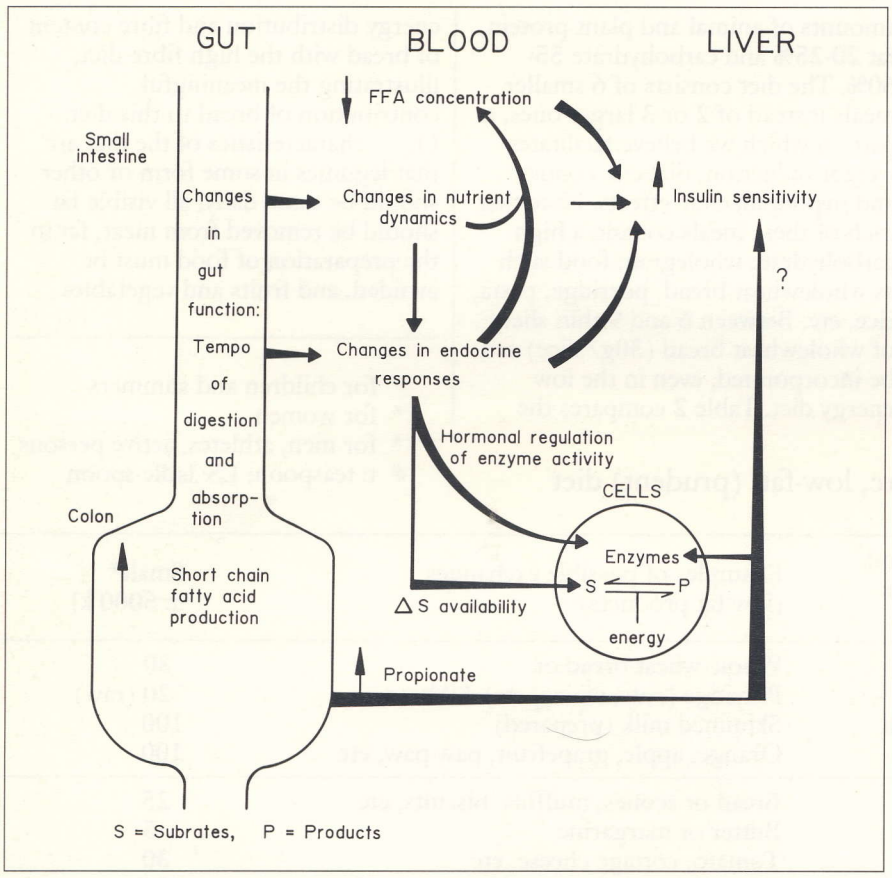

Figure 2. Schematic presentation of factors which influence the physiological effects of dietary fibre. (Adapted from Vorster[10])

in figure 2. Figure 1 further indicates that changes in gut function with fibre ingestion lead to changes in the endocrine response after meals, as well as in the tempo of concentration changes of several nutrients in the blood (nutrient dynamics). Cellular substrate availability and hormonal regulation of enzyme concentration and activity, the main determinants of metabolism, are therefore influenced by dietary fibre. Continuous and longterm ingestion of fibre will eventually, through this mechanism, lead to an improved insulin sensitivity and glucose tolerance, lower circulating low-density lipoprotein cholesterol and higher high-density lipoprotein cholesterol levels, and probably also to an improved blood coagulation profile.[3] The colonic production of short chain fatty acids from fibre may further contribute to these beneficial effects.[11] In addition,

The emphasis is on moderation

the presence of dietary fibre in the gut has a marked effect on gut motility[12] which will also contribute to its favourable effects, especially regarding the prevention of constipation-related diseases.

How to increase dietary fibre intake: characteristics of high fibre diets

Dietary fibre intake can be increased by eating more fibre-rich foods and/or supplementing the diet with fibre concentrates such as bran, pectin or konjac-glucomannan, a gel fibre concentrate, particularly suitable for use by diabetic patients.[13] The latter can be seen as a pharmacological intervention in therapeutic diets and not nutritionally as beneficial as "natural" high-fibre diets. Because dietary fibre is only present in plant foods, more plant foods in unrefined form and less foods from animal origin should be eaten if fibre intake is to be increased. This does not necessarily imply a vegetarian diet. The emphasis is on moderation, and an increased intake of wholegrain cereals, legumes, fruits and vegetables.

Dietary fibre mixed with carbohydrates will flatten the glucose and insulin response curve

Our research group has been using a high-fibre, low-fat diet, designed for South Africans[14] very successfully in the individual treatment of obese, diabetic and hyperlipidaemic patients. This diet has also been tested under controlled conditions in type 1 and 2 diabetes mellitus patients[13] who found the diet easy to follow and very economical. The diet improved metabolic control in these patients

... Dietary Fibre

without jeopardising mineral status. Side effects, such as increased flatus, were of a transient nature. A meal plan of the diet is given in table 1.

The diet is designed on three energy levels of approximately 5 000, 7 800 and 9 200 kJ/day. Depending on food choices, the dietary fibre content of the diet for the three levels is either 20, 30 or 35-40g per day. The energy distribution of the diet is as follows: protein contributes 20% of the total energy with equal amounts of animal and plant protein, fat 20-25% and carbohydrate 55-60%. The diet consists of 6 smaller meals instead of 2 or 3 larger ones, a pattern which we believe facilitates weight reduction, diabetic control and hypolipidaemic effects. Note that each of these meals contain a high carbohydrate wholegrain food such as wholewheat bread, porridge, pasta, rice, etc. Between 6 and 9 thin slices of wholewheat bread (30g/slice) can be incorporated, even in the low energy diet. Table 2 compares the energy distribution and fibre content of bread with the high fibre diet, illustrating the meaningful contribution of bread to this diet. Other characteristics of the diet are that legumes in some form or other should be eaten daily, all visible fat should be removed from meat, fat in the preparation of food must be avoided, and fruits and vegetables

* for children and slimmers
** for women
*** for men, athletes, active persons
\# t: teaspoon; LS: ladle spoon

Table 1: Meal plan of the high-fibre, low-fat, (prudent) diet

Meal	Guideline food: group or type of food	Examples of possible exchanges (low-fat products)	Small* ± 5000 kJ
Breakfast ± 07h00	Whole grain	Whole wheat bread or	30
		Porridge (oats, maize, etc) All bran	20 (raw)
	Protein/Milk	Skimmed milk (prepared)	100
	Fruit	Orange, apple, grapefruit, paw-paw, etc	100
Morning tea (± 10h00)	Wholegrain	Bread or scones, muffins, biscuits, etc	25
	Spread	Butter or margarine	5
	Filling	Tomato, cottage cheese, etc	30
	Protein/Milk	Skimmed milk (prepared)	30
Lunch (± 13h00)	Protein: Animal or Plant	Meat or eggs, fish, cheese, poultry	50
		Cooked dried legumes	100
	Wholegrain	Bread or pasta, samp, rice potato in skin, wheat, etc	100
	Vegetable	Any vegetable, without sugar or fat additions, cooked or raw	200
	Fruit	Any fresh fruit (portion sizes of dried are smaller)	100
Afternoon coffee (± 15h00)	Wholegrain	Bread or scones, muffins, biscuits etc	25
	Spread	Butter or margarine	5
	Protein/Milk	Skimmed milk (prepared)	30
Supper (Dinner) (± 18h00)	Protein: Plant or Animal	Cooked dried legumes	100
		Meat or eggs, fish, cheese, poultry	50
	Wholegrain	As for lunch	50
	Spread	Butter, margarine or oil for salad	5
	Vegetable or fruit	Any, fresh	100
Late night (± 22h00)	Wholegrain	Bread or scones, muffins, etc	25
	Spread	Butter or margarine	3
	Protein/Milk	Skimmed milk (prepared)	100

should be eaten fresh and with skins and peels where possible. Processed foods, known to have a high fat and salt content, should be avoided.

Table 3 indicates the amount of fibre in some foods and the contribution these foods could make to daily fibre intake.

Potential benefits of increased fibre intake

A question that should be considered is what are the potential benefits of switching from our very palatable high-fat (38% plus of energy) low-fibre refined diet to the recommended high-fibre low-fat diet? Although there is a lot of controversy

Dietary fibre influences the cholesterol levels and blood coagulation profile

regarding the ideal fatty acid composition of the diet (saturated *versus* mono- and polyunsaturated fatty acids) and the role of the micronutrient antioxidants (ß-carotene, selenium, vitamin C and E) in disease aetiology, there is agreement in the literature that increased dietary fibre intake will lead to the already mentioned metabolic improvements (lower glucose, insulin, total and low-density lipoprotein cholesterol levels in blood, higher high-density lipoprotein cholesterol levels, increased defecation frequency, improved control of food intake and possibly also decreased blood hypercoagulability and thrombus formation).

Household units #	Quantities (g) Medium** ± 7800 kJ	Household units	Large*** ± 9200 kJ	Household units
1 thin slice	or 50	1½ thin slices	60	2 thin slices
100 ml All bran	35	175 ml	40	200 ml
100 ml	125	125 ml	150	150ml
1 small apple	125	1 medium apple	150	1 medium apple
1 plain scone 50 x 25 mm	50	2 scones	75	3 scones
5ml: 1t	5	5ml: 1t	5	5ml: 1t
1 level LS	30	1 level LS	50	1½ level LS
30 ml	30	30 ml	30	30 ml
1 egg or 40 mm meat ball	80	2 meat balls	80	2 meat balls
125 ml beans	150	190 ml beans	200	250 ml
3 thin slices	150	5 slices	175	6 slices
300 ml mixed vegetables	300	500 ml	350	600 ml
1 peeled orange: 50 x 50 mm	125	1 peeled orange	150	1½ peeled orange
1 rusk: 60 x 30 x 35 mm	25	1 rusk	50	2 rusks
5 ml: 1t	5	5 ml: 1t	5	5 ml: 1t
30 ml	30	30ml	30	30 ml
as for lunch	150		200	
as for lunch	80		80	
1 medium slice of bread	50	1 medium slice	75	2½ thin slices
5 ml: 1t	5	5 ml: 1t	5	5ml: 1t
150 ml mixed vegetables	100	150ml	200	300ml
4 provitas	100	3 thin slices of bread	100	3 thin slices
3 ml	5	5 ml	5	5ml
100 ml	100	100	100	

Table 2: Composition of the high-fibre low-fat (prudent) diet* and wholewheat bread (with and without spread)

Nutrient	Prudent diet	Wholewheat bread (100g: 3 thin slices)		
		without spread	with 15g/100 gm butter	with 15g/100g soft margarine
Total energy (TE) (kilojoules)	5000-10000#	1121	1571	1601
Protein (% of TE)	20,0	15,0	10,9	10,5
Plant protein (% of TE)	10,0	15,0	10,7	10,5
Animal protein (% of TE)	10,0	0,0	0,1	0,0
Fat (% of TE)	20-25	11,5	37,6	36,9
SAFA (% of TE)	< 10	2,6	18,2	7,5
MUFA (% of TE)	< 10	6,6	12,1	14,2
PUFA (% of TE)	< 10	2,0	2,0	13,5
Carbohydrate (% of TE)	55-60	61,0	43,6	42,9
Dietary fibre (g)	30-35	8,9	8,9	8,9
Dietary fibre (g/1000kJ)	3-6	7,9	5,7	5,6

* Reference [14]
** According to South African Food Tables[15]
\# Energy requirement will depend on sex, age and activity level

The sooner, the better; dietary habits are established in childhood!

The benefits derived from these changes will probably depend on the magnitude and duration of the change, the age at which it is introduced, as well as the presence, type and degree of degenerative disease.

It should be kept in mind that these diseases are all multifactorial in origin, and that diet is but one of the environmental factors which may precipitate the disease in a genetic susceptible individual. Comparative studies have shown that people with life long high fibre intakes such as rural Africans or vegetarians are at lower riks of these diseases.[1] Because dietary habits are to a large extent established in childhood the message really is: the sooner, the better!

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Table 3: Dietary fibre content of edible portion size of some foods

Food	Portion size	Dietary fibre (g)
Cereals and bread		
All-bran flakes	25 g (125 ml)	7,5
Oats porridge (cooked)	100 g (100 ml)	0,9
Weetbix	25 g (88 x 40 x 20 mm)	3,2
Wholewheat bread *	30 g (1 thin slice)	2,7
White bread	30 g (1 thin slice)	0,8
Brown bread	30 g (1 thin slice)	1,6
Maize porridge	130 g (125 ml)	1,3
Muesli	65 g (125 ml)	4,8
Rice (cooked: brown)	70 g (125 ml)	0,9
Legumes		
Cooked beans	100 g (125 ml)	7,4
Cooked lentils	90 g (125 ml)	3,3
Cooked peas	85 g (125 ml)	4,3
Vegetables		
Broccoli	75 g (125 ml)	3,1
Cabbage (raw)	40 g (125 ml)	0,9
Carrots (raw: grated)	95 g (125 ml)	2,4
Mixed vegetables (cooked)	75 g (125 ml)	3,0
Tomatoes (raw: chopped)	100 g (125 ml)	1,5
Spinach (cooked)	90 g (125 ml)	2,4
Green beans (cooked)	80 g (125 ml)	3,1
Fruits (raw)		
Apple	150 g (52 x 66 mm)	4,7
Orange (peeled)	120 g (55 x 55 mm)	2,4
Banana (peeled)	100 g (148 x 31 mm)	3,0
Peach	80 g (53 x 50 mm)	1,0
Pineapple (peeled)	80 g (2 rings: 85 x 10 mm)	1,2
Pawpaw (cubes)	70 g (125 ml)	0,6
Pear	100 g (60 x 52 mm)	2,5
Watermelon	220 g (330 x 70 mm)	0,7

*The 255 to 565 g wholegrain allowed in the diet, could providee 23 to 50 g fibre if eaten as wholewheat bread

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