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The variability of vitamin C in our diet

By R. J. L. ALLEN and M. BROOK
Beecham Group Limited, Brentford, Middlesex
and S. R. BROADBENT
Research Services Ltd, 20–24 Broadwick Street, London, W1

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1. The variability in the purchase and consumption of vitamin C in the diet of people living in the United Kingdom has been studied using the Annual Reports of the National Food Survey Committee and new observations gathered independently.

2. The sources of variability examined have been family household composition, social class, seasonal and week-to-week sampling variation.

3. The distribution of mean household daily intakes of vitamin C approximates closely to a log-normal distribution. Assuming this to be so, it may be calculated that about one-quarter of households have vitamin C intakes averaging less than the 30 mg/person per day recommended by the British Medical Association Committee on Nutrition to provide a good margin of safety. Households with intakes below 20 mg/person per day may average 5% of the total. These percentages fall during the late summer and rise correspondingly in the remainder of the year.

4. Allowing for the many uncertainties involved, it is suggested that up to 10% of households and an even greater proportion of individuals may have a vitamin C intake that is permanently below 30 mg/person per day.

The Annual Reports of the National Food Survey Committee are the main sources of information about dietary vitamin C intake in the United Kingdom. In this paper, unless stated otherwise, Annual Report means the Annual Report of the National Food Survey Committee for 1963 (Ministry of Agriculture, Fisheries and Food: National Food Survey Committee, 1965).

The Annual Report records the average amount of vitamin C 'consumed' per person per day. This is not the amount of vitamin C ingested but an amount calculated from standard food composition tables after allowing for wastage, cooking losses and meals eaten outside by members of the household or eaten in the household by visitors. The Annual Report (p. 121) recognizes that the method is not entirely suitable for investigating the variability of vitamin C in our diet.

In this paper we adopt the description 'purchases' for the measurement just described and reserve 'consumption' for records of what is actually ingested. This information is not now collected by the National Food Survey.

The Annual Report records (p. 71) that the average amount of vitamin C purchased per person per day had been quite constant over the 6 years previous to 1963 at between 49 and 52 mg. Taking into account adjustments necessary for age, pregnancy and lactation, the average amount of vitamin C purchased had been 2·2–2·4 times the appropriate minima recommended by the Committee on Nutrition of the British Medical Association (1950). This committee concluded that 'while 20 mg a day or even less may be an adequate quantity for adults, 30 mg daily would provide a good margin of safety'.

Comparison of average purchases of vitamin C with recommended minimum allowances is often used as evidence that the population of this country receives an adequate supply of vitamin C. For example, in a debate on welfare orange juice for children the Parliamentary Secretary to the Ministry of Health (1957) said 'There is nearly 100% margin'. Taylor (1961) criticized vitamin C supplements as unnecessary, and the Annual Report itself says (p. 29) 'The average diet of households of all social classes was nutritionally more than adequate'.

It is not valid to conclude that the whole population ingests more vitamin C than the recommended minimum from the fact that the average purchased lies well above this minimum. Information must first be obtained about the distribution of purchases. The distribution of consumption is even more relevant. It is these distributions and the causes of their variability that this paper examines.

EXPERIMENTAL

The Annual Report for 1961 (Ministry of Agriculture, Fisheries and Food: National Food Survey Committee, 1963) records vitamin C intakes regionally and by type of area (urban, rural, etc.) and the regions may be classified in three groups representing high intakes of vitamin C (53 mg/person per day or more), medium intakes (49–52 mg) and low intakes (48 mg or less).

To obtain a representative national sample of households we selected thirty administrative (local government) areas with a probability proportional to population and after stratifying all the areas in the country according to reported vitamin C intake by region and type of area. The thirty selected administrative areas were grouped in ten groups each of three areas representative of a high, a medium and a low intake region. Within each administrative area two polling districts were randomly selected as sampling points and about nine names and addresses of households were randomly selected within each sampling point for initial interview.

By this procedure a sample of 535 households was selected for initial interview, but 111 of these were eliminated because the premises were unoccupied. Of the 424 effective addresses 312 households agreed to co-operate (73%) and 250 of these completed the survey period. This is a satisfactory success rate for this kind of study and is higher than that achieved by the National Food Survey.

In each of the co-operating households the housewife was asked to record, in a prepared logbook left with her, by description and quantity, all the food which entered the household, food eaten away from home by members of the household and meals eaten by visitors to the home. The logbook methodology adopted was similar to that of the National Food Survey given in Appendix E of the Annual Report. Records were made throughout each of ten periods of 5 weeks from February 1964 to January 1965. Each of the selected households kept a logbook for 1 week during the period.

At the first interview the interviewers recorded the presence in the house of selected items of food and weighed all food containing vitamin C. At the final call, 1 week after the first call, the diary was checked and food containing vitamin C weighed again.

In this survey, unlike the National Food Survey, this procedure made it possible to calculate consumption as well as purchases. During the survey week the interviewer visited on alternate days where the housewife was unwilling or unable to do the recording herself or appeared unlikely to complete the logbook without assistance.

The food composition tables used for the National Food Survey were made available to us by the Ministry of Agriculture, Fisheries and Food, and we used them to calculate the vitamin C contribution of the various foods.

RESULTS

Examination of the Annual Report

Sources of variability. In the Annual Report several sources of variability were discussed. It was concluded (p. 30) that the composition of the family generally exerts a greater influence than social class. For example (p. 74), taking households

Table 1. *Household composition and vitamin C purchases*

Composition of family household	Vitamin C purchases (mg/person per day)
One man and one woman:	
Both under 55	64
One or both 55 or over	55
One man and one woman and:	
One child (under 15) only	52
Two children only	45
Three children only	40
Four or more children	37
Adolescents (15–20) only	55
Adolescents and children	43

Table 2. *Social class and vitamin C purchases*

Social class	Gross weekly income of head of household or principal earner	Vitamin C purchases (mg/person per day)
A_1	£39 and over	64
A_2	£23 10s. and under £39	58
B	£14 10s. and under £23 10s.	50
C	£9 and under £14 10s.	46
D	Under £9	44–47*

* Varies with presence or absence of old-age pensioners and earners.

with one man and one woman and the different numbers of children and adolescents shown in Table 1, there was a clear decrease in purchases for larger families. Social class, as defined by income, however, also had an effect (p. 73), as Table 2 records.

Region and type of area also influenced purchases (p. 72). The highest vitamin C purchase average was in the London conurbation, where fruit and vegetables are cheapest and most plentiful, where it reached 56 mg/person per day.

The amount that each of these sources contributes to over-all variability is indicated in the Annual Report for 1962 (Ministry of Agriculture, Fisheries and Food: National Food Survey Committee, 1964, pp. 28, 29) by the coefficients of variation found when

each is compared with the national average. A high value indicates a division of the households into clearly separated groups by vitamin C purchases.

The coefficient of variation for all household averages is high. It was 56% in the Annual Report for 1953 (Ministry of Agriculture, Fisheries and Food: National Food Survey Committee, 1955) when the uncorrected mean intake was 53 mg/person per day. Coefficients of variation were not published again until the Annual Report for 1964 (Ministry of Agriculture, Fisheries and Food: National Food Survey Committee, 1966) when they were around 50% for various types of household with average vitamin C purchases ranging from 37 to 47 mg/person per day.

Relatively small coefficients were found in the Annual Report for 1953 for type of family at 13·6%, social class 9·5%, region 8·8% and type of area 7·8%. Other causes of variation in addition to these effects must contribute to the 56% coefficient of variation published in the Annual Report for 1953 and these are now considered.

There will clearly be some week-to-week variation, due partly to sampling and partly to the season of the year. A week is the minimum period over which measurements of purchases may validly be made. Not only does a week give some chance for the disturbing effect of keeping a logbook (the method used to collect the information) to be overcome, but it allows also for the known large day-to-day variation in purchases. A special analysis of this variation was carried out in the Annual Report for 1962 (Ministry of Agriculture, Fisheries and Food: National Food Survey Committee 1964, pp. 124–7). Four months were investigated (March, July, September and December). Certain fresh fruits and vegetables (listed in the Report) were analysed. Purchases were concentrated on Friday and Saturday (23% and 30% of all purchases) and were lowest on Monday (8%). For the three other weekdays, 12% or 13% of purchases were made.

It is not known what the total week-to-week variation is. Because the labour of keeping a logbook for more than a week may reduce the proportion of housewives willing to co-operate and may result in further bias in the sample, values were not collected from the same households for a 2nd week. It is assumed that the survey week gives an unbiased estimate of the mean for other weeks.

The season of the year might cause variation in the level of vitamin C purchases but quarterly figures are not given directly in the Annual Report. The Report for 1964 calculates the seasonal variation of vitamin C consumption to reach a peak in the third quarter at 60 mg/day, falling to 37 mg/day in the first quarter.

There is a person-to-person variation within a household. The average calculated per person within any one household would be the purchase for one individual in the household only if each person in the household ate the same amount. This would be a difficult point to investigate in practice on a large scale with a random sample. The condition stated is most unlikely to be fulfilled and this is no doubt one of the reasons why the Annual Report makes the reservation noted earlier about the nutrition of individuals. But it is clear that this factor must make the variability between all individuals greater than the variability between household averages.

Differences between purchases and consumption should be taken into account. The Annual Report points out that the amount consumed in the household may differ

from the amount purchased. It states that the averages of the two will agree over a sufficiently large number of households, but that 'a general change in larder stocks is possible in the short run'.

Such a general change is certainly possible, and a difference with an individual household is even more possible. In fact the difference may not only affect variability (we go into more detail about this in the last section), it may be a cause of bias. Before 1951, stocks held by the housewife were weighed and recorded at the beginning and end of the survey week. This made possible the calculation of the food actually consumed (purchases ± stock difference). It is stated in the Annual Report (p. 121) that this was discontinued in 1951 because it affected the response rate adversely, distorted the normal pattern of consumption though not its volume, and depressed expenditure by drawing the housewife's attention to her existing stocks. There is of course danger of the survey itself distorting both purchases and consumption habits. It is not prima facie obvious whether this will abnormally raise or reduce purchases or consumption during the survey week, or which of these measures is likely to be nearer the housewife's undisturbed (unobservable) behaviour. Clearly the housewife's review of her larder is likely to make her use up stocks. Even without this, because she is recording the cost of all her purchases, she may become reluctant to spend as much as she normally does or to record all she spends; on the other hand, she might spend or consume more than normal to show the interviewer how well she looks after her family. This aspect of the method is complex and evidence on it is needed; we return to it below.

The various adjustment factors (for example, an allowance of 10% is made for edible wastage and feeding of pets) may in practice differ from household to household and so increase the variability of actual consumption of vitamin C.

In addition to all these factors a residual variability is to be expected. This simply expresses the differences from household to household in dietary preferences and habits, and may make a major contribution to the coefficient of variation of 56% mentioned above. It is not possible from the published information to allocate this residual variability.

The result of variability. In this section we consider a mean uncorrected vitamin C purchase of 49 mg/person per day (Annual Report for 1963) and a coefficient of variation of 56% (as reported for 1953) in relation to a recommended daily allowance of 31 mg (this ensures the 30 mg British Medical Association recommendation for adults with 'a good margin of safety' already noted, when taking into account the different types of people in the population who have different requirements, e.g. adolescents and pregnant women). We have already made clear the reservations with which each one of these figures must be treated, but the calculations give an interesting and important result.

Woolf (1954) suggested that results from surveys of this kind, with a high coefficient of variation, unimodal and positively skewed, may be fitted by a gamma distribution but some observations of individual household purchases (not recorded here) suggested that this distribution may not be a very good fit. It was found that the observations reported in the Annual Report were rather more grouped at the mode and the proportion actually lying below any requirement was a little smaller than the gamma distri-

bution suggested. However, the same observations were well fitted by a log-normal distribution. This distribution is generated when each observation is the product of independent variables. This seems not unreasonable for vitamin C, where household income, region, availability of vitamin C-rich food and variability of menus might be multiplicative in their effect.

By calculating means and standard deviations based on the logarithms of the original observations the tables of normal distribution can be used as measures of the proportion of the area of the distribution curve outside any required distance from the mean value. This procedure leads to the conclusion that 28% of households have purchases of vitamin C below 31 mg/person per day in the survey week, the amount recommended for 'a good margin of safety'.

Information collected independently

Household averages. Table 3 records the average purchases of vitamin C throughout the year by the 250 households who participated in our survey. It shows a peak in the third quarter between July and September when the average of purchases was 72 mg/

Table 3. *Purchases of vitamin C by 5-week periods*

	Period	No. of households	Vitamin C purchases, average of households (mg/person per day)	Measured no. of households below 31 mg/person per day
1	3 Feb.–7 Mar. 1964	24	37	13
2	9 Mar.–11 Apr.	29	45	5
3	13 Apr.–16 May	22	52	8
4	18 May–20 June	27	47	8
5	22 June–25 July	27	72	2
6	27 July–29 Aug.	22	58	2
7	31 Aug.–3 Oct.	26	55	3
8	5 Oct.–3 Nov.	24	46	5
9	9 Nov.–12. Dec.	23	44	9
10	14 Dec.–16 Jan. 1965	26	43	7
1–10	Whole sample	250	50	62

person per day, well above the 50 mg/person per day for the annual average of the whole sample. For six other periods the average was correspondingly depressed below the annual average. The Annual Report for 1964 (Appendix E) confirms this seasonal variation.

In Fig. 1 the distribution of average purchases of vitamin C by households is presented as a histogram. From it we deduce that the standard deviation of daily household averages per person was 27 mg, and it follows that the coefficient of variation of our observations was 53%, which is close to the published figure of 56% (Annual Report for 1953). The small number of sampling points (30) for which our information was collected will be borne in mind here. The log-normal distribution with the same mean and coefficient of variation which 250 observations would follow is plotted as the smooth curve also shown in Fig. 1. The fit is evidently reasonable and the χ^2 test confirms this ($\chi^2 = 4{\cdot}4$ with six degrees of freedom).

If household averages do follow this distribution, then 5% of households would have vitamin C intakes below 20 mg/person per day and about 20% below 31 mg/person per day. These percentages are not negligible. They do not, however, take fully into account the seasonal effect recorded in Table 3. For example, from Table 3 we see that over half the households failed to achieve an average intake of 31 mg/person per day during the February–March period.

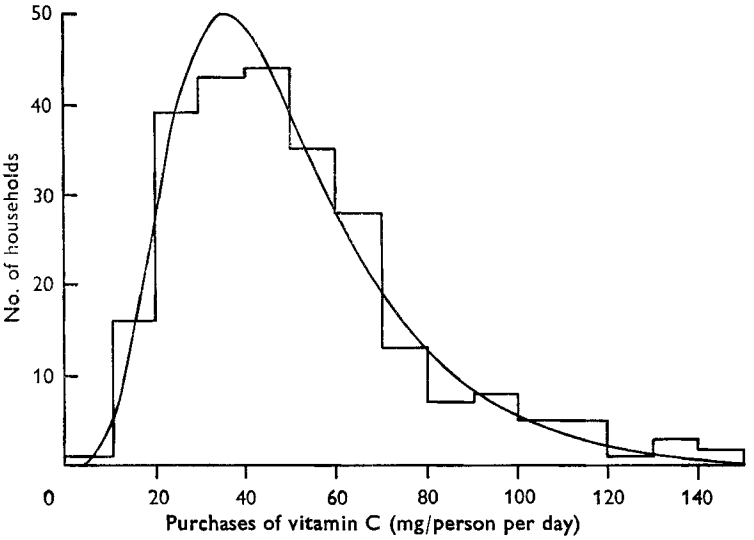

Fig. 1. Distribution among 250 households of average purchases of vitamin C.

Table 4. *Household composition and vitamin C purchases from independent survey*

Composition of family household	Vitamin C purchases (mg/person per day)
Four persons or more in the household	46
One person	42
Adults, children and infants	40
DE social grades*	44
All households	50

* Semi-skilled or unskilled manual workers, casual workers and state pensioners including widows.

Other causes of variability. We know nothing about person-to-person variations within a household, though these presumably cause an even greater proportion of individuals than of households to fall below any level.

Our sample was not large enough to give the same detail in our analysis as in the Annual Report, but in Table 4 we show that in larger and one-person households and in those containing children and infants purchases of vitamin C are lower than average. Purchases by semi-skilled and unskilled manual workers, pensioners and casual workers are also low.

Although we measured stocks at the beginning of the survey week our purchase average was higher than the National Food Survey average (corrected for edible wastage, meals out, etc.). This indicates that the fact of measuring stocks probably does not

of itself decrease purchases very seriously. It may increase consumption, as we obtained a consumption average about 10% higher than purchases (55 mg/person per day against 50 mg). Alternatively purchases may be depressed by the fact of participating in a survey. Uncertainty on this point has deterred us from analysing consumption as thoroughly as purchases. However, the over-all distribution found is worth reporting and is shown in Fig. 2. The mean, as already stated, was 55 mg/person per day and the coefficient of variation was 50% .The shape of the distribution was again typically log-normal and this was confirmed by the good fit obtained (χ^2 with four degrees of freedom was 5·1).

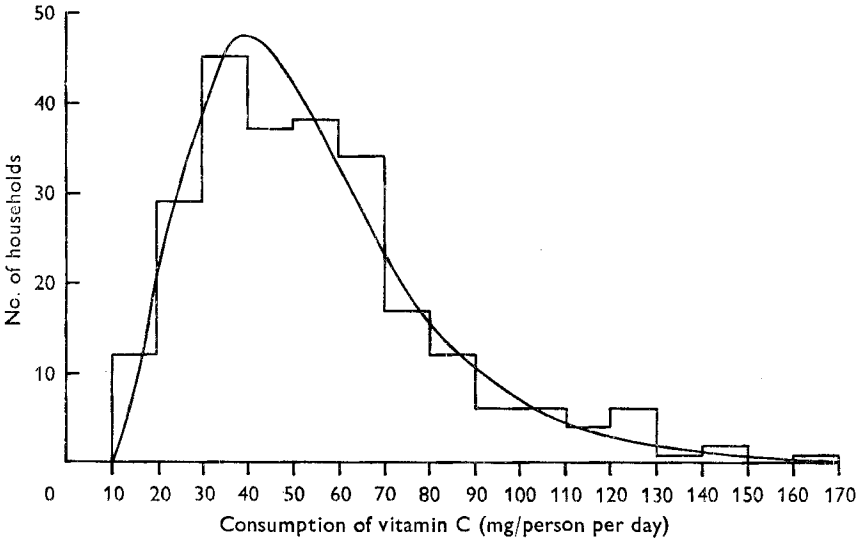

Fig. 2. Distribution among 250 households of average consumption of vitamin C.

The higher mean and smaller coefficient of variation for consumption indicates that the calculated percentages of households falling below 20 mg and 30 mg/person per day were 3% and 15% respectively, rather less than calculated for purchases but not negligible. The actual reasons for these percentages being smaller could be complex. They might arise, for example, if households with low intakes of vitamin C were more likely to consume from stock during the survey week, as might happen if potatoes were bought in larger units than a week's consumption. A two-person household consumes 7 lb potatoes a week. If these are bought as 14 lb every fortnight then in the survey half such households will appear to purchase no potatoes and half to purchase 14 lb. The first half will contribute to an apparently low vitamin C intake by purchases. So week-to-week variations could be one possible way, in addition to the other causes mentioned, in which the distributions of purchases and consumptions differ.

The National Food Survey Committee believe week-to-week variations to be a real cause and we understand they are attempting to get some kind of measure of it. The week-to-week variation in purchases by each household has not been investigated by us.

DISCUSSION

As excess vitamin C is quickly excreted, it is reasonable to assume that 30 mg/person per day of vitamin C, recommended by the British Medical Association (1950) Committee on Nutrition to provide a good margin of safety, is a level of intake intended to be maintained throughout the year, rather than an average intake. This being so, a cautious interpretation of the evidence we have collected leads to the conclusion that many of the United Kingdom population fail to obtain the amount of vitamin C recommended to provide a good margin of safety. Indeed, as many as 54% (thirteen out of twenty-four) households in the February to March period of our survey (Table 3) failed to achieve the recommended intake. This is very different from the comments reported in our introduction, based on considerations of average intake, which state or imply that vitamin C purchases among our population are 'more than adequate'. We believe that there are no grounds for complacency. This opinion is reinforced by the most recent study, made in 1964 by the National Academy of Sciences of the National Research Council of the USA (National Research Council, 1964), which has adopted 70 mg daily as the recommended dietary allowance for adults.

This is a complex field and our study is not exhaustive, but we hope that our paper will encourage others to investigate the problem in more detail.

We are grateful to the Ministry of Agriculture, Fisheries and Food for allowing us to use the National Food Survey food composition tables and for many helpful suggestions during the course of this work and for their constructive criticisms on the manuscript.

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