Conversion Factors for Vegetable and Animal Foods for Human Consumption

By K. L. BLAXTER (IN RECEIPT OF A SENIOR AWARD OF THE AGRICULTURAL RESEARCH COUNCIL)
Hannah Dairy Research Institute, Kirkhill, Ayr

To translate animal and vegetable foods, meat, milk, eggs, cereals and vegetables, into terms of human consumption and then to discuss their adequacy in meeting the nutritional demands of man, necessarily involves decisions on common denominators. During translocation of crop or animal from the farm to the consumer many inevitable losses occur and, even in the hands of the consumer, further considerable, culinary, waste takes place. The first problem is, therefore, to decide on the unit to be used to assess this wastage. It could be a monetary one—the amount of food purchased for a given amount of money—or a unit of human endeavour—the amount of food produced per unit of man-power. Production per acre of agricultural land, however, is probably the most generally acceptable unit to use, and this I have chosen. The second problem is concerned with evaluation in terms of human needs. So far we have been concerned solely with protein supplied from vegetable and animal products, in some instances partly purified. We must also think in terms of dietary energy, essential vitamins, minerals and possibly as yet unidentified nutrients.

I have, therefore, considered requirements not only for protein but also for dietary energy, calcium, vitamin C, vitamin B_1 and vitamin A. As, however, most of the discussion on the differences between, or complementary virtues of, vegetable and animal foods revolves around their respective proteins, protein supplies from these two sources must be evaluated in terms of their ability to meet protein requirements. Biological values of single proteins have little practical value in this respect, since the biological value of the proteins of a mixture of two foods is not the arithmetic mean of the biological values of the proteins of the two foods determined separately (Mitchell, 1924). Even supplementation of the medium-quality proteins of wheat with the poor-quality proteins of gelatin results in a biological value of the mixture greater than that of the wheat proteins alone (Chick & Slack, 1945).

A solution to this difficulty is to express human requirements in terms of essential amino-acids. Requirements for amino-acids should be additive. Table 1 shows three estimates of the daily amino-acid requirement of man (Rose, 1949; Block & Bolling, 1945; Macy, 1943). It will be noted that the values given by Rose are considerably less than those given by the other authors. Rose's values, however, are double the requirement for the particular amino-acid necessary to maintain nitrogen equilibrium in young men, and as such are the only experimental values so far available. That they are approximately correct may be seen in Table 2, where the minimum requirements for particular proteins for the maintenance of nitrogen equilibrium have been expressed in terms of amino-acids. The amino-acid present in limiting concentration—lysine for wheat flour and methionine for milk proteins—is present in amounts almost

Table 1. *Recommended daily requirement of amino-acids for an adult human subject*

Amino-acid	Experimentally determined by Rose (1949)* (g.)	Calculated from analysis of diets	
		Block & Bolling (1945) (g.)	Macy (1943) (g.)
Tryptophan	0·5	1·1	0·9
Phenylalanine	2·2	4·4	4·2
Lysine	1·6	5·2	4·6
Threonine	1·0	3·5	3·2
Valine	1·6	3·8	3·2
Methionine	2·2	†	†
Leucine	2·2	9·1	9·6
Isoleucine	1·4	3·3	3·1
Histidine	Not required	2·0	1·6
Cystine and methionine	—	3·8	3·7

* Requirement taken as double the mean requirement necessary to maintain nitrogen equilibrium in a young adult male.

† See cystine and methionine.

Table 2. *Daily protein requirement for maintenance of nitrogen equilibrium in an adult human subject with basal metabolic rate of 1700 Cal./24 hr., expressed in terms of essential amino-acids*

Amino-acid	Proteins		Mean requirement of amino-acid for nitrogen equilibrium (Rose, 1949) (g.)
	Whole milk, 29·3 g.* (g.)	Wheat flour, 50·6 g.* (g.)	
Tryptophan	0·47	0·40	0·25
Phenylalanine	1·67	2·75	1·1
Lysine	2·19	0·90†	0·8
Threonine	1·35	1·35	0·5
Valine	1·93	2·50	0·8
Methionine	1·08†	1·50	1·1
Leucine	3·31	4·50	1·1
Isoleucine	1·81	2·25	0·7

* Bricker, Mitchell & Kinsman (1945).

† Limiting amino-acid in the nutrition of man when this source of protein used.

identical with those experimentally determined by Rose. These requirements do not allow for adult growth, loss of skin debris, growth of epidermal structures and minor changes of body form (Bricker, Mitchell & Kinsman, 1945; Hrdlička, 1936). Results of balance experiments have shown that this adult growth and loss of epidermal tissues is approximately 0·98 mg. nitrogen/basal Cal. of heat produced. This effectively doubles the protein requirement for mere nitrogen equilibrium. The recommended allowances of Rose, which are arbitrarily double the minimum, appear, therefore, to be quite suitable as standards of requirement, and better than those based on analysis of diets.

In Table 3 are listed the requirements of adult man for a whole year, based on Rose's estimates of amino-acid requirement, and the (U.S.A.) National Research Council's (1943) recommended allowances. Only tryptophan, lysine and methionine have been included in the estimates of requirement, as it seems unlikely that other amino-acids would ever be short.

Table 3. *Daily and yearly requirements of an adult human subject for certain nutrients*

Nutrient	Requirement	
	Daily	Yearly
Calories	3000 Cal.*	1·1 million Cal.
Tryptophan	0·5 g.†	182 g.
Lysine	1·6 g.†	584 g.
Methionine	2·2 g.†	803 g.
Calcium	800 mg.*	292 g.
Aneurin	2·0 mg.‡	730 mg.‡
Ascorbic acid	75 mg.*	27·4 g.
Vitamin A	5000 i.u.*	1·8 million i.u.

* (U.S.A.) National Research Council (1943). Recommended daily allowances.
† Rose (1949). Recommended daily allowances.
‡ Probably too high an estimate, especially for high-fat diets.

In the conversion of animal and vegetable crops into human food many losses undoubtedly occur as, for example, in the production of sugar from sugar beet and of flour from wheat. The losses of gross calorific value of the two crops are very considerable indeed, and Table 4 shows that large amounts of by-products are retained on, or sent back to, the farm, where they can be utilized by livestock. This point will be considered later.

The computed amounts of human nutrients produced per acre of land by animal and vegetable crops, disregarding for the present this return of by-products and their utilization by animals, are shown in Table 5. As we all know, wheat, sugar beet and potatoes are primary sources of dietary energy for the population, whereas animal products from a similar acreage supply only one-tenth to one-quarter as much. An acre of good agricultural land sown to wheat could supply the calorie needs of 2·4 people for a year, but could supply sufficient lysine for only 1·8, little, if any, ascorbic acid or vitamin A activity, and, without fortification of the flour with chalk, could supply the calcium needs of only 0·3 people. Except possibly for the lack of ascorbic acid in the egg, the utilization of the calories of the animal foods is not limited by the supply of amino-acids, calcium or vitamins B_1, C or A. Yet milk could supply the lysine needs of 4·1 people, the calcium needs of 3·6 and the vitamin A needs of nearly 2·0. In other words, the total nutritive value of the main vegetable crops is limited by their shortage of vitamins and, to a much lesser extent, of essential amino-acids, whereas animal crops provide a superabundance of these nutrients but a shortage of calories. What the housewife calls vegetables, i.e. green crops of various sorts, occupy a special position. They supply considerable excesses of vitamins A and C and in addition provide large quantities of essential amino-acids. Bulkiness limits their usefulness, since they do not supply a large number of calories. An adequate human diet can be planned from an arable acreage including a green crop, but it would not necessarily be palatable. A further point is that an entirely vegetable dietary for man is not necessary from the point of view of maximal production from our land resources, since by-products have to be utilized. This entails feeding to livestock the waste products of the food industry as well as the utilization of the straw, tops and unsaleable produce left on the farm.

Table 4. *Conversion of sugar beet and wheat crops into human food, direct products for human consumption from* 1 *acre of average farm land*

Crop	Total saleable produce	By-products			Total yield for direct human consumption	
		Retained	Returned to agriculture from factory	Processing losses	Weight	As percentage of total dry matter of whole crop
Wheat	Grain, 18 cwt.	Small corn } 1·5 cwt. Seed corn } Straw, 1 ton	Miller's offals; part of screenings	Cleaning, 2 % Drying, 5 %; Extraction, 25 %	Flour, 850 kg.	50 (including straw)
Sugar beet	Beet (washed), 6 tons	Tops and crowns, 7 tons	Crude molasses; dried beet pulp	Sugar not extracted from pulp, 15 %	Sugar, 750 kg.	29 (including tops)

Table 5. *Number of adult human subjects who can be supplied with* 1 *year's requirement of calories and nutrients from the vegetable and animal production of* 1 *acre of agricultural land*

Crop	Yield	Calories	Tryptophan	Lysine	Methionine	Calcium	Aneurin	Ascorbic acid	Vitamin A	By-products for stock feeding
Vegetable:										
Wheat	18 cwt.	2·4	2·4	1·8	2·1	0·3	3·8	0·2	0·1	Available
Sugar	6 tons	3·2	0·0	0·0	0·0	0·0	0·0	0·0	0·0	Available
Potatoes	5 tons (ware)	3·3	1·7*	3·6*	—	0·8	7·7	24·7	0·1	Very little
Cabbage	20 tons	0·8	12·7	9·4	3·1	17·1	8·2	182·5	49·3	Very little
Animal:										
Milk	200 gal.	0·6	2·8	4·1	1·5	3·6	0·6	0·7–0·0	1·0–2·0	None
Pork and bacon	2 bacon pigs†	0·5	1·1	2·0	0·6	0·5	2·2	0·2	1·0	Available (cereal straw)
Beef	¼ fattening animal	0·4	1·5	3·0	0·9	0·4	0·1	0·2	0·7–1·2	None
Eggs	2400 (20 birds)‡	0·2	1·4	0·8	1·5	0·3	0·5	0·0	0·7–1·2	Available (cereal straw)

* Based on analysis of isolated protein.

† Including purchase of 0·5 cwt. fish meal.

‡ Including purchase of 1 cwt. fish meal.

The following papers were consulted in constructing the table: Andross (1946), Booth, Carter, Jones & Moran (1946), Halnan (1944), Kon (1946*a*,*b*), Lampitt & Goldenberg (1946), Leitch (1944), Leitch & Godden (1941), Lockwood (1945), McCance & Widdowson (1946), Orr (1944), Pyke (1946), Watson & More (1942), Wood & Newman (1928).

Some crops leave little waste. Potato haulms are not edible under most conditions, and the only waste products are small unsaleable potatoes and a variable recovery of potato peelings in swill. To utilize these, the pig is normally used, and, as The Nutrition Society has often been informed, the pig is not a very efficient converter of food. Where cellulosic materials are available, the cow is the most efficient animal. Table 6 shows the conversion of waste products from the wheat industry and the sugar-beet industry into human food. These calculations were based on the starch equivalent supplied by the by-products and the fact that the cost of rearing a cow and her production of 1800 gal. milk involves feeding her with 9300 kg. starch equivalent. The amount of milk produced from by-products is then calculated by proportion as shown in Table 7. The utilization of the waste products of these two crops by animals provides a very large additional supply of nutrients. With wheat, the milk produced from the bran and tail corn supplies almost sufficient lysine to make good the deficiency of lysine of the 75 % extraction flour and more than doubles the calcium supply.

Table 6. *Contribution of animal products to the human-food production from 1 acre of land devoted to wheat or sugar beet*

(All results expressed in terms of the number of adults that could be supplied for 1 year from 1 acre)

	Wheat		Sugar beet	
Nutrient	Direct (flour)	Indirect (27 gal. milk)	Direct (sugar)	Indirect (134 gal. milk)
Calories	2·4	0·1	3·2	0·4
Tryptophan	2·4	0·4	0	1·9
Lysine	1·8	0·6	0	2·7
Methionine	2·1	0·2	0	1·0
Calcium	0·3	0·5	0	2·4
Aneurin	3·8	0·1	0	0·4
Ascorbic acid	0·2	0·1	0	0·5
Vitamin A	0·1	0·1–0·2	0	0·7–1·4*

* According to season of year.

Table 7. *Equivalent in terms of milk of the waste products from 1 acre of agricultural land of the sugar-beet industry*

	Starch equivalent (kg.)
7 tons tops, with 25 % wastage, starch equivalent 8 %	420
1·5 cwt. dried beet pulp per ton of washed beets = 9 cwt., starch equivalent 61 %	274
Total	694

A cow requires 9300 kg. starch equivalent during her lifetime to produce 1800 gal. milk (rearing and 3 years' milking life)

So by-products from 1 acre sugar beet are equivalent to

$$\frac{1800 \times 694}{9300} = 134 \text{ gal. milk}$$

In conclusion, therefore, in dealing with the conversion of plants and animals into human food it is not with their comparative merits that we have to deal but with their complementary merits. An agricultural system devoid of livestock is not an efficient method of using our land nor is a system based in its entirety on livestock production.

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Economic and Statistical Aspects of Vegetable and Animal Foods

By D. A. BOYD, *Rothamsted Experimental Station, Harpenden, Herts.*

In deciding what balance of vegetable and animal foods shall be available to the population of this country the relative nutritional and gastronomical values of the foods have to be weighed very carefully against what is economically practical. Though we know that it is possible to live and work on a diet containing only a very small contribution of animal protein and fats, most of us would probably work better and live more happily on a more mixed diet containing a larger amount of animal foods. The balance between the two types of food is largely determined by three factors: the acreage of land available for agriculture, the size of the agricultural labour force, and the extent to which we can rely on imported food. In this paper, I shall first indicate the relation of these economic factors to the physiological aspects of vegetable and animal foods, and then give some indication of how far home agriculture can be expected to make a greater contribution to our food requirements.