REFERENCES

Association of Official Agricultural Chemists (1950). *Official and Tentative Methods of Analysis*, 7th ed. Washington, D.C.: Association of Official Agricultural Chemists.
Evans, K. L. & Arnold, L. E. (1938). *Trans. R. Soc. trop. Med. Hyg.* **32**, 355.
Farris, E. J. & Griffith, J. Q. (1949). *The Rat in Laboratory Investigation*, 2nd ed. Philadelphia: J. B. Lippincott Co.
Hassall, C. H., Reyle, K. & Feng, P. (1954). *Nature, Lond.*, **173**, 356.
Hill, K. R. (1952). *W. Indian med. J.* **1**, 243.
Jelliffe, D. B. & Stuart, K. L. (1954). *Brit. med. J.* i, 75.
Jordan, E. O. & Burrows, W. (1937). *Amer. J. Hyg.* **25**, 520.
Nelson, N. (1944). *J. biol. Chem.* **153**, 375.
Nicholls, L. (1945). *Tropical Nutrition and Dietetics*, 2nd ed. London: Baillière, Tindall and Cox.
Patrick, S. J. (1954). *J. appl. Physiol.* **7**, 140.
Platt, B. S. (1945). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 263.
Rhodes, K. (1952). *Brit. J. Nutr.* **6**, 198.

The Intakes of Essential Amino-acids of Children Who Were Deriving Most of Their Protein from Bread and Vegetables*

BY B. P. HUGHES

Medical Research Council Department of Experimental Medicine, University of Cambridge

(*Received* 12 *May* 1955)

The recently published studies of Widdowson & McCance (1954) on the nutritive value of different kinds of bread demonstrated that undernourished children grew rapidly in height and weight and improved in physical condition on diets in which about 60–80 % of the total protein was provided by wheat. Of the remainder of the protein in the diet about 12–21 % came from animal sources and 5–15 % from vegetables, chiefly potatoes. The bread was baked from flours of three different extraction rates—100, 85 and 70 %—and each flour was found to be equally effective in promoting growth and health.

The children taking part in these investigations, whose ages ranged from 4 to 15 years, lived in two orphanages. At one (Duisburg), wheat provided 75 % of the total calories and the average protein intake was approximately 61–73 g a day, of which about 8 g were derived from animal sources. At the other (Vohwinkel), wheat contributed 35 % of the calories and another 35 % were derived from sugar and fat. The total protein intake at this orphanage averaged 51–55 g a day, of which about 11 g were of animal origin. The Vohwinkel diets were thus appreciably lower in protein, but on account of the additional sugar and fat they were actually some 10 % higher in calories.

The approximate intake of amino-acids provided by these diets has now been calculated and compared with the intake provided by a diet which did not differ greatly

* The term 'essential amino-acids' refers to the ten common amino-acids shown to be essential for the normal growth of weanling rats (Rose, Oesterling & Womack, 1948).

in calories or total protein, but in which a much higher proportion of the protein was of animal origin. The diet selected for comparison was based on the results of investigations by Widdowson (1947) into the amounts of food eaten by British children of the same ages before the recent war. These children consumed 65 g of total protein a day of which 42 g were animal protein.

METHODS

Sources of information about amino-acids. The values for the amino-acids in foods have been based on analyses, carried out mainly by microbiological techniques, which have been published within the last 10 years. An exhaustive search was made, and, wherever possible, the results found by different workers have been compared and the average of the most representative figures chosen.

It is necessary, first of all, to consider how far this information is complete and how far it is applicable to the foods as they were actually eaten by the German children. The data for the common foods of animal origin, although not complete, are reasonably satisfactory in so far as the essential amino-acids are concerned and, moreover, the published figures reveal no significant loss of amino-acids on cooking. Losses of the biological availability of these acids due to cooking, which may not be shown by the technical methods employed, are unlikely to be important with meat (Kuiken & Lyman, 1948), and for milk severe loss has only been demonstrated after storage of powdered milk for long periods or under conditions of excessive moisture (Henry, Kon, Lea & White, 1948). There is apparently no similar information for fish, but appreciable impairment of the nutritive value of fish on cooking seems improbable. Normal cooking methods are thus unlikely to have much adverse effect on the quality of animal protein.

The literature contains consistent data for the amounts of the essential amino-acids in the whole grain of wheat, but information about milling fractions and flours is either conflicting or not applicable in the present instance. However, it is generally agreed that it is the concentration of lysine that is likely to limit the nutritive value of wheat protein (Block & Mitchell, 1946), and lysine is the amino-acid that is probably the most affected by milling, since it varies considerably in amount from one part of the grain to another. There is less in the endosperm than in either the germ or the bran (Barton-Wright & Moran, 1946). Moreover, lysine is also the amino-acid most likely to be affected by heat processing (Liener, 1950). The loss on baking bread, revealed by analysis of the acid hydrolysates, can amount to 16% (Rosenberg & Rohdenburg, 1951), and loss of biological availability may be considerably greater (Liener, 1950).

Information concerning the composition of the other plant foodstuffs in the diets is rather meagre. Fortunately, their contribution to the total protein intake is small, and consequently uncertainties in the analytical data are of minor importance.

In view of these limitations only the daily intake of the essential amino-acids has been calculated; deficiencies in these are most likely to limit the nutritive value of the diets, and they are the amino-acids for which the available analyses appear to be most reliable.

Method of calculation. Two of the Duisburg and two of the Vohwinkel diets described by Widdowson & McCance (1954) are considered. The members of each pair differ in that the extraction rate of the flour used was in one instance 100 % and in the other 70 %. The data used in the calculations are shown in Tables 1 and 2. The average daily consumption of the various foodstuffs by the German children and by the British children (Table 1) is taken from Widdowson & McCance (1954, p. 16, Table 8). The total nitrogen in these foodstuffs is calculated from the tables of McCance & Widdowson (1946), except that the total nitrogen of the flours was derived from data published in the account of the experiments being considered (Widdowson & McCance, 1954, p. 14, Table 7). Table 2 gives the composition of the various foodstuffs in g amino-acid/16 g total nitrogen. If this table is compared with similar tables given by Block & Bolling

Table 1. *Mean daily consumption (g) by children of the various sources of dietary protein*

Foodstuff	Diet: Duisburg	Diet: Vohwinkel	Diet: Prewar British
Meat (cooked weight)	6	7	86
Fish (cooked weight)	11	22	24
Cheese	7	5	8
Milk (mostly skim)	82	113	450 (whole milk)
Potatoes	168	257	113
Green vegetables	63	98	28
Dried pulses	2	6	4
Semolina	34	36	127 (total wheat products)
Flour:			
100 % extraction	447	250	
or	or	or	
70 % extraction	418	240	

The small quantities of fruit and root vegetables consumed are omitted, because their amino-acid composition is largely unknown. Since, however, the amount of protein is very small, the effect of this omission will be negligible.

Table 2. *Amino-acid composition of various foodstuffs**

(g amino-acid/16 g total nitrogen)

Amino-acid	Meat	Fish	Milk	Whole wheat	Patent flour†	Potatoes	Green vegetables‡	Pulses§
Arginine	6·4	5·9	3·9	4·2	3·1	4·9	7·3	7·0
Histidine	3·0	2·0	2·8	2·0	1·54	1·5	2·1	2·5
Isoleucine	5·0	6·4	5·9	3·8	3·7	4·0	3·1	5·5
Leucine	8·4	8·0	9·6	6·4	7·5	4·7	3·7	5·4
Lysine	8·5	8·2	7·2	2·7	2·2	5·2	3·9	5·8
Phenylalanine	4·0	4·5	4·8	4·5	5·6	4·2	1·9	4·1
Methionine	2·3	3·3	2·3	1·6	0·96	1·5	1·3	0·7
Threonine	4·1	4·5	4·5	2·7	2·5	3·3	2·8	2·9
Tryptophan	1·1	1·0	1·5	1·2	0·98	1·5	0·9	0·3
Valine	5·5	5·1	7·3	4·3	4·2	4·5	4·0	5·3

* See p. 374.
† Stokes, Gunness, Dwyer & Caswell (1945).
‡ Values for cabbage (Lyman & Kuiken, 1949).
§ Recalculated from Vijayaraghavan & Srinivasan (1953).

(1951), it will be seen that agreement between the two sets of values for whole wheat is good except that the present value for methionine is lower. For foods of animal origin the present values are lower for several of the amino-acids.

Block & Bolling give figures for flour but do not specify whether it is white or brown. Stokes, Gunness, Dwyer & Caswell (1945) give figures for a highly refined or 'patent' flour, which is likely to have been of a considerably lower extraction than 70%. In an attempt to estimate the worst effects that milling may have on the nutritive value of the bread, particularly on its lysine content, these figures have been used to calculate the composition of the diets based on flour of 70% extraction, except that the figure for methionine in whole grain has been taken. This was done because the results of Stokes *et al.* (1945), for the concentration of methionine in foods, appear to be rather low, and from the data of Barton-Wright & Moran (1946) it seems likely that the methionine concentration in the flour would be only slightly different from that in the whole grain. The semolina, which was of low extraction, has been assumed to have had the same composition as the white (70%) flour.

The somewhat arbitrary selection of data which has been necessary in making these calculations serves to emphasize the need for more accurate information on the amino-acid composition of the milling fractions of wheat.

RESULTS

Table 3 gives the approximate daily amino-acid intakes of the children. The minimum adult requirements for nitrogen equilibrium as determined by Rose (1949) are also included.

Table 3. *Amounts of amino-acids (g/day) consumed by children*

Amino-acid	Diet: Duisburg 100%*	Duisburg 70%*	Vohwinkel 100%*	Vohwinkel 70%*	Prewar British	Minimum adult requirement†
Arginine	3·2	2·3	2·5	2·0	3·3	Not essential for nitrogen equilibrium
Histidine	1·5	1·1	1·1	0·9	1·7	
Isoleucine	3·1	2·7	2·3	2·1	3·2	0·7
Leucine	5·0	5·0	3·7	3·8	5·1	1·1
Lysine	2·5	2·0	2·2	2·0	4·2	0·8
Phenylalanine	3·4	3·5	2·5	2·6	2·8	1·1
Methionine	1·3	1·1	1·0	0·9	1·4	1·1
Threonine	2·2	1·8	1·7	1·5	2·5	0·5
Tryptophan	0·9	0·7	0·7	0·6	0·8	0·25
Valine	3·4	3·0	2·6	2·4	3·7	0·8

* Rate of extraction of flour.
† Rose (1949).

A comparison of the German children's amino-acid intakes with those of the prewar British children shows that the Duisburg diet containing flour of 100% extraction provided quantities of the essential amino-acids similar to those of the British diet, except for lysine. The Vohwinkel diet containing white flour supplied the smallest quantities of amino-acids, and the other two provided intermediate amounts. Even the worst German diet, however, supplied the essential amino-acids, with the exception of methionine, in double the minimum amounts required for nitrogen equilibrium in the adult. Loss of available lysine in cooking could have occurred to the extent of 25 % of the raw value without bringing the intake below this minimum value. The only amino-acid that may possibly have been scarce, judged by this criterion, is methionine.

DISCUSSION

There is no reason to suppose that either of the Duisburg diets was deficient in any of the essential amino-acids, and in terms of protein nutrition the apparently normal development which they both promoted is not surprising. Although there was some evidence (Widdowson & McCance, 1954, p. 67) that general development on the Vohwinkel diets may have been rather less satisfactory, the effect was marginal over the experimental period, and no definite conclusion can be drawn as to whether it was due to any specific amino-acid deficiency.

The minimum amino-acid requirements of children for normal growth are not known, and any conclusions about the adequacy of a diet derived from a comparison with adult needs must be treated with reserve. However, since the German children grew rapidly and improved in health, their amino-acid requirements must presumably have been satisfied by the protein foods which they were eating, and these were chiefly plant foods. Adequate nutrition of children thus appears to be possible without the need to consume large quantities of animal protein.

The information about the amounts of the essential amino-acids provided by these diets may help to establish the requirements for satisfactory growth.

SUMMARY

1. A survey of the recent literature on the amino-acid composition of foods has been made. The adequacy of this information for calculating the composition of diets is considered, and it is concluded that the data are adequate only for the essential amino-acids.

2. A table has been constructed showing the amounts of essential amino-acids in various foods.

3. The essential amino-acid intake of children in two German orphanages who thrived on diets consisting largely of bread and vegetables has been calculated and compared with the intake of children on a diet much richer in animal protein. The diets low in animal protein provided somewhat less of most of these amino-acids, but with the exception of methionine provided double the amounts required for nitrogen equilibrium in the adult.

The author is indebted to Dr E. M. Widdowson for helpful advice and criticism.

REFERENCES

Barton-Wright, E. C. & Moran, T. (1946). *Analyst*, **71**, 278.
Block, R. J. & Bolling, D. (1951). *The Amino Acid Composition of Proteins and Foods*. Springfield, Ill.: C. C. Thomas.
Block, R. J. & Mitchell, H. H. (1946). *Nutr. Abstr. Rev.* **16**, 249.
Henry, K. M., Kon, S. K., Lea, C. H. & White, J. C. D. (1948). *J. Dairy. Res.* **15**, 292.

Kuiken, K. A. & Lyman, C. M. (1948). *J. Nutr.* **36**, 359.
Liener, I. E. (1950). *Trans. Amer. Ass. Cereal Chem.* **8**. 162.
Lyman, C. M. & Kuiken, K. A. (1949). *Bull. Tex. agric. Exp. Sta.* no. 708.
McCance, R. A. & Widdowson, E. M. (1946). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 235.
Rose, W. C. (1949). *Fed. Proc.* **8**, 546.
Rose, W. C., Oesterling, M. J. & Womack, M. (1948). *J. biol. Chem.* **176**, 753.
Rosenberg, H. R. & Rohdenburg, E. L. (1951). *J. Nutr.* **45**, 593.
Stokes, J. L., Gunness, M., Dwyer, I. M. & Caswell, M. C. (1945). *J. biol. Chem.* **160**, 35.
Vijayaraghavan, P. K. & Srinivasan, P. R. (1953). *J. Nutr.* **51**, 261.
Widdowson, E. M. (1947). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 257.
Widdowson, E. M. & McCance, R. A. (1954). *Spec. Rep. Ser. med. Res. Coun., Lond.*, no. 287.

Antibiotic and Copper Supplements for Fattening Pigs

By R. S. BARBER, R. BRAUDE and K. G. MITCHELL
National Institute for Research in Dairying, University of Reading

(*Received* 16 *May* 1955)

Barber, Braude, Mitchell & Cassidy (1955) reported observations suggesting an improvement in the rate of growth of fattening pigs given a high-copper mineral supplement in the diet. These observations were later confirmed in a field trial involving eight centres and 182 pigs (Bowler, Braude, Campbell, Craddock-Turnbull, Fieldsend, Griffiths, Lucas, Mitchell, Nickalls & Taylor, 1955). The responses obtained with the high-copper diets resembled in many ways those repeatedly obtained at Shinfield under similar environmental conditions by the feeding of antibiotics (Barber, Braude, Kon & Mitchell, 1953; Barber, Braude & Mitchell, 1953, 1954). In view of this similarity and the possibility that the copper might have some bactericidal action in the pig's intestine, it was considered of interest to compare the effects of the copper and antibiotic supplements and to determine whether there was any synergic action between the two.

EXPERIMENTAL

The composition of the basal diet is given in Table 1. The mineral supplement XF (a proprietary mixture supplied by Minsal Ltd, Northwich), consisted mainly of calcium oxide, sodium chloride with 4% of copper sulphate, a small amount of ferrous sulphate and traces of manganese sulphate, cobalt sulphate and potassium iodide.

Table 1. *Percentage composition of the basal diet*

Barley meal	30
Fine wheat offal	50
Flaked maize	10
White fish meal	10
Rovimix (Roche Products Ltd) (containing 50,000 i.u. vitamin A and 5000 i.u. vitamin D_3/g)	4·5 g/100 lb.