Error in the provision of diets of known electrolyte content

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In the care of patients it is sometimes necessary to prescribe diets of definite and known electrolyte content. For instance, a diet containing daily 10 m-equiv. of sodium or less may be desirable in the management of patients with congestive heart failure. The balance method may be used in the study of disease and for it it is necessary to know gains and losses. The former are provided by the fluid and solid components of the diet, whose composition may be calculated from the weights of individual food items by means of published tables such as those of McCance & Widdowson (1946). Variability in the mineral content of foods is a recognized source of error in this method. Alternatively, the composition of the diet may be derived from analysis of representative samples or of individual items of food composing it. This method involves considerable wastage of food. It also entails much work, which may limit the scope of balance studies. Errors due to variability in the composition of foods are less with this method, as the foods analysed are from the same batch, but are not obviated.

It is the purpose of this communication to consider errors attendant upon the provision of diets of specified composition with the facilities available in a busy general hospital with a diet kitchen.

EXPERIMENTAL

Diets supplied for balance studies. Two diets provided for balance studies (diets 1 and 2 in Tables 1 and 2) and diets provided during the routine management of patients have been analysed and the values found for sodium, potassium and chloride compared with those found by calculation from McCance & Widdowson's (1946) tables of food composition. Diets 1 and 2 have been considered as a whole and also by considering separately the contribution of the milk and solids in them.

The diets were prepared over a period of 6 weeks and three were made up on any one day, selecting the same cut of meat and chicken, the same loaf of bread, milk from the same churn and potatoes and peas from the same boiling. All twenty-one examples (eleven of diet 1 and ten of diet 2) were prepared by the same person.

Low-sodium diet supplied in routine management of patients with congestive heart failure. Ten examples of such a diet were constructed by the staff of the diet kitchen to supply daily 10 m-equiv. of sodium or less, and were prepared, each in triplicate,

in the manner usual with such diets. The three replicates of each diet were prepared on the same day.

Analysis of diets. After preparation, the whole of each diet was homogenized and made to constant volume (900 ml.) with distilled water. Sodium and potassium were estimated with the EEL flame-photometer (Evans Electroselenium Ltd) after heating with a measured volume of conc. A.R. nitric acid (50 ml. homogenate, 25 ml. HNO_3).

Table 1. *Composition of diets 1 and 2*

(All values in g)

Constituent	Diet 1	Diet 2
Milk	810·0	780·0
Bread: white*	90·0	—
brown*	—	60·0
Butter	22·5	30·0
Porridge oats	15·0	15·0
Eggs	60·0	16·0
Sugar	40·0	51·0
Fillet steak†	60·0	—
Potatoes	60·0	30·0
Peas, frozen‡	30·0	30·0
Rice, raw	15·0	—
Jam, seedless	30·0	30·0
Tomatoes	30·0	—
Chicken breast§	30·0	—
Jelly¶	50·0	100·0
Ice-cream	31·5	—
Bournvita (Cadbury)	7·5	15·0
Marmalade	—	15·0
Plaice, fillet	—	100·0
Custard powder	—	5·0
Cheese	—	15·0
Cream crackers	—	20·0
Kosher margarine	—	16·0
Flour, plain, white	—	21·3
Baking powder	—	0·22

* From different loaves on different days.
† Raw, weighed before cooking.
‡ From same consignment, weighed after cooking.
§ Weighed after steaming.
¶ Packet jelly reconstituted to 20 fluid oz.

Table 2. *Sodium, potassium and chloride contents (m-equiv./day) of diets 1 and 2, calculated from tables of food composition (McCance & Widdowson, 1946)*

Diet	Sodium	Potassium	Chloride
1	44·5	60·2	47·3
2	49·4	55·9	49·3

This method was found to be more consistent than the method of dry ashing. The ratio of sodium to potassium in these diets caused no interference effects. Chloride was estimated titrimetrically by the method of Volhard, on a sample of the original homogenate. The results obtained by this method agreed with those obtained on a filtrate from the homogenate to which conc. A.R. nitric acid had been added and which had stood for 24 h at room temperature. It was found that the homogenate treated as for sodium and potassium analysis gave too low values for chloride.

Milk and solids from diets 1 and 2 were analysed separately in the same way. The drinks included in the diets low in sodium were added to the rest of the diet before homogenization.

RESULTS

Estimations of sodium, potassium and chloride in duplicate portions withdrawn from the homogenates of three examples of diet 1 and of eleven examples of the low-sodium diet agreed to within 1%.

Diets 1 and 2. The correspondence between calculated content and that found by analysis is summarized in Table 3. On average, calculation gave a 13·5% underestimate for sodium, a 10·4% overestimate for potassium, and a 1·4% overestimate for chloride.

Table 3. *Diets 1 and 2. Discrepancy between the calculated values and those found by analysis for the sodium, potassium and chloride content of the whole diets and of the solids and milk in them*

(Mean values for the difference (calculated − analytical value) expressed as a percentage of the mean analytical value)

	Whole diet			Solids			Milk
	Diet 1	Diet 2	Mean for diets 1 and 2	Diet 1	Diet 2	Mean for diets 1 and 2	Mean for diets 1 and 2
Na	−12·1	−14·8	−13·5	−17·3	−20·5	−18·9	− 2·5
K	+ 4·2	+16·5	+10·4	+ 2·5	+23·2	+12·8	−24·8
Cl	+ 0·4	+ 2·0	+ 1·4	+ 4·3	0·0	+ 1·6	− 3·6

Table 4. *Diets 1 and 2 and low-sodium diet. Variation between triplicate examples prepared on the same day*

(The diets prepared on any one day have the same calculated sodium, potassium and chloride content. The difference between the highest and the lowest of the three values found on analysis is expressed as a percentage of the mean of the three values found on that day)

	Solids			Milk			Whole diet		
Diet	Na	K	Cl	Na	K	Cl	Na	K	Cl
1 and 2: mean	4·2	2·6	7·3	3·4	1·8	3·3	4·1	3·2	3·2
range	0–8·6	0·9–8·7	2·1–14·5	0·8–6·2	0–7·2	1·3–5·8	0·3–10·1	0·7–10·5	0·8–6·7
Low-Na: mean	—	—	—	—	—	—	17·8	8·0	12·2
range	—	—	—	—	—	—	3·6–53·3	1·0–21·9	7·0–19·5

The variation between the triplicate examples prepared on any one day is summarized in Table 4. This variation, which may be considered a measure of the sum of analytical and sampling errors and the error introduced in the preparation of the several examples, was, on average, 4·1% for sodium and 3·2% for both potassium and chloride.

The variation between the examples of either diet on the different days is presented in Tables 5 and 6. This variation is a measure of that contributed by analytical and sampling errors, the preparation of triplicate examples (cf. Table 3) and also of that

Table 5. *Diets* 1 *and* 2 *and low-sodium diet. Variation in the sodium, potassium and chloride content found by analysis of the several examples of the same diet prepared on different days*

(The differences between the individual examples and the mean of all the examples have been expressed, regardless of sign, (*A*) as percentages of this group mean and (*B*) in m-equiv.)

		A						*B*					
		Mean value			Range			Mean value			Range		
Component	Diet	Na	K	Cl	Na	K	Cl	Na	K	Cl	Na	K	Cl
Solids	1	8·0	13·0	5·1	0·3–15·7	8·0–23·1	2·0–8·5	3·2	4·4	1·5	0·1–6·2	2·7–7·8	0·6–2·5
	2	5·1	10·0	4·4	0·4–16·1	0·8–29·1	1·8–12·8	2·4	2·4	1·4	0·2–7·6	0·2–7·1	0·7–4·2
Milk	—	1·6	8·0	1·8	0 –6·5	4·2–20·5	0 –5·0	0·2	1·7	0·3	0 –0·8	0·9–4·4	0 –0·8
Whole diet	1	6·3	10·6	1·3	0·8–11·3	7·0–16·2	0·2–2·1	3·3	5·9	0·6	0·4–5·9	3·9–9·0	0·1–1·0
	2	4·6	10·4	1·3	1·2–13·3	6·1–22·6	0 –6·0	2·7	4·8	0·6	0·7–7·9	2·8–10·4	0 –2·9
	Low-Na	24·7	15·3	35·6	0·4–99·6	0 –37·9	4·7–97·4	5·1	8·8	8·3	0·1–20·5	0 –21·9	1·1–22·7

due to variations in the food selected for use on the different days. Rather less variation was found in the sodium and chloride content of milk than in that of the solid components of the diet. Table 7 presents the correspondence between the contents determined by calculation and analysis assessed in the same manner as for the variation between days (Table 5). For chloride, variation both about the calculated composition and about the mean of the values found on analysis was of the same order.

Table 6. *Diets 1 and 2 and low-sodium diet. Variation in the sodium, potassium and chloride content found by analysis of the several examples of the same diet prepared on different days*

(The differences between the highest and lowest values of the individual examples have been expressed as percentages of the group mean)

Component	Diet	Na	K	Cl
Solids	1	29·4	22·6	14·2
	2	13·7	29·3	18·3
Milk	—	12·8	31·2	8·8
Whole diet	1	22·3	27·2	4·2
	2	9·7	26·2	7·9
	Low-Na	134·4	60·8	138·0

Table 7. *Diets 1 and 2. Mean discrepancy between calculated values and those found by analysis for the sodium, potassium and chloride content of the diets and of the solids and milk in them*

(The differences between the individual examples and calculated content have been expressed, regardless of sign, as percentages of the calculated content)

Component	Diet	Na	K	Cl
Solids	1	20·8	2·5	5·5
	2	25·8	18·8	4·4
Milk	—	2·6	24·8	3·3
Whole diet	1	13·7	4·0	1·3
	2	17·4	14·1	2·2

Low-sodium diet. Variation of sodium, potassium and chloride content shown by the three examples prepared on any one day is summarized in Table 4. The variations in sodium, potassium and chloride contents between the ten examples of this diet prepared on different days are summarized in Tables 5 and 6. It is to be noted that analysis showed that all the diets contained more sodium than the upper limit prescribed (from 3·4 to 28·5 m-equiv., mean 10·6), and from 4·0 to 32·0 m-equiv. more than the quantity intended by the diet kitchen (mean 7·5), i.e. from 50·5 to 326·0% more than calculated (mean 76·2%).

DISCUSSION

Mean discrepancies of 2–11% for potassium, 61–122% for sodium and 51–80% for chloride are recorded by Pearson, Balikov & Reiss (1955) between contents determined by calculation and analysis of diets prepared for balance studies. Their three diets were calculated to contain rather less sodium and more potassium than those we considered. The discrepancies observed by them in sodium and chloride, and those

previously reported by Hummel, Shepherd, Galbraith, Williams & Macy (1942) are greater than those we have found.

Since errors are incurred at other stages in constructing a balance sheet it is desirable that those in assessing composition of diets should be minimal, which places a premium on care in the preparation of diets. It is noticeable that with the lesser degree of care in the preparation of the routine low-sodium diets greater variations were found within triplicate examples on any one day than were present between the triplicates of the balance diets. The variations were in fact equal to or greater than those observed between days with the latter diets.

Our results draw attention to the considerable fluctuation of intake that can occur on a so-called constant diet, prepared with some care from the same foodstuffs on different days. This finding has been noted previously (Bassett & Van Alstine, 1935; Word & Wakeham, 1938), and synthetic diets have been devised whose object is to minimize such errors by providing an entirely fluid diet of constant known composition. Such diets are less palatable, and for many balance studies the more conventional diets are still used.

Variation could be decreased by preparing diets during several weeks from the one stock of food, which is possible if the stock is stored in deep freeze. The foods may be stored in weighed and wrapped portions, either before or after cooking. Variation from day to day can also be reduced by restricting the number of items of food in the diet. All such procedures, however, introduce an element of monotony in both preparation and presentation of food, which together with the lesser degree of choice may result in a poor intake, especially where appetite is already impaired. Such a possibility must be borne in mind, as well as the potential errors, in every instance when a diet is prescribed for purposes of metabolic study.

For sodium and, with milk, for potassium the variation from day to day within our examples of diets (Table 5) was less than that found between our individual examples and their calculated content (Table 7). It would be so if some of the foods we used in the construction of our diets were of different composition from those analysed when compiling the tables, or if the techniques used imparted a systematic difference to the analysed content. The foods used in our diets 1 and 2, although from different batches on the different days, were all obtained within a period of 6 weeks. The samples analysed by McCance & Widdowson (1946) for their tables may well have been obtained at a different time in the season; almost certainly the vegetables would have been grown in different soils. Wide variations in mineral content of fruits, vegetables and grain grown under different conditions of soil and climate have been reported (McCance & Lawrence, 1929; McCance, Widdowson & Shackleton, 1938; Bishop, 1934; Coleman & Ruprecht, 1935; Davidson & LeClerc, 1936; Greaves & Hirst, 1928–9; Schrumpf-Pierron, 1932).

Even with the care given to the routine provision of a low-sodium diet, its sodium content differed considerably from that intended. In fact all diets contained more sodium than the upper limit prescribed, and there was a marked daily variation. Such error could probably be lessened by providing a constant diet low in sodium. Where the sodium content is low, however, a constant diet would be even less likely to sustain or

titillate the fastidious appetite of most of the patients for whom it is an essential part of treatment. Some sacrifice of accuracy must be made with such patients if they are to eat an adequate diet. Clearly, however, the preparation of these diets must be given the same detailed care as diets for balance studies if their sodium content is to be kept to the level prescribed.

SUMMARY

1. Twenty-one examples of two diets provided for balance study have been analysed for sodium, potassium and chloride.

2. The examples were prepared over a period of 6 weeks, and three were made up on any one day with foods taken from the same batch.

3. The results have been examined for variations occurring from day to day in the same diet, and for departures from the prescribed composition calculated from tables of food composition.

4. Both the daily variation and the discrepancy between the calculated composition and that found by analysis were greater than analytical or sampling errors, presumably owing to intrinsic variation in items of the diet.

5. Less variation was found between triplicate diets prepared on the same day from the same stock of food than between diets prepared on different days from other stocks of food.

6. Three examples of each of ten low-sodium diets supplied by the hospital diet kitchen have been analysed similarly and the errors are discussed.

7. All low-sodium diets were found to contain more sodium than prescribed.

8. The variation found between the diets prepared on the same day and those prepared on different days was with both greater for the low-sodium diets than for diets provided for balance studies.

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