replacing co-enzymes lost by side reactions—and as a rule unknown side reactions at that!

In the evidence submitted to the Panel the essential fatty acids and the tocopherols did not receive much attention, again possibly because of too little firmly established relevant information.

If we regard scientific knowledge as something which must be accepted when it is understood—the science of nutrition is then like a small island of undoubted fact in a large sea of ignorance. It has, however, a very nice beach, good for building sand castles and for bathing. We may like to pitch a tent on the shore in high summer and play on the beach but a house should be built on dry land. Scientists and science writers, in dealing professionally with nutrition policy—must distinguish between knowledge and 'could be' knowledge, however rightly they may value speculation in research.

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Nutritional aspects of high-extraction flour

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Introduction

In 1945 The Nutrition Society held a one-day scientific meeting upon 'Factors affecting the nutritive value of bread as human food'. This was some months after the extraction rate of flour for human consumption had been reduced from 85 to 82·5%, and shortly after the extraction rate had been further reduced to 80%. Then as now the Chairman was Sir Rudolph Peters who in his introductory remarks referred to the 85% extraction flour as 'a very beautiful and wonderfully chosen foodstuff' (Peters, 1946). His final words are as true now as they were then: 'I know that those who have a more purely chemical discipline often feel that it is

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illogical for biologists to believe in the value of unknown substances but, if you continue to work on these matters for some years . . . you become certain that there are valuable substances, present in a complex material such as wheat, of which you do not yet know, and you would prefer to be on the safe side when responsible for advice'.

The first paper discussed the composition and milling of wheat, and combined scientific facts with forthright comments. '. . . the provision of National wheatmeal flour not only saved the country a great deal of shipping but also provided the people with a much more nutritious bread than they had been eating before the war. . . . Some months ago the percentage of wheat to be used for human consumption was reduced to 82·5, and still more recently to 80. Quite frankly, we consider that in doing this the Government made a mistake. Nutritionally the country has suffered, and will suffer more still if the extraction is further reduced. He would be a very bold man who offered to replace by enrichment all the valuable amino-acids, minerals and vitamins that are to be found in those "mighty atoms", the embryo, the scutellum and the outer endosperm'. That was McCance & Widdowson (1946).

I shall start with an uncontroversial statement: flour, with bread made from it, is the most important single item in our diets. I claim no priority for this discovery, but the evidence is worth examining briefly. In Table 1 are listed the approximate

Table 1. *Moderately active woman's daily dietary allowances and proportion supplied by rationed amounts of four foodstuffs with 70% bread for comparison (see p. 30)*

		Percentage supplied by			
Aliment or nutrient	Allowance	Bread, 85% extraction, with chalk	Bread, 72% extraction	Potatoes	Butter and margarine
Calories	2500 Cal.	27	24	4	7
Protein	60 g	37	31	5	0
Carbohydrate	360 g	37	35	7	0
Fat	85 g	4	2	0	24
Iron	10 mg	46	26	10	1
Calcium	750 mg	21	8	2	0
Phosphorus	1000 mg	33	19	6	0
Vitamin A	833 i.u.	0	0	0	61
Carotene	3 mg	0	0	0	3
Vitamin D	200 i.u.	0	0	0	19
Thiamine	1·0 mg	49	13	16	0
Nicotinic acid	10 mg	33	18	17	0
Riboflavin	1·5 mg	19	7	4	0
Vitamin C	25 mg	0	0	86	0

daily allowances or 'requirements' of aliments and certain nutrients of a moderately active woman, whose requirements are approximately those of the average person in the population. These figures are adapted from Table 8 in a previous article of mine (Sinclair, 1951), and the allowances are those of the Oxford Nutrition Survey (Sinclair, 1948) which were subsequently adopted almost entirely by the British Medical Association: Committee on Nutrition (1950); it is unimportant here to discuss the connotation of 'requirement'. The amounts of the four listed foodstuffs—bread of 85% extraction, potatoes, butter and margarine—are the rationed amounts in December 1947, and white bread (72% extraction) has been included for comparison; her daily ration of bread and flour was then 9 oz. It will be seen that the high-extraction bread provides her with between one-third and one-half of her allowances of thiamine, iron, protein, phosphorus and nicotinic acid, and with considerable amounts of calcium and riboflavin; about 27% of her calories come from bread. If one compares the high-extraction bread (with added chalk) with 72% extraction, one notes large differences in iron, calcium, phosphorus and in three vitamins of the B complex (thiamine, nicotinic acid and riboflavin).

These basic facts are so well known that they are now dull. A beginning was made with the addition of calcium carbonate to flour in May 1942, and by the end of April 1943 about 89% of the National flour produced in this country was fortified with it at the rate of 7 oz. per sack of 280 lb. (i.e. 0·16%). The Flour Order, 1953 (Great Britain. Parliament, 1953) required that all flour, except wholemeal, should have 14 oz. of *creta praeparata* added per 280 lb.; it was amended by the Flour (Composition) Regulations, 1956 (Great Britain. Parliament, 1956*b*) to a minimum of 235 mg and maximum of 390 mg/100 g flour.

The Flour Order, 1953, also prescribed that flours of an extraction rate less than 80% should have added sufficient iron, thiamine and nicotinic acid to ensure a minimum content of 1·65, 0·24 and 1·60 mg respectively per 100 g flour. This Order was amended by The Flour (Revocation) Order, 1956 (Great Britain. Parliament, 1956*a*) and the Flour (Composition) Regulations, 1956 (Great Britain. Parliament, 1956*b*), which came into force on 30 September 1956, to apply to all flour for ordinary use. Although there is evidence that added synthetic thiamine is less stable during the baking of bread than that occurring naturally in the grain (Holman in Widdowson & McCance, 1954, Appendix C), this difference is probably unimportant. The addition of nicotinic acid (or nicotinamide, which is allowed by the 1956 Regulations) acts in the opposite sense since all that is added is available whereas some that is present in the grain is in bound form and is not all absorbed from the gut (Braude, Kon, Mitchell & Kodicek, 1955).

The difference between flour of high-extraction and 70% extraction as regards protein may be unimportant, despite the lower lysine content of low-extraction flour. It is doubtful if the same is true of riboflavin. The Conference on the Post-War Loaf (Great Britain. Parliament, 1945) believed, on the late Sir Jack Drummond's advice, that since other foods such as milk, meat, eggs, potatoes and vegetables contained riboflavin added amounts of it were not required in low-extraction flour; with flour of the minimum standard recommended by its Sub-Committee (0·14 mg riboflavin/100 g), 'only about 20 per cent. of the total riboflavin requirement of the diet is likely to be provided by flour and flour products'. As the Cohen Report (Great Britain. Parliament, 1956*c*) points out, however, the ingestion of riboflavin is less satisfactory than that of any of the other vitamins covered by the 1953 Report of the National Food Survey (Ministry of Agriculture, Fisheries and Food: National Food Survey Committee, 1955), and for certain classes the supply appears to be marginal to requirements; the same is true of some of the children studied by Widdowson & McCance (1954) in whose intestinal tracts riboflavin was apparently synthesized since faecal output exceeded intake. The Oxford Nutrition Survey studied working-class persons in Oxford City in late 1941 and early 1942, before and just after the rise in extraction rate from 75% to 85% on 23 March 1942; 31% of them were receiving less than 100% of their requirement and more than 72%, and 3% were receiving less than 72% (Sinclair, 1951). In a similar study of persons in an Oxfordshire village in August and September 1942, when 85% extraction flour was almost universal, the corresponding figures were 23% and 0%. Therefore in the first instance a third of the persons appeared to be receiving insufficient riboflavin according to the standards later adopted by the British Medical Association and even with flour of 85% extraction nearly a quarter of the persons appeared to receive insufficient; the higher-extraction flour contained about twice as much as the lower. In February 1943 the food consumed by a moderately active worker provided 24% of his riboflavin in the form of bread and flour if he consumed a pint of beer daily, and 28% if he did not but then his requirements were not met (Sinclair, 1951); bread and flour were the most important single source of riboflavin, the corresponding figures for milk being 20% and 23% respectively. It appears therefore that more attention should be paid to high-extraction flour as a source of riboflavin and that low-extraction flour—if we must have it—might well be fortified with riboflavin as is done in the U.S.A. and Canada.

Apart from the above considerations, the question arises whether flour of 72% extraction enriched with iron, thiamine and nicotinic acid is equivalent nutritionally to higher-extraction flour. This question is easily answered because, although accurate figures for analyses are mostly not available, the lower-extraction flour certainly has less of several nutrients, as indicated in Table 2 in which neither flour

Table 2. *Some nutrients in flours of different extraction*

Nutrient	Approximate content (mg/100 g) 80% extraction flour	72% extraction flour
Pyridoxine	0·29	0·15
Pantothenic acid	0·37	0·34
Biotin	0·0023	0·0008
Folic acid	0·026	0·014
Linoleic acid	800	530
α-tocopherol	1·6	0·85

is assumed to have been treated with 'improvers' such as chlorine dioxide. The significance of these differences depends upon two factors: first, the requirement, if any, for the nutrient by man; secondly, the contribution made by flour to the diet in relation to the supply of the nutrient from other sources. Upon both these topics we are profoundly ignorant because the requisite experimental research has not been done. That there are uncharacterized factors of nutritional importance in flour is indicated by the recent report by Coppock & Ottaway (1958) that there is a substance in bran other than tocopherols that acts as an extremely powerful antioxidant. According to estimates in the Cohen Report, a flour of 80% extraction provides 39% of the pyridoxine, 18% of the pantothenic acid, 14% of the biotin and 28% of the folic acid in the diet as estimated from the food consumption levels of the 1952 National Food Survey (Ministry of Food: National Food Survey Committee, 1954). For a 'patent' flour (40% extraction) the corresponding figures would be 19, 16, 4 and 15% respectively. Since the first and last two nutrients in Table 2 are grossly neglected, interact with one another and are, I believe, very important in human nutrition, I propose to examine them briefly.

Pyridoxine

We have just seen that with flour of 80% extraction about 39% of the pyridoxine in the diet was provided by flour. Rather less was provided by potatoes (which contain about 0·27 mg /100g), and these two foods together accounted for about three-quarters of the pyridoxine. According to an unpublished table shown to this Society by Hollingsworth, Vaughan & Warnock (1956), the *per caput* consumption of pyridoxine in 1952 was of the order of 1·7 mg of which 0·75 mg (44%) came from flour and other cereals, about 0·6 mg (35%) from potatoes, and the small remainder from other vegetables and miscellaneous sources. High-extraction flour is undoubtedly the most important single source. Low-extraction flour contains rather more than half of the pyridoxine in flour of 80% extraction and therefore the adoption of low-extraction flour unfortified with pyridoxine seriously reduces the *per caput* consumption of pyridoxine, from about 1·7 mg to about 1·3 mg daily. The Cohen Report states that 'good estimates of dietary requirements have not been made' for lesser vitamins of the B complex including pyridoxine and 'It has not been shown that the differences between flours of 70 per cent. extraction and 80 per cent. extraction in respect of these vitamins are significant to human nutrition'. The usual estimates that have been made for pyridoxine are of the order of 1·5 mg daily. However, recent careful work upon monkeys by Greenberg in California (reported to a Conference in San Francisco in February 1957) has indicated that if the requirement of man is of the same order as that of the monkey on a body-weight basis, then man requires about 4 mg of pyridoxine daily. It is not surprising, therefore, that some workers such as myself have viewed with some alarm the relatively low *per caput* consumption of this important vitamin even when flour of 80% extraction was in general use.

Vitamin E

As with pyridoxine, flour of 80% extraction contains rather less than twice as much vitamin E as low-extraction flour. However, the most significant factor is the destruction of tocopherols in flour during bleaching or 'improvement' which was first detected by Engel (1942) and has since been studied by various workers. The effect of chlorine dioxide, which is the most important 'improver' at the present time, has been extensively studied by Moran, Pace & MacDermott (1953), by

Frazer, Hickman, Sammons & Sharratt (1956) and by Moore, Sharman & Ward (1957). Treatment with chlorine dioxide causes almost complete destruction of tocopherols, and rats fed on such flour develop signs of deficiency of vitamin E whereas sufficient tocopherols survive the baking of bread from untreated flour to prevent such signs appearing (Moore *et al.* 1957). The possible significance for human nutrition will be mentioned below.

Essential fatty acids (E.F.A.)

Almost no attention has been paid to the presence of these in flour, though I have recently discussed this matter elsewhere (Sinclair, 1957). According to Horder, Dodds & Moran (1954), 1 g wheat contains 10 mg linoleic acid, linolenic acid and arachidonic acid. It might be noted in passing that arachidonic acid has never been found in any plant source by any reputable worker although the error of Horder *et al.* was also to be found in a recent note of Williams & Thomas (1957) who used a plant oil alleged to contain this substance. Wheat-germ oil contains about 57% linoleic acid and 9% linolenic (Gunstone & Hilditch, 1946). No information appears to be available upon the type of the latter which is relevant since only γ-linolenic has full E.F.A. activity. The phosphatides of wheat germ are also extremely rich in highly unsaturated fatty acids. According to our own analyses made by the unsatisfactory technique of alkali isomerization and spectrographic determination, flour of 80% extraction contains about 800 mg and that of 72% extraction about 530 mg linoleic acid/100 g. White flour is indeed a surprisingly rich source of E.F.A. since these highly reactive compounds are adsorbed to both the starch and the protein. Indeed, signs of deficiency of fat were not produced in lower animals until H. M. Evans replaced purified starch in the diet of rats with sucrose (Evans & Burr, 1928). Linoleic acid is much more easily oxidized in the air than are the tocopherols, and the presence of these in flour protects the linoleic acid. As already mentioned, the flour 'improvers', such as nitrogen trichloride and chlorine dioxide, are used because of their strong oxidizing power and destroy most of the tocopherols. We have some evidence, as yet very incomplete, that chlorine dioxide not only oxidizes some of the linoleic acid but adds chlorine to some of the double bonds to give a chlorinated stearic acid. In this way part of the E.F.A. activity in flour is destroyed and a substance is formed that might increase the dietary E.F.A. requirement. It is well known that this requirement is increased by saturated fat such as stearic acid or by the presence of certain isomers of linoleic acid. On chemical grounds, a chlorinated stearic acid would be expected to be a more antagonistic compound than stearic acid and therefore its ingestion from flour treated with so-called 'improvers' might be of considerable importance in human nutrition if significant amounts of chlorinated stearic acid are formed.

Metabolism and function of essential fatty acids

The usual form of E.F.A. in foods is linoleic acid which can apparently itself fulfil some but not all of the roles of E.F.A. in the body. It is converted through

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γ-linolenic acid into arachidonic acid which is usually regarded as the true essential fatty acid. For this conversion pyridoxine is required (Witten & Holman, 1952). In addition, the tocopherols are relevant to E.F.A. since they are distributed in nature in approximately the same proportion as is linoleic acid and therefore act in foods to protect this highly unstable compound. They afford further protection in the gut and, if absorbed, also protect E.F.A. within the body. Indeed, it is conceivable that most of the functions of vitamin E are related to its anti-oxidant property of protecting E.F.A. The type of tocopherol is of some importance: γ-tocopherol is much more active than α- as an anti-oxidant but it is probably not absorbed from the gut whereas α- is readily absorbed; maize oil, which contains about 50% of linoleic acid and in which most of the tocopherols are of the γ form with a small amount of the α, is therefore an extremely good source of E.F.A. provided pyridoxine is also supplied in the diet. It will be apparent, therefore, that E.F.A. deficiency can arise from dietary deficiency of linoleic acid, or of pyridoxine or of vitamin E.

It appears that all the functions of E.F.A. can at present be explained in terms of structure. Cholesterol is esterified with these highly unsaturated fatty acids and they also form part of certain phospholipids such as phosphatidyl ethanolamine. Evidence has been presented elsewhere (Sinclair, 1956) that atheroma may be explained in terms of deposition of unusual cholesterol esters formed with more saturated fat and therefore less soluble and less easily transported or metabolized; a secondary factor is probably in the increased permeability of endothelium. The combination of atheroma together with increased coagulability of blood which might be caused by unusually saturated phosphatidyl ethanolamine being present in increased amounts in serum could account for myocardial infarction, and the increased coagulability of blood could account for the increase in pulmonary embolism and infarction that the Registrar General (1957) has recorded. The cholesterol esters and phospholipids, containing E.F.A., take part in the formation of cell membranes, of the myelin sheath of nerves, and probably of mitochondrial membranes. In addition, connective tissue (such as mesenchymal ground substance, bone and cartilage) are improperly formed in rats and mice deficient in E.F.A. Therefore, as I have pointed out elsewhere (Sinclair, 1956), dietary deficiency of E.F.A. may be relevant to a variety of disorders that are occurring in the more highly civilized countries in which processed foods are consumed and that are increasing in these countries. One such disease, not unimportant, is dental caries.

It appears that myocardial infarction was rare in this country until around 1917 when it began to increase. A more rapid increase occurred around 1926 and there has been progressive acceleration except for the years 1941–2, 1948 and 1953. The two main oxidizing agents that are used as flour 'improvers', agene and chlorine dioxide, were patented in the early 1920's and may have played some part in this increase. A study of the epidemiology of myocardial infarction in various countries indicated that 'improvers' might play a part in the causation of the disease in these countries also. Myocardial infarction appears to be rare in France in which country flour 'improvers' are forbidden by law, but it is very common in certain other countries such as New Zealand where the 'improvers' are also not used. Further research is required to determine what part, if any, is played in the aetiology of human disease by the destruction of tocopherols, and by possible oxidation and chlorination of linoleic acid through the use of flour 'improvers'.

Arguments against high-extraction flour

The arguments have been admirably summarized in the Cohen Report (Great Britain. Parliament, 1956*c*). The representatives of the industry maintain 'that between National Flour of 80 per cent. extraction and white flour of lower extraction, enriched with vitamin B_1, nicotinic acid and iron to the levels obtaining in National flour, any differences in composition are insignificant when related to the diet as a whole'. They further maintain that the flour of 80% extraction has technical disadvantages and that there is a strong demand for pure white flour and bread. The Cohen Panel was 'impressed by the evidence for the demand for white flour and white bread' but a powerful request for production of this evidence (Passmore, 1956) has met with no response.

The well-known experiment by Widdowson & McCance upon undernourished German children cannot be discussed in any detail. According to McCance & Widdowson (1956, p. xi): 'All the breads were equally satisfactory, and the nutritional state of the children improved greatly. . . . A nutritional difference between wholemeal and white flour could be demonstrated only when rats were reared on the diets from the age of three to four weeks. While differences in the nutritional values of these flours certainly exist, it is unlikely that they have any practical importance in Britain today'. This conclusion differs somewhat from that of the report of the Medical Research Council's Committee (Medical Research Council: Conference Appointed to Prepare Evidence for Submission to the Government Panel on Composition and Nutritive Value of Flour, 1956), to which McCance was a signatory, in which it was concluded that 'the consumption of a 70%-extraction flour, even if this is partially fortified, would lead to a reduced intake of some nutrients. Although such a reduction would not necessarily lead to a recognisable illness, it would, in the present state of knowledge, constitute a risk which can be avoided'. The Committee also 'noted . . . that the 70%-extraction flour used in the feeding trial in Germany was rich in some nutrients and indeed, on the analyses available, in some respects more nearly resembled the 80% than the 70% flour used for breadmaking in this country'. In view of this, of the shortness of the experiment, and of the unknown composition of the soups liberally consumed by the children, it seems rash to conclude that there is no nutritional difference between flour of 85% extraction and white flour unenriched that is likely to have 'any practical importance in Britain today'.

Part of the conclusion of Widdowson & McCance (1954, p. 68) arises from their belief 'that a balanced diet, adequate in all its nutritional aspects, can be provided with minimal amounts of milk and meat, if plenty of wheat and vegetables are available'. We have evidence (Wokes, Badenoch & Sinclair, 1955) that pure vegetarian diets, which contain no vitamin B_{12}, may lead to deficiency of this nutrient.

The children in the German experiment obviously did not have 'minimal' milk and meat; Vegans subsist on less of these. This conclusion of Widdowson & McCance cannot therefore readily be accepted.

Cohen Report

Professor Morton (1958) has defended the Cohen Panel of which he was a member. The Panel rightly concluded that 'It is . . . important that the flour should be as nutritious as possible'. To some it may seem obvious that the present enriched white flour would be more nutritious were it not treated with chlorine dioxide and if it did not have much of the pyridoxine removed.

Conclusion

In the long history of the use of wheaten flour as admirably summarized by McCance & Widdowson (1956), there have been innumerable unscientific statements and conclusions based on prejudice. When Lind (1753) wrote his celebrated *A Treatise of the Scurvy*, he wrote in his Preface as follows: 'But as it is no easy matter to root out old prejudices, or to overturn opinions which have acquired an establishment by time, custom and great authorities; it became therefore requisite for this purpose, to exhibit a full and impartial view of what has hitherto been published. . . . Indeed, before this subject could be set in a clear and proper light, it was necessary to remove a great deal of rubbish'. The same is true for bread. But when we have removed the rubbish there is not a great deal of relevant scientific fact left to contemplate.

In a Rede Lecture on the relation of mind and brain delivered 24 years ago in this University, one of its greatest scientists posed for himself this question: 'But indeed, what right have we to conjoin mental experience with physiological?' Sir Charles Sherrington, the centenary of whose birth we celebrate this year, answered his question thus: 'No scientific right; only the right of what Keats, with that superlative Shakespearian gift of his, dubbed "busy common sense". The right which practical life, naïve and shrewd, often exercises. . . . Science, nobly, declines as proof anything but complete proof; but common sense, pressed for time, accepts and acts on acceptance' (Sherrington, 1933). We have scientific proof from analyses that high-extraction flour is of greater nutritional value than our present white flour because it contains more of certain vitamins of the B complex, of tocopherol and of linoleic acid; we believe that it probably contains more of other factors whose nutritional significance is not yet appreciated. This scientific proof and this belief are inadequate for dictation of policy on purely scientific grounds: we have not sufficient knowledge about man's requirements of those nutrients or about the dietary sources of them to decide on objective scientific grounds whether we can afford to ignore the loss we sustain in adopting low-extraction flour. Common sense, pressed for time, must decide in a matter of key importance in practical life; the decision surely should be, first, that we cannot afford to take the risk, and secondly that we must do all we can to ensure that research is done to give us the scientific proof one way or the other. We have not the scientific knowledge, and our agnosticism should make us use common sense while the facts are obtained through research. Passing a little beyond the realm of common sense, the agnostic dietist might fancifully conclude that the change from National flour to partially fortified white flour on 30 September 1956 is a public-health event of such significance that future historians will describe the era before that date as 'B.C.'—'Before Cohen'—and the subsequent decline as 'A.D.'—'After Decontrol'.

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