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LINEAR PROGRAMMING TECHNIQUES FOR THE CONSTRUCTION OF PALATABLE HUMAN DIETS

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Abstract

From the earliest days, electronic computers have been applied to calculations on human diets, and there are now software packages which virtually eliminate the computational drudgery in obtaining a nutritional analysis of a diet. However, dietitians have long worked with the reverse problem; namely, advising patient what they should eat and in what quantities, to meet the nutrient intake levels recommended for either general health or disease-related reasons. Many textbooks on linear programming mention the diet problem; that is the divising of a diet which meets nutrient targets at minimum cost. This is seen as an illustration of mathematical techniques rather than a contribution to human dietetics, although the approach is widely used in formulating animal feedstuffs. The pioneer of work on human dietary optimization was George Stigler who showed how to feed a grown man for one year at a total cost. This 'optimal' diet was, needless to, say very restricted, boring and unpalatable. Subsequent work has incorporated constraints, additional to the strict requirements of nutrition, to increase the variety and acceptability of the diet. A benchmark is provided by a study in the US Mid-West which constructed nutritious and economical diets with a range and variety similar to actual eating patterns.

Keywords: *Drudgery, Nutrient, Optimal, Meringue Pie.*

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Introduction

A mathematical approach to be applied to the provision of clinically appropriate diets and dietary advice to individual patients. Three points relating to the modelling of diet have needed attention. Firstly, the strictly economic objective of 'least monetary cost' has been replaced by an objective function which represents the acceptability of the diet to an individual subject. Secondly, the selection of candidate foodstuffs for possible inclusion in the diet is based on individual preferences, rather than on average or popular tastes, as has been the case in earlier work. Finally, it has been necessary to allow for a greater variety of constraints within the model, in order to reflect the requirments of clinical dieties and to maintain the orientation towards individual preferences. In addition, it has been our intention throughout to implement the model of the diet on a microcomputer, in order to make it widely available to medical personnel. The details of the linear programming model which has been employed. Some computed diets suitable for an individual renal patient, obtained using these principles and illustrating the use of post-optimal analysis, are also given.

A PATIENT-CENTRED APPROACH

In principle, the linear programming problem for an individual is set up as follows. The patient and a medical advisor, usually a dietitian, sit together at the microcomputer and input an actual or typical day's diet, in term of foods eaten and the quantities.

This will be taken as the starting point for all the subsequent optimizations, it being assumed to reflect the patient's individual preferences and habits. Nutrient targets for the particular patient's diet are then set, when appropriate, disease-related requirements. To be clinically useful, several types of nutrient target must be considered, in addition to those usually considered in the diet problem. Provision for each of the following types of constraint has been made in the software, both in the user interface and in the underlying calculation:

1. the daily intake of specified nutrients:

2. the intake of a particular nutrient from a subset of foods- those making up one meal, for example;

3. the percentage of energy intake derived from fat, protein or carbohydrate;

4. the ratio of polyunsaturated to saturated fat (the pis ratio) in the diet;

5. the fraction of nitrogen intake derived from particular amino acids.

This approach to dietary calculation is demonstrated by constructing a diet suitable for an individual patient with chronic renal failure, starting from a realistic daily food intake record.

The tables show the foods and quantities resulting from several linear programming optimizations (Table A), the corresponding nutrient analyses and the nutrient targets (Table B). The slight discrepancies between targets and computed totals arise from the rounding of food quantities to the nearest gramme. The first column in Table B shows the foods and quantities in the original diet, except for lemon meringue pie which was added to the diet at a later stage, as we shall explain. The second column shows the results of the first optimization, and represents the smallest change, to the original food quantities in order that the targets be met.

TABLE A, FOODS AND QUANTITIES

Food Name	**Food quantity (g) in diet number**				
	(Original)	**2**	**3**	**4**	**5**
Muesli with extra fruit	50	50	112	50	50

Yogurt, flavoured	125	0	63	63	63
Tea, Indian infusion	200	0	100	200	200
Coffee, infusion	200	0	100	200	100
Wholemeal bread	70	70	0	70	70
Cottage cheese	75	75	265	75	75
Tomatoes, raw	50	0	25	50	25
Cucumber, raw	50	0	25	50	50
Pepper	1	1	99	1	1
Pears, eating	100	100	0	100	100
Coffee, infusion	400	0	200	200	200
Chicken, roast light meat	150	95	0	82	82
Garlic, raw	10	10	10	10	10
Butter, salted	10	10	54	10	10
Potatoes, old mashed	75	0	38	38	38
Spaghetti, canned in tomato sauce	75	259	75	75	75
Apples, eating	200	254	667	57	57
Tea, Indian infusion	200	172	0	200	200
Milk chocolate	50	223	53	50	98
Milk, semi skimmed	200	0	100	100	100
Lemon meringue pie (form diet 4 onwards)	(200)	→	→	297	220

Table B. Nutrient targets and analyses

Nutrient	**Target**	**Analysis for diet number**				
		1 (original)	2	3	4	5
Water (g)	<1500	1878	777	1342	1477	1328

% energy from fat	< 38	46	38	38	35	37
Energy (kcal)	>2100	1436	2099	2106	2101	2099
Protein (g)	> 72	84	72	72	72	72
Sodium (mg)	<2300	1559	2299	2302	2002	1904
Potassium (mg)	< 2340	2988	2338	2344	2343	2340
Phosphorus (mg)	< 1240	1317	1239	1243	1167	1217
Nitrogen/Lysine (dimensionless ratio)	> 1.00	1.26	1.18	1.00	1.07	1.11

The diet produced is. in almost all respects, far from palatable; of the 20 foods in the original diet, the quantities of ten have changed by a factor of at least two. Additional constraints to limit the changes in the quantities of these ten foods to half or twice the original quantities were imposed and the optimization carried out again, with the results shown in column number 3. These are even more extreme in culinary terms but, at this stage, the post-optimal analysis provides significant insight into the problem. The nutrient targets and food quantity constraints are, when listed in decending order of their shadow costs:

Energy > 2100 kcal,

Phosphorus < 1240 mg

Potassium < 2340 mg

Protein > 72 g

Milk, semi-skimmed > 100 g etc.

CONCLUSION:

It is now clear that, in order to reduce the changes to the food quantities, another real high in energy and low in phosphorus and potassium, needs to be brought into the diet. A renal dietitian could probably have predicted this, but the software makes possible a search through the entire database for such foods. This provides a list of about 30 possible foods, of all types, from which a patient could choose. Lemon meringue pie was near the top of this list and so was brought into the diet, with an initial quantity of 200g, and the optimization carried out a third time. The results are shown in column number 4 and, clearly many of the palatability problems have been resolved. An upper limit of 220 g was placed on the quantity of lemon meringue pie and optimization was carried out again to produce the results in the final column. The entire process, beginning with the initial diet, to produce the final, acceptable, diet took about five minutes, using a 386SX microcomputer.

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