DIETARY FIBRE &
RELATED SUBSTANCES

Dietary Fibre and Related Substances

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Series Introduction

Consumer safety has become a central issue of the food supply system in most countries. It encompasses a large number of interacting scientific and technological matters, such as agricultural practice, microbiology, chemistry, food technology, processing, handling and packaging. The techniques used in understanding and controlling contaminants and toxicity range from the most sophisticated scientific laboratory methods, through industrial engineering science to simple logical rules implemented in the kitchen.

The problems of food safety, however, spread far beyond those directly occupied in food production. Public interest and concern has become acute in recent years, alerting a wide spectrum of specialists in research, education and public affairs.

This series aims to present timely volumes covering all aspects of the subject. They will be up-to-date, specialist reviews written by acknowledged experts in their fields of research to express each author's own viewpoint. The readership is intended to be wide and international, and the style to be comprehensible to non-specialists, albeit professionals.

The series will be of interest to food scientists and technologists working in industry, universities, polytechnics and government institutes; legislators and regulators concerned with the food supply; and specialists in agriculture, engineering, health care and consumer affairs.

One of the most notable developments of recent years in our views about the effect of diet upon health has been in the field of dietary fibre. But although realization of the beneficial role of fibre has entered the public arena, modifying food manufacturing and retailing practice, and changing clinical procedures, there is less awareness of possible adverse effects that may arise.

The authors of this book are recognized internationally as authorities in the field of dietary fibre, and here they have given a definitive account of the present knowledge of the subject. They have also provided, probably for the first time, a wide-ranging description and discussion of the antinutritional and toxicological aspects of high-fibre diets and the regulatory implications. This will be of particular interest and value to professional health workers and legislators, but the book as a whole will be found by all those concerned with our food supply to encompass the whole topic of high-fibre diets in a comprehensible and highly readable way.

J. Edelman

Preface

Opinions vary as to the precise date at which the dietary fibre hypothesis emerged but it is safe to say that it has been a key nutritional concept for nearly a quarter of a century. For much of that time it has been the subject of intense research. Most previous texts have been prepared from papers written for scientific meetings. Inevitably such books tend to focus on new developments in each separate branch of the subject. In this text however we aim to provide the reader with a short but detailed review of the basic concepts surrounding the dietary fibre hypothesis.

The chemistry of cell walls and the problem of analysis are intimately linked, as are the physiological effects of cell wall polysaccharides and the disease states against which dietary fibre is thought to provide protection. This book attempts to provide an integrated and critical review of these issues, assessing both the benefits and possible disadvantages of increased fibre consumption. In keeping with the theme of this series we have focussed particular attention on the food safety issues that surround the consumption of dietary fibre, and which have often been neglected in previous treatments of the subject.

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CHAPTER

—1—

An Introduction to the Dietary Fibre Hypothesis

—— 1.1 ——
THE ORIGINS OF THE HYPOTHESIS

Although there are many references in the medical and popular literature since the time of Hippocrates to the benefits of consuming unrefined foods, in its current form the 'dietary fibre hypothesis' stems from the writings and lecturing of two medical men, Mr Denis Burkitt and Dr Hugh Trowell, in the early 1970s (*Burkitt & Trowell, 1975*). These two men had both worked in East Africa for a large part of their professional careers and had been intrigued by the differences in the pattern of diseases they saw compared with the Western communities where they had been trained. Trowell was especially interested in the 'metabolic' diseases, obesity, diabetes and coronary heart disease, whereas Burkitt, as a surgeon, was particularly interested in large bowel diseases and especially large bowel cancer. Both men had been influenced by earlier workers,

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especially ARP Walker working in Southern Africa, and in the popular writing of Surgeon Commander P Cleave who had developed the concept of the 'saccharine diseases' based on the consumption of excessive refined sugars.

In 1971 a paper was published which postulated that diverticular disease was due to a deficiency of fibre in the diet (*Painter & Burkitt, 1971*). This was followed by papers on large bowel cancer and ischaemic heart disease where Trowell (*1972*) used the term 'dietary fibre', which had been used earlier by Hipsley (*1953*), for the constituents of the plant cell walls in the diet (see review by *Southgate, 1992*).

The 'dietary fibre hypothesis' can be expressed formally as follows:

> Diets rich in foods containing plant cell wall material in a relatively natural state are protective against a range of diseases that are prevalent in Western affluent communities, for example, diabetes, coronary heart disease, obesity, gall bladder disease, diverticular disease and large bowel cancer.

In some cases the consumption of diets poor in these plant foods may be causative, diverticular disease for example, but in others it may provide the conditions where other aetiological factors become active. The hypothesis is therefore, strictly speaking, one that refers to the protective effects of a type of diet, i.e. one that is rich in plant foods that contain their original cell wall material. Burkitt and Trowell focussed the attention of the clinical world, medical researchers and the general public on the plant cell wall material for which the name 'dietary fibre' became generally accepted. Nevertheless it should not be forgotten that the protective diets that they identified were different in many other ways from the low-fibre diets eaten in Western communities such as the UK and the USA.

These differences are important because they, together with the specific effects of the dietary fibre, contribute to the protective effects (Table 1.1). There is growing recognition that the amount of dietary fibre present in the diet provides a 'marker' for diets that are protective. Thus the consumption of plant foods, especially fruits and vegetables but also cereal foods, brings a range of non-nutrients into the diet which have important biological activity. In this text we will be focussing on dietary fibre and will draw attention to the more important groups of compounds associated with the dietary fibre in plant foods.

The hypothesis proposed by Burkitt and Trowell has proved

Table 1.1 Characteristics of high-fibre diets

Characteristics	Comments
Bulky	Lower physical density g/ml
Energy density	Lower metabolizable energy per unit weight (kcal/kg) but only when fat intakes are also lower
Starch	Proportion of complex carbohydrates: simple sugars increased
Lower-fat	In the context of diets over the world as a whole, the fat also tends to be primarily from vegetable sources and more polyunsaturated
Protein	Vegetable protein sources are more important than animal ones

extremely productive scientifically and current evidence suggests that such high-fibre diets do seem to be protective. However, much of the physiological research that has been carried out since the early 1970s has tended to show that the mechanisms of action originally proposed were naive (Figs 1.1 and 1.2), primarily because they did not take into account the true nature of the chemical and physical properties of the components of the plant cell wall, but also because the research stimulated by the hypothesis has substantially advanced our knowledge of the effects of diet on the gastrointestinal tract.

1.2
THE DEFINITION OF DIETARY FIBRE

Before one can discuss the quantitative effects of dietary fibre it is necessary to examine the problem of definition because this has been a cause of considerable debate since Trowell reused the concept originally introduced by Hipsley. Trowell was convinced that the plant cell walls in the unrefined foods making up the diet of the rural African were the active principles. He first spoke of 'the skeletal remains of the plant cell wall' before adopting the term 'dietary fibre'. At that time he was unaware of the chemistry of the plant cell wall, but he was conscious that the 'fibre' values that had been measured by the food chemists for more than a century were not meaningful measures of what he envisaged as the active components in the protective diets. Burkitt was also aware that these 'fibre' values did not include the major part of the indigestible fraction of human foodstuffs which he had come to believe was important for large bowel function and health.

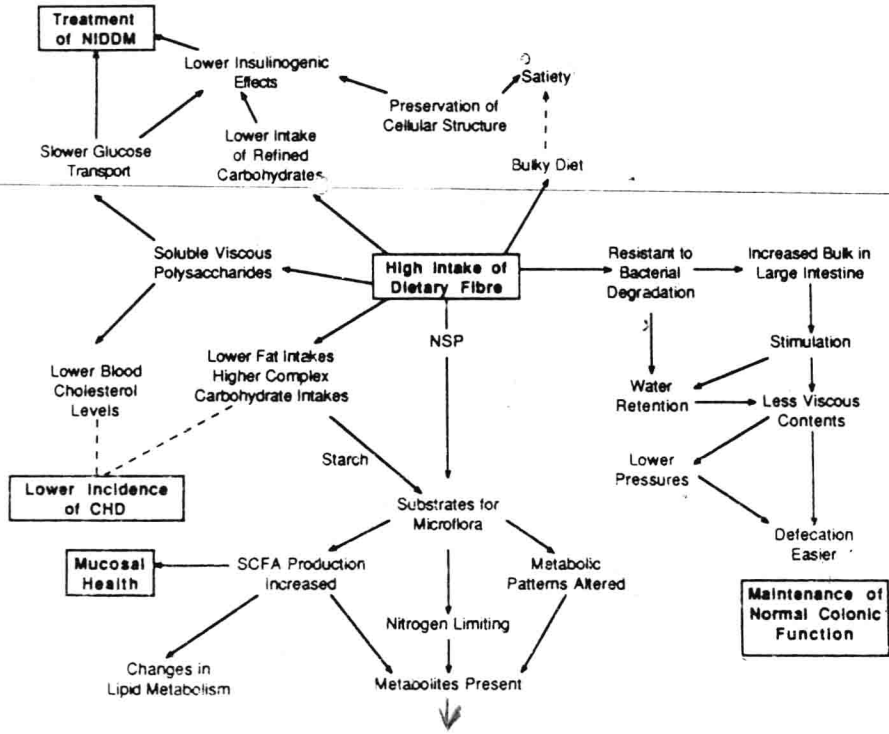

Figure 1.1
Schematic outline of the original hypotheses on the mechanism of action of dietary fibre. (Reproduced from Southgate [1991] *with permission from the* Journal of the Royal Society of Health.*)*

The use of the word 'fibre' led many researchers to start using the published values for foods. These were 'crude fibre' values which gave a poor measure of the cellulose and lignin in foods, and therefore were insensitive measures of the plant cell wall material in the diet. Other workers turned to the 'detergent fibre' procedures developed by PJ Van Soest (*Van Soest, 1963*), which had been shown to be analytically and conceptually superior to the older crude fibre methods. However, these had been designed for animal feeds and did not measure the soluble components of plant cell walls.

The concept of 'unavailable carbohydrates' originally developed by

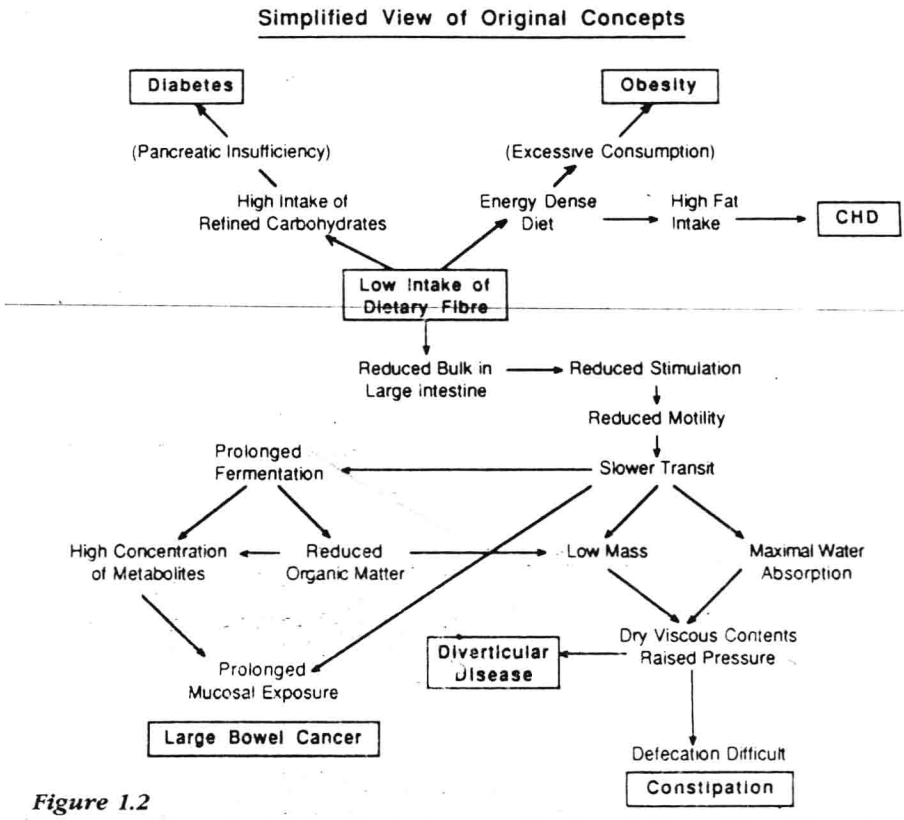

Figure 1.2
Current evidence for the physiological modes of action of dietary fibre. (Reproduced from Southgate [1991] *with permission from the* Journal of the Royal Society of Health.*)*

McCance and Lawrence in 1929 included all the constituents of the plant cell wall and in 1976 Trowell and a group of researchers proposed that dietary fibre should be defined as:

> The sum of the lignin and the plant polysaccharides that are not digested by the endogenous secretions of the mammalian digestive tract.

This would include all the major components of the plant cell wall, although it excluded the small amounts of protein, waxes and inorganic material that typically account for less than 10% of the wall. It was recognized that isolated polysaccharides would also be included by this definition. The decision to include such components was deliberate because they were being used, at the time, as 'models' in the study of the physiological effects of dietary fibre, and pragmatic, in that most were

structurally related to cell wall constituents and could not be distinguished from them analytically.

1.3 THE ANALYSIS OF DIETARY FIBRE

The establishment of an accepted definition of dietary fibre enabled biomedical researchers and food scientists to use analytical methods developed for unavailable carbohydrates to quantify the dietary fibre in foods, and therefore the diet. This was a major priority for dietary fibre research in the 1970s. Other workers focussed on the indigestibility of dietary fibre and developed 'physiological' methods which incorporated proteolytic and amylolytic enzymatic treatments to remove digestible components, leaving an indigestible dietary fibre residue. The methods used gravimetric assay techniques, and the residue could be used in studies of the properties of isolated dietary fibre preparations (*Asp et al., 1983*). In practice these methods did not differ very greatly from the unavailable carbohydrate procedures, which also employed enzymatic methods to remove starch, but which used colorimetric methods to measure the carbohydrate components directly, followed by the gravimetric measurement of lignin. In practice also, the residue always contained residual protein and it became customary to correct the residue for this. Some starch was subsequently found to be enzymatically resistant and this was included in the gravimetric residue or analysed with the unavailable carbohydrates. This will be discussed in detail later in Chapter 2.

The colorimetric measurement of the carbohydrate constituents in the unavailable carbohydrates developed in the 1960s (*Southgate, 1969*) was prone to mutual interference effects and subsequent developments have used gas-liquid chromatography (GLC) and more recently high-performance liquid chromatography (HPLC). In these methods considerable care has been taken to remove any interference from enzymatically resistant starch and to measure the non-alpha-glucans of the plant cell wall with precision. These methods, which describe the fraction measured unequivocally, have been called the 'non-starch polysaccharide' (NSP) methods (*Englyst & Cummings, 1988*). The fraction measured does not include lignin and is thus formally not identical to dietary fibre as originally defined. However, because the NSP account for about 90% of most plant

cell walls their measurement provides a good index of dietary fibre as originally conceived and this method is preferred by the UK Ministry of Agriculture, Fisheries and Food (MAFF) for the nutritional labelling of foods.

The gravimetric indigestible residue procedures have been extensively developed in the USA (*Prosky et al., 1984*) and in some European countries as methods for determining total dietary fibre (TDF), because it is believed that gravimetric methods are simpler, more rapid, require less investment in capital equipment, and are therefore more suitable for regulatory control of labelling.

1.3.1 Differences between the Analytical Methods

The two major types of method in use at the present time give slightly different values for some foods. When making comparisons between the composition of foods or comparing dietary intakes it is important to know the actual method used. In general the gravimetric TDF values are slightly higher than the NSP values, because the former include lignin and resistant starch. The differences are small, and indeed insignificant for most vegetables and fruits, but they may be of the order of 1 g/100 g for unprocessed cereal foods because of the non-inclusion of lignin in NSP values. In heat-processed cereal foods and potato the TDF values may be 2 or 3 g/100 g higher because of the inclusion of resistant starch. The UK tables of food composition 'McCance and Widdowson's The Composition of Food' (*Holland et al., 1991*) give values for two methods: the older, colorimetric 'Southgate' method and the NSP method. The former values are higher because they include lignin and some resistant starch and are similar in magnitude to the TDF values for cereal products.

1.4 INTAKES OF DIETARY FIBRE IN DIFFERENT POPULATIONS

As mentioned above, when making comparisons between estimates of dietary fibre intakes by different populations it is essential to take recognition of the methods used for the dietary fibre values. Much of the comparative data that does exist relates to measurements made using the older 'unavailable carbohydrate' methods, which give higher values than

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