Enrichment

Dr. D. W. Kent-Jones (88 Madeley Road, Ealing, London, W.5)

Introduction

In this paper only the question of enrichment of flour and bread will be considered, although it is pertinent to remember that enrichment of other foods is now practised, such as the addition of vitamins A and D to margarine, and even the iodizing of salt or the incorporation of cod liver oil in certain rations intended for young stock or for winter feeding may be regarded as forms of enrichment.

Before it is possible to discuss enrichment, sometimes referred to as fortification, of flour and bread by the addition of certain substances which are desirable for the maintenance of health, it is necessary, if a proper appreciation of the subject is to be obtained, to understand how the idea arose. In the past, two main types of flour and consequently of bread were known, namely, white flour, which was rarely of more than 72 per cent. extraction and often of less, and brown flour, usually of about 95 or 100 per cent. extraction. The value and virtues of the two types were argued and discussed for years. At one time bread of the wholemeal type was advocated because it was said to be richer in protein than white bread and to contain good roughage and minerals but, although the justification for these views was open to question, there was no doubt that its main advantage was its higher content of certain vitamins, particularly those of the B group. The disadvantage of wholemeal was its unpalatability to most people, its comparatively low digestibility and, as discovered in later years, its higher content of phytic acid which might have a serious effect on calcium absorption.

While bread made from white flour was more generally liked and better digested, it certainly contained much less iron and much less of the vitamins of the B group than bread made from the longer extraction meals. Those who advocated white flour considered the fact that it was poor in the B vitamins to be of minor importance, since these factors would be contributed by other portions of the diet. Further, the milling of white flour resulted in the production of by-products which were available for animals and which thus, in due course, produced foods comparatively rich in vitamins. There was considerable justification for this point of view which has been supported in the past by many able and experienced investigators, but it has to be admitted that the foods thus produced, though rich in vitamins, are generally of a more expensive nature; it was realized, therefore, that the poorer classes, living on a restricted diet in which bread was the major constituent, tended to receive less of certain essential vitamins than is desirable. With increase of knowledge, and from the results obtained from reliable nutritional surveys, it was definitely shown thar poorer people living on such a diet did not receive sufficient of the B vitamins and, in consequence, tended to exhibit minor but definite signs of malnutrition.

The extent to which flour provides the vitamin B_1 of the diet is not always realized. Clements, Slater and Rial (1941) have shown that the white flour used in Australia provides for the better paid classes nearly 20 per cent. of their total vitamin B_1 intake while, with the poorer classes

whose diet is admittedly low in this factor, the flour and bread contribute 46 per cent.

Reference should be made also to the work of Orr (1936) in this country and to the report of Stiebeling and Phipard (1939) in the United States. These nutritional surveys convinced many of the believers in white flour that an improvement in its vitamin content was desirable but, knowing the practical disadvantages of brown flour, they did not consider that to lengthen the extraction was the right way to achieve this result. At this juncture, the nature and composition of many of the B vitamins were elucidated and it was found possible to manufacture them synthetically at a price which made their addition to flour an economic possibility. To the supporters of white flour, therefore, this seemed to be the obvious solution of the problem. White flour and bread of the type demanded by the public and to which they were accustomed would be available with no lessening of digestibility and attractiveness, but the insufficiency of the B vitamins would be rectified.

It is interesting to note that enrichment of white flour with vitamin B_1 to the extent of 0·2 g. per 280 lb. sack was first suggested to the British millers by Professor E. C. Dodds; the proposal was a British one, and later this scheme was accepted by the Ministry of Food. It is perhaps worth while recording the publicly expressed opinion of Sir Jack Drummond, the senior scientific adviser of the Ministry of Food, and of Dr. Moran, his deputy, on this subject (Drummond and Moran, 1940):

> "The introduction of the new white loaf will undoubtedly stultify the controversy about white versus brown bread, since it is mainly in respect of B_1 that the white loaf has been open to attack. There is not the same evidence that we are deficient in E or the members of the B_2 complex, which are present in wholemeal flour, while, as regards the mineral constituents, the relative merits of the two flours are uncertain because of the higher phytic acid content of wholemeal flour. The practical objections to wholemeal bread, however, are at the moment overriding."

However, in 1942, owing to the seriousness of the shipping position, 85 per cent. extraction flour was made compulsory and many nutritional authorities preferred this type of flour or even flour of longer extraction to enriched white flour, claiming that enrichment may fail to incorporate in the flour all the desirable factors.

The Position Today

Just as the white flour school amended its views in consequence of the results of further scientific discovery, so also the brown flour school, except the extremists, has altered its position. Many of its adherents now advocate, not a 100 per cent. extraction, but milling in a certain way by which the branny and fibrous material is excluded, thus permitting the production of a flour, near white but still containing a high proportion of the natural vitamins. This is possible since it has now been shown by many workers and particularly by Hinton (1944) that it is not the fibrous outer covering of the grain which is the main source of the B vitamins, or even the germ proper or embryo which contains only 6 per cent. of the total vitamin B_1 of the grain. The main source is the scutellum which, although comprising only about $1\frac{1}{2}$ per cent. of the

weight of the grain, contains about 60 per cent. of the total vitamin B_1. This new fact is an important one. Largely owing to the work of British millers and cereal chemists it is now possible to include the scutellum in the flour and hence to produce a near white flour of about 80 per cent. extraction which has the relatively high vitamin B_1 content of about 0·8 I.U. per g. or 1·1 mg. per lb. Milling to such an extraction, besides increasing the vitamin B_1 content, presumably has the advantage of ensuring also that other vitamins of the B group will be present.

The original scheme for enrichment of flour put forward by the British millers contemplated, at any rate at the commencement, only the addition of vitamin B_1; in the U.S.A., however, flour enrichment with many additions is now practised on a large scale while the alternative system of milling a near white flour of about 78 per cent. extraction, called Canada Approved, is advocated in Canada. It is interesting to note that Canadian workers arrived at a conclusion similar to that reached by workers in England who, however, approached the problem from a rather different angle. In England, the milling system generally was adapted to meet the new conditions. In Canada, the 78 per cent. extraction, high vitamin B_1, flour was usually obtained by adding to white flour of 75 per cent. extraction 3 per cent. of a concentrate rich in vitamins rubbed off the by-products.

Certain points favouring enrichment may now be considered:

(1) Synthetic vitamins and natural vitamins are identical and have the same physiological activity.

(2) There are no insuperable difficulties in mixing the various addenda uniformly into white flour.

(3) Fortification of flour leaves milling by-products available for animal feeding and for the production of foods rich in vitamins.

(4) Many nutritional authorities in the U.S.A., who have approved enrichment of white flour, are not opposed to wholemeal. The American public, however, like the British public, refuses to eat wholemeal bread and so, as realists, these authorities favour the enrichment policy as being the only practical system to achieve the objects they have in mind.

(5) The full enrichment practised in the U.S.A., which will be described later and which has achieved such good results, includes the addition to flour of vitamin B_1, riboflavin, nicotinic acid and iron. This only costs 18 cents, about 9d., per person per annum.

(6) The enrichment policy as pursued in the U.S.A., has achieved its objects. Thus, Dr. Jolliffe of the New York University College of Medicine testified at the public hearing held by the War Food Administration on 21st January 1943 (U.S.A. National Research Council, 1944): "I attribute to bread enrichment a marked and unmistakable decrease in the incidence of florid beriberi and florid pellagra in my wards at Bellevue Hospital. In 1938–39 little bread was enriched; in 1942–43 seventy-five per cent. or more has been enriched in New York City. This has been accompanied by a decrease of three-fourths in our cases of florid beriberi and of two-thirds in florid pellagra." Furthermore, the results of carefully controlled experiments at various places such as the Mayo Clinic have shown that enrichment is beneficial (U.S.A. National Research Council 1944).

It must be remembered that conditions in the U.S.A. and in this country are different and, curiously enough, there has not yet been any

reliable evidence to show that there is any shortage of riboflavin and nicotinic acid in the diet of the poorer classes in this country. Different food habits in the two countries may partly account for this; Drummond and Moran (1944) have pointed out that we may obtain not inconsiderable amounts of riboflavin and other factors from our beer and tea. For this reason, the criticism made by Chick (1940) and answered in part by M. D. Wright (1941), that the original flour enriched with vitamin B_1 lacks riboflavin, is not of serious importance at present. The losses in riboflavin in modern milling are not nearly as severe as the losses in vitamin B_1 and nicotinic acid. If deficiencies other than that of vitamin B_1 were found in the diet later on, it would seem that they could be adequately dealt with as in the U.S.A.

Enrichment in the United States

In order to appreciate the modern enrichment policy, it is necessary to know how this is carried out in the U.S.A., and the grounds for fixing the standards. A pamphlet entitled *Enrichment of Flour and Bread* (U.S.A. National Research Council 1944) summarizes the position. The Committee on Cereals of the Food and Nutrition Board worked on the recommended daily allowances of the National Research Council (U.S.A. National Research Council, 1941). Having established the need for larger amounts of certain vitamins and minerals in the American diet, the Board set out its views in the following 7 points which it adopted on 1st October 1941:

"(1) That the Committee endorses the addition of specific nutrients to staple foods (as indicated under 6 below) which are effective vehicles for correcting the above deficiencies in the diets of the general population or of significant age, geographic, economic or racial segments thereof.

(2) That the Committee opposes the inclusion of additions of specific nutrients under definitions and standards which may be promulgated under the Food, Drug and Cosmetic Act, except in the case of foods which constitute such effective vehicles of distribution.

(3) That the Committee favours unequivocally the fulfilment of the nutritional needs of the people by the use of natural foods as far as practicable and to that end encourages education in the proper choice of foods and the betterment of processes of food manufacture and preparation so as to retain more successfully the essential nutrients native thereto.

(4) That to avoid undue artificiality of food supply the Committee favours whenever practicable, the choice as vehicles for the corrective distribution of vitamins and minerals those foods which have suffered losses in refining processes and recommends that the vitamins and minerals added to such foods should preferably be the kinds and quantities native thereto in the unrefined state.

(5) That the addition of other than natural levels of vitamins and minerals to foods which are suitable as vehicles of distribution may be sanctioned when available as measures to correct known nutritional deficiencies.

(6) That at present the Committee favours appropriate enrichment of flour and bread (and perhaps corn meal), the fortification of milk with vitamin D, the suitable addition of vitamin A to table fats and of iodine

to salt for dietary use. There is no information available to the Committee at the present time which indicates that it will be desirable to recommend the addition of vitamins and minerals to foods other than those named.

(7) That specifically the Committee opposes the addition of synthetic vitamins to carbonated beverages and confectionery."

In consequence of these decisions certain Federal standards for enriched flour and bread were enforced, the bread standard being established by order of the War Food Administration. The standards reproduced from the American publication (U.S.A. National Research Council, 1944) are given in Table 1.

TABLE 1

ENRICHMENT STANDARDS FOR BREAD AND FLOUR

Substance to be added	Amount to be added, mg. per lb. unless otherwise stated			
	Flour standard		Bread standard	
	Min.	Max.	Min.	Max.
Required				
Thiamine, vitamin B_1 ..	2·0	2·5	1·1	1·8
Riboflavin	1·2	1·5	0·7	1·6
Niacin, nicotinic acid ..	16·0	20·0	10·0	15·0
Iron	13·0	16·5	8·0	12·5
Optional				
Calcium	500	1500	300	800
Vitamin D (U.S.P. units)	250	1000	150	750

With these figures as basis, it is possible to calculate the effect, on the intake of vitamin B_1, riboflavin and nicotinic acid, of including enriched flour and bread in the American diet (see Table 2).

TABLE 2

EFFECT OF ENRICHING FLOUR AND BREAD ACCORDING TO THE STANDARDS IN TABLE 1 ON THE INTAKE OF VITAMIN B_1, RIBOFLAVIN AND NICOTINIC ACID IN THE U.S.A.

Basis for calculating intake	Intake per 2500 Calories		
	Vitamin B_1 mg.	Riboflavin mg.	Nicotinic acid mg.
National Research Council's recommendation	1·5	2·2	15
Average American diet before application of enrichment scheme*	0·8	1·4	11
Average American diet with all flour and bread assumed to be enriched	1·6	1·6† 1·8‡	17

* White bread in diet assumed to contain on an average 3 parts milk solids per 100 parts flour.

† Use of milk in bread assumed to have been discontinued.

‡ Use of milk in bread assumed to be as at present.

Which is the Best Nutritional Policy for Bread?

It is not possible to deal with every aspect of this problem but it is pertinent to bear in mind certain facts.

(1) It is impossible to arrive at the correct answer to the question of the correct nutritional policy for bread without, at least, bearing in mind the matter of public taste. Wholemeal bread is unpopular and it is not practicable to try to increase the vitamin content of the diet in this way, since the intake of bread might fall; even if compulsion was used, there would probably be serious repercussions from the public. This has been clearly shown many times as, for instance, in Switzerland where, even when brown bread was subsidized so that it was sold at an appreciably lower price than white bread, it was still not consumed. This is the main and the practical justification for removing certain nutrient factors in milling and replacing them later on. It is not facing the question to ignore this position; even the dietician, when dining, usually eats what he likes and not necessarily what his research work shows is the best for him. On the other hand, will the public accept the present day 80 per cent. flour which is much higher in vitamin B_1 than the old, unfortified, white flour but is much nearer to it in colour and palatability than wholemeal or even than the original flour of 85 per cent. extraction? The colour, palatability and digestibility are certainly much nearer those of white flour than of wholemeal, but some authorities consider that such flour falls between two stools. It is not quite white enough, and efforts to produce a rather whiter flour result in a considerable loss of vitamin B_1. On the other hand, the amount of vitamin B_1, though higher than in ordinary white flour, is appreciably less than in wholemeal or enriched white flour.

(2) In the U.S.A. the voluntary demand for enriched white flour reached 65 per cent. of the total flour consumption because it was of the type the public liked. In this way, even before compulsion, a definite increase in the vitamin intake of the average diet was effected. In Canada, where the near white flour called Canada Approved was strongly advocated, the consumption of this flour only reached 7 per cent. of that of the total flour, because it was still not as pleasing to the public as true white flour.

(3) The principles of food fortification were discussed by Bacharach (1942), and the technological aspect of fortification was discussed by Amos and Kent-Jones (1942). The advantages and disadvantages of the alternative schemes of fortified white flour and longer extraction flour were discussed by N. C. Wright (1941) and Bacharach (1941), and especially by Robertson (1943), who, after reviewing the whole position with respect to wholemeal bread, enriched white bread and bread made from 85 per cent. extraction flour, concluded that the best all round loaf from the nutritional aspect was that made from white flour fortified with vitamin B_1, riboflavin, nicotinic acid and calcium. The work of McCance and Widdowson (1942) on the effect of phytic acid on calcium absorption also has to be remembered, with reference particularly to the increase in rickets, reported in young children in Dublin, after the introduction of 100 per cent. flour, by Pringle, Reynolds and Jessop (1943), and by Croasdaile, Collis, Pringle and Jessop (1943).

When all the facts are borne in mind, surely the crux of the position is to find out what is the best way of ensuring that the diet of the poorer classes is pleasing to them and still satisfactory in containing enough of certain vitamins which, at present, it may tend to lack. While it must never be forgotten that the main function of bread in diet is the providing of a cheap source of calories and proteins, yet, if the national policy is to increase the intake of vitamins through flour and bread, it is necessary to know the amounts of vitamins and other nutrients provided by the various types of flour.

An attempt has been made in Table 3 to compare the amounts of the principal nutrients, expressed in mg. per lb., contributed by the different types of flour. The figures are as correct as can be obtained at present; in some cases, it has only been possible to obtain reliable figures from the results of recent microbiological tests. It has to be admitted that, if it is desirable or necessary to incorporate good supplies of certain nutrients in the diet by means of the flour, then enriched flour, as made in the U.S.A., has great advantages over other types. Thus, at its maximum, the U.S.A. enriched flour provides nearly twice as much vitamin B_1 as 85 per cent. National flour, nearly 4 times as much riboflavin, 3 times as much nicotinic acid and about twice as much iron.

TABLE 3

AMOUNTS OF VARIOUS NUTRIENTS CONTRIBUTED BY DIFFERENT TYPES OF FLOUR

Type of flour	Nutrients, mg. per lb.				
	Vitamin B_1	Ribo-flavin	Nicotinic acid	Available* iron	Available* calcium
White flour, 75 per cent., no addition	0·70	0·35	3·5	5	100
White flour, 75 per cent., 0·2 g. vitamin B_1 added per 280 lb. sack	1·40	0·35	3·5	5	100
National flour, 85 per cent., 7 oz. *creta praeparata* added per 280 lb. sack	1·40	0·50	7·0	10	260
National flour, 80 per cent., 7 oz. *creta praeparata* added per 280 lb. sack	1·15	0·40	5·5	8	260
Canada Approved flour, 78 per cent.	1·10 to 1·15	0·40 to 0·45	5·0 to 5·5	8	90
U.S.A. flour min. ..	2·0	1·2	16	13	500
max. ..	2·5	1·5	20	16·5	1500

* After allowance has been made for the amount of the mineral made unavailable by the presence of phytic acid.

Conclusions

It is a difficult task to attempt to deal with this complex subject in a short paper or to pronounce an impartial judgment. It is hoped, however, that the facts given will explain the present position with respect to enrichment. It is recognized that the intake of vitamin B_1 should be

related to the amount of calories consumed. Thus, most authorities advocate that there should be not more than about 6 Calories not derived from fat per I.U. of vitamin B_1. If the ratio becomes 8 to 1 or more, ill health may result. The National Research Council's figure of 1·5 mg. vitamin B_1 per 2500 Calories works out at 5 Calories per I.U. This is the real basis of the objection to white flour, that the public thereby receives a large number of calories without sufficient intake of vitamin B_1. Thus, half a pound, which is about the average daily consumption, of pre-war white flour of 72 per cent. extraction, provided about 850 Calories, but contained only 75 I.U. vitamin B_1, the ratio being 11 to 1.

In looking at the question of the diet as a whole, it is important, however, to remember that sugar provides a not inconsiderable amount of calories and that this substance is a much worse offender than white flour because it is devoid of vitamin B_1. Clements, Slater and Rial (1941) stated that 25 per cent. of the total calories in the average Australian diet were derived from cakes, biscuits, sugar and sweets, which contributed scarcely any vitamin B_1. Hay (1943) has pointed out that in pre-war days the average daily consumption of sugar was nearly $4\frac{3}{4}$ oz. This would provide over 500 Calories without contributing any vitamin B_1. Ordinary white sugar as commonly used is, therefore, a more serious menace in the diet than white flour, a matter usually quite forgotten. Indeed, there is a more urgent need to fortify white sugar than white flour. In this connexion, Hay has pointed out that, in war conditions, the consumption of sugar from all sources has decreased enormously, by more than half, to under 2 oz. per head daily. Nowadays, only about 200 Calories daily are supplied by sugar without any compensating supply of vitamin B_1 instead of 500 Calories. This may have had an effect on the national health quite comparable with that due to the increased amount of vitamin B_1 in the flour.

The only scientific argument which it is perhaps possible to use against the enrichment policy is that, even in the U.S.A., the addition of synthetic vitamins may still result in the exclusion of some essential factors present in longer extraction flour. This may, of course, be so, although it seems unlikely with the comprehensive system of enrichment practised in U.S.A., which could presumably be practised in this country also if thought desirable. It is, of course, almost impossible to combat such an argument. Evidence on the point may, however, be forthcoming. In pre-war days malnutrition was rife in Newfoundland where people were living under severe conditions, and this was doubtlessly due in part to lack from the diet of the B group of vitamins. In pre-war days also, longer extraction flour was made compulsory and improvement in health soon took place. Newfoundland has now changed to enriched U.S.A. flour. If the improvement in health continues, as is confidently expected that it will, then perhaps it can be safely and fairly agreed that in present day enriched flour no unknown essential factor is missing.

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Discussion

Dr. E. Kodicek (Dunn Nutritional Laboratory, Cambridge), joint opener: Before a few specific points are discussed, results will be presented, obtained in this laboratory on flours of varying extractions, most of which were kindly supplied by the Cereals Research Station of the Ministry of Food (Table 1). The values obtained for vitamin B_1

TABLE 1

VALUES FOR VITAMIN CONTENT OF CEREAL PRODUCTS AND OF FLOURS OF VARYING EXTRACTIONS OBTAINED AT THE DUNN NUTRITIONAL LABORATORY

Product	Vitamin B_1, fluorimetric method of Harris and Wang (1941) μg. per g.	Riboflavin			Nicotinic acid, chemical method μg. per g.
		Fluorimetric method μg. per g.	Microbiological method μg. per g.	Results of other authors* μg. per g.	
Flour 100 per cent. extraction	4·2 (3·0 to 5·1)	1·1 to 1·3	1·1	1·0 to 1·3	48·5 (35·5 to 60·0)
85 ,,	3·5	0·7	0·6	—	17·8
80 ,,	2·7	0·5	0·5	—	9·9
70 ,,	1·0	0·36	0·32	0·35 to 0·40	9·1
Wheat germ ..	19·0	7·6	—	—	51·9
Bran	11·0	3·6	—	—	235·0

* Andrews (1943); Andrews, Boyd and Terry (1942); Conner and Straub (1941); Munsell (1942); Swaminathan (1942).

and nicotinic acid agree well with those of the previous speakers. With decreasing extraction, the values for vitamin B_1 decrease from 4·2 μg. to 1·0 μg. per g. and for nicotinic acid from 50 μg. to 9 μg. per g. The high nicotinic acid content of bran, 235 μg. per g., though well known, is worth mentioning. The value of 11 μg. vitamin B_1 per g. in bran was found by Harris and Wang (1941) on various samples, but a recent sample contained only 4·2 μg. per g. which is comparable with the value reported by Moran (1945) for cleaned bran.

The riboflavin values obtained fluorimetrically and microbiologically decrease from 1·1 μg. to 0·7, 0·5 and 0·36 μg. per g. with decreasing extraction. These values are in good agreement with those of other