Special Topics in Diabetes

Dietary-fiber Hypothesis of the Etiology of Diabetes Mellitus

H. C. Trowell, M.D., Woodgreen, Fordingbridge, England

SUMMARY

A hypothesis has been proposed that dietary fiber-depleted starchy foods are conducive to the development of diabetes mellitus in susceptible human genotypes.[1] DIABETES *24*:762-65, August, 1975.

Africans south of the Sahara. In 1960 a study of noninfective disease in Africa stated that diabetes had been a rare disease in African hospital patients in all countries south of the Sahara 1920-60. This was related to high-carbohydrate low-fat diets.[2] In 1961, Walker in South Africa began to discuss the possibility that cereal fiber might prevent diabetes[3] and many other diseases.[4] Ischemic heart disease has remained rare in all Africans south of the Sahara,[1,5] even among diabetics.[6]

DEFINITIONS

Crude fiber and dietary fiber. Crude fiber (CF) is that portion of plant food left after sequential hydrolysis by dilute acid and dilute alkali. On the average, CF contains only 50-80 per cent of the celluloses, 20 per cent of hemicelluloses, and 10-50 per cent of lignins.[7] Dietary fiber (DF) is that portion of plant cell walls remaining after hydrolysis by the digestive enzymes of man.[1,8,9] DF appears to be composed of unavailable carbohydrate and lignin.[10,11] CF is estimated by internationally agreed upon methods, but there is not agreement concerning the methodology for measuring celluloses, hemicelluloses, and lignins.[10] Since food tables do not report the constituents of DF, it is impossible to determine definitely the role of DF in health or disease from published reports.[12] Consequently, DF hypothesis must be assessed provisionally in terms of CF.[1] African adult men in rural areas eat on the average CF 10-25 gm. per day, about half associated with unprocessed or lightly processed starchy food.[13] British adults eat an average CF 4 gm. per day, about 0.5 gm. per day in association with fiber-depleted cereal products and about 1.0 gm. per day from potato that is not depleted of fiber.[14]

Dietary fiber-depleted starchy food. A fiber-depleted starchy food is defined as one in which the fiber of the plant food has been considerably reduced by processing.[15] Man has selected as natural foods cereals that contain CF 0.5-1.0 gm./100 kcals.[15] Skinned starchy roots (e.g. potato) and peeled starchy fruits (e.g. banana) contain, in proportion to available energy, approximately as much CF as whole cereals, and these foods are not unduly depleted of fiber by preparation.

Captive and domesticated animals and fish (e.g. carp) may be offered food of a lower

$$\frac{\text{unavailable dietary fiber}}{\text{available energy}} \qquad \left(\frac{F}{E}\right)$$

ratio than their traditional food. The former food is defined as fiber-reduced *for the species concerned.* For instance, sand rats, accustomed to fibrous desert vegetation of a high F/E ratio, may be offered cereal chow of a lower F/E ratio. This chow is designated as fiber-reduced for sand rats but not for mice accustomed to eating whole cereals.

Table 1 presents data concerning DF and CF of whole wheat meal, 100 per cent extraction, and wheat white flour, 70 per cent extraction. DF is about five to twenty times CF.[11] The DF content of many foods is not known.

ANIMALS

Spontaneous diabetes syndromes in laboratory animals. These syndromes have been detected most frequently in rodent species habituated to semidesert vegetation—sand rats, hamsters, and spiny mice. No

Formerly Department of Medicine, Makerere University, and Mulago Hospital, Uganda.

Present address: Woodgreen, Fordingbridge, Hants, SP6 2AZ, England.

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TABLE 1

Dietary fiber (DF) and crude fiber (CF) of whole wheat meal and wheat white flour, 70 per cent extraction

Investigator	Wheat	gm./100 gm. Dietary fiber				Crude fiber
		cellulose	lignin	hemicellulose*	total	total
Southgate[16]	whole wheat meal	1.1	2.6	7.5	11.2	2.1
Fraser[17]	whole wheat meal	4.4		6.5	10.9	2.1
Fraser[17]	wheat white flour	0.4		2.0	2.4	0.1

*Expressed as monosaccharide.

experiment has been reported that attempted to assess the role of fiber in producing diabetes syndromes in laboratory animals. Nevertheless, captive rodents have been fed fiber-reduced foods, reduced for the species concerned. For instance, sand rats traditionally feed on *Chenopodiaceae* desert vegetation, which is low in carbohydrate, high in fiber. Different batches of captured sand rats vary slightly in their response to various laboratory cereal diets, but few abnormalities have been reported in rats fed ad libitum high-fiber mixed-vegetable diets of CF 2.6 gm./100 kcals.[18] One group of sand rats fed this vegetable diet averaged 30.1 kcals per day.[19] Obesity and diabetes often occurred if sand rats were fed ad libitum high-carbohydrate Purina laboratory chow CF 1.2 gm./100 kcals.[20,21] Littermates of the first group of sand rats, those fed the vegetable diets, were fed a very low-natural-fiber synthetic diet ad libitum; they averaged 39.6 kcals per day. These rats developed decreased carbohydrate tolerance, their plasma insulin levels rose, and their body weight increased.[19] It would appear that fiber-reduced food promoted diabetes and obesity.

Certain rodent mutants develop diabetes, and usually obesity, if fed various cereal foods; health in both of these diseases improves if dietary intake is reduced. No experiment has been reported that assessed the role of fiber in producing or altering the incidence of diabetes syndromes in rodent mutants. Indeed, the crude fiber content of the experimental laboratory diet is seldom stated. For instance, it was mentioned in only three out of twenty-nine communications at a recent symposium.[22] Diabetes syndromes have also been studied in a few susceptible inbred rodent strains, but no experiments have been reported that attempted to assess the role of fiber. Suggestions arise from an experiment in which Wellesley hybrid mice and some commercial Swiss mice were fed ad libitum Old Guildford (Mouse) Breeder pellets (CF 2 per cent); they developed hyperglycemia, increased body weight, and elevated levels of immunoreactive insulin. These features quickly decreased after a dietary switch to Purina laboratory chow pellets (CF 5 per cent) fed ad libitum. The Old Guildford pellets contained more fat (11 per cent) than the Purina chow (4 per cent), so that the increased incidence of diabetes and obesity was attributed to differing caloric concentrations.[23] Further experiments with the Swiss mice, fed diets of different fat content, suggested that increased body weight was not related to the amount of fat or the calorie content of the tested diet.[24] Different varieties of fat had, however, been employed in these experiments; but no further experiments were reported to assess the effect of the fiber, which had varied considerably. In concluding this review of laboratory experiments it should be noted that, except for infections, all other diabetogenic mechanisms in spontaneous diabetes in animals have been associated with long-standing or transient hyperinsulinemia.[25]

MAN

It is therefore desirable to study in man long-standing fasting insulinopenia, likewise low levels of fasting blood glucose. It is the mean level of the fasting blood glucose that acts throughout most of the day and night as a stimulus to the beta cells of the pancreatic islets. The blood insulin response to oral glucose loading should also be studied. There are no data from prehistoric man except from African Bushmen and Pygmies who still have insulinopenia, both fasting and following an oral glucose loading.[26] Diabetes has not been reported in Bushmen or other food-gatherer hunters, such as Hottentots, Laplanders, or Australian aborigines.[27] There are few data from man at the next stage of evolution, the peasant cultivator of crops that were not processed severely, but early reports from rural Africa in 1940-60 commented on the frequency of marked hypoglycemia, blood glucose 40-70 mg./100 ml., in healthy fasting African adults.[2] During 1972 the fasting blood glucose of South African rural Transvaal Bantu children averaged 43 mg./100 ml., but that of South African

urban white children averaged 88 mg./100 ml. The former ate much lightly refined corn meal, the latter ate Western diets. Blood insulin was not estimated.[28] During 1969, South African Bantu adults of Johannesburg had significantly lower mean blood insulin levels after oral glucose loading than comparable group of whites, but fasting blood insulin levels, likewise blood glucose levels, fasting and also after oral glucose loading, were similar in the two groups.[29] Urban Bantu in the Transvaal still consume large amounts of sorghum and lightly processed corn meal, CF 0.8-1.4 gm./100 gm., although Westernized diets are increasing.[30] During 1972, in Salisbury, Rhodesia, fifty African cleaners, who consumed lightly refined corn meal, had mean fasting blood glucose 68 mg./100 ml. They had a smaller secretion of insulin after oral and intravenous glucose than Rhodesian white students of comparable age. Rhodesian African students who ate semi-Westernized diets had an intermediate response.[31] Westernized diets are being consumed increasingly in urban areas of Rhodesia, and diabetes is appearing more frequently in hospital patients.[32] It is hoped that further South African diabetes prevalence surveys will identify Bantu groups habituated to high-fiber corn meal or to low-fiber refined cereal products, survey all aspects of the diet, and amplify data that had demonstrated that Cape Town Bantu have more diabetes (3.6 per cent) than Cape Town whites (3.2 per cent) but found less disease among 2,015 rural Transvaal Bantu.[33]

Perhaps it is relevant to note that in the United States all sixty-seven healthy controls aged nineteen to twenty-four years, but only thirteen out of thirty-three latent (subclinical) diabetics of comparable age, had fasting blood glucose <100 mg./100 ml.[34] Is a rising fasting blood glucose one of the signs that latent (subclinical) diabetes is commencing in the observed individual?

SUGGESTIONS

1. It is desirable to re-examine the decrease in diabetes death rates in certain countries during periods of war. In England, standardized diabetes deaths fell 55 per cent in men and 54 per cent in women during the period of the high-fiber National flour 1941-56.[1,35] 2. Suggestions that fiber retards and reduces the digestion of starch by amylase in vitro should be investigated.[36] 3. Suggestions that the coarse leaflike villi of the jejunal mucosa, found in almost all African tropical inhabitants, is the normal mucosa for traditional *homo sapiens* should be examined.[15] Their absorption curves of glucose, galactose, and D-xylose are flatter than those of European controls[37] but are considered by me to be normal. 4. Suggestions that fiber-depleted plant foods promote obesity[38] should be assessed experimentally. 5. A very high prevalence of diabetes, such as that occurring among Pima Indians, may reflect sudden change from high-fiber carbohydrates of food-gatherer huntsmen to low-fiber cereal products of Western man. 6. It should be emphasized that certain high-carbohydrate diets improve glucose tolerance and decrease serum insulin levels,[39] but these facts by themselves have not explained either spontaneous diabetes in laboratory animals or falling death rates in man. 7. While a hypothesis concerning one factor should be stated succinctly, other factors, largely unidentified, influence the onset and course of diabetes mellitus.

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