TRIAL AND ERROR METHODS, "EXPERT" GUESSING OR LINEAR PROGRAMMING?

FORMULATING SOUND NUTRITIONAL RECOMMENDATIONS FOR COMPLEMENTARY FEEDING

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During complementary feeding, children require a nutrient-dense diet to meet their high nutritional requirements. International interest exists in promoting affordable, nutritionally adequate diets during complementary feeding prepared with locally available foods, and possibly some fortified foods. In this context, two questions arise:

- is it possible to design a diet suitable for the complementary feeding period using locally available food?

- if so, what is the lowest-cost, easily available, nutritionally adequate diet?

These questions are usually answered using a "trial and error" approach or by "expert" guessing. However, an efficient and rigorous technique based on linear programming is also available to answer these questions. This technique examines the compatibility of different mathematical inequalities using simple mathematics. Until recently, its application was limited by the large number of equations to be solved simultaneously. This short paper examines the principle of this method and illustrates how with a computer it can be used to answer very practical questions.

Designing a diet complying with multiple nutritional constraints

A very simple example can explain the basic principles behind linear programming. A meal from rice and beans is needed with a minimum and maximum energy content of 400 kcal and 600 kcal respectively, and a minimum of 15 g of proteins and a maximum of 100 mg of sodium. Table 1 reports the protein and sodium content of the rice and beans used for this theoretical example.

Firstly, compatibility between all the constraints can be determined using a graph. For this, the constraints are expressed as $y > ax + b$. The constraint for the minimum energy content can be expressed in three ways using this equation, taking into account that 1 g of rice provides 3.5 kcal and 1 g of beans provides 3.2 kcal: weightrice * 3.5 + weightbeans* 3.2 > 400; or weightbeans > (400 - weightrice * 3.5)/3.2; or weightbeans= - 3.5/3.2 * weightrice + 400/3.2.

On a two dimensional graph (beans on Y axis, rice on X axis), all rice and bean combinations fulfilling this constraint are above the minimum content of the energy line (Figure 1, next page). In the same way, the constraints on the maximum content of energy and sodium and the minimum content of protein can be represented as straight lines. These straight lines on the graph limit the areas respecting and not respecting the constraint. They form a polygonal "feasible region". All rice and bean combinations represented within this feasible region have a nutritional composition that respects all the constraints defined initially.

For some sets of constraints, there is no feasible region and no food combination can be found to fulfil the initial nutritional constraints. All paediatricians know, for instance, that no combination of rice and milk can provide a young child all the iron he/she needs during the complementary feeding period. This can be shown formally on a graph. Using this example, the iron content of milk (65 kcal/100 ml) and rice are 1 mg/100 g and 0.1 mg/100 g respectively, but a breastfed child cannot consume more than 600kcal from complementary food and has an iron requirement of 10 mg. Figure 2 (next page) shows that the feasible area for energy (below the "energy line") has no common part with the feasible area for iron (above the "iron line"). Therefore, these constraints are not compatible. To meet these constraints, a third iron rich (possibly fortified) food needs to be introduced.

Determining the least expensive food combination that respects multiple nutritional constraints

Using the first example of rice and beans, the next step is to select the least expensive combination fulfilling all

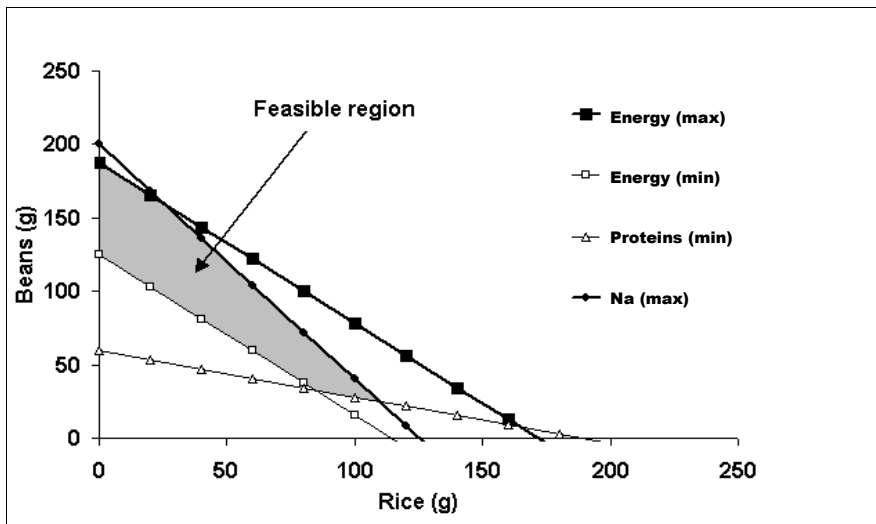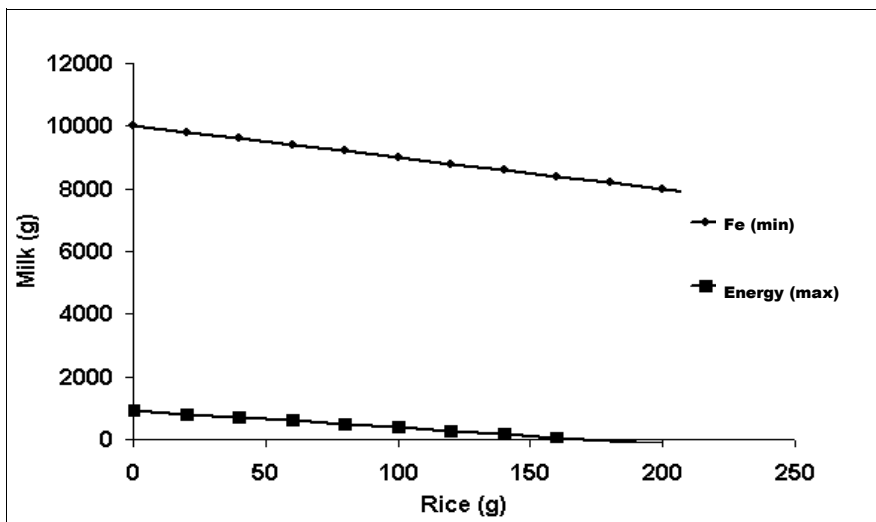| Table 1		Energy (Kcal/100g)	Proteins (g/100g)	Sodium (mg/100g)
Composition of foods used in the examples in the text. Note: the values do not correspond to the real nutrient content of these foods	**Rice**	350	8	80
	Beans	320	25	50

Figure 1

Figure 2

the constraints. What would this combination be if rice costs one currency unit (CU) and beans two CU per kg?

In theory, this question can be easily solved mathematically. The least expensive solution is always at one of the feasible region corners. The right solution can be found by comparing the price of rice and bean combinations corresponding to each corner. This involves solving the systems of equations corresponding to the two lines crossing each other at each corner. In practice, this becomes complicated. Since the feasible region has five corners, this means that even in a very simple example, five systems of two equations each need to be solved in order to find the right solution.

Here an Excel spreadsheet, or equivalent programme, can help find the solution. First, the food composition table should be displayed on the spreadsheet as shown in Figure 3 (next page). Below this, lay out a recipe as shown in Figure 3 and calculate the total nutrients of the recipe. This should be done using the standard spreadsheet functions. The amount of rice and beans in this example are set at 50 g arbitrarily. Next, activate the solver function. This function is not installed by default in all computers and can be installed following instructions from the help menu.

Once the solver function is activated (Figure 4, next page), select the variable to be optimized. In this example, total cost should be minimized, therefore, enter it as a target cell (C15 in this example) with the "minimize" option activated. Then choose the "variable cells". In this example, this represents the quantity of rice and beans (B12 and B13) to be adjusted in order to minimize the cost. Eventually, enter constraints in the model by activating the "Add constraint" menu. In these examples, constraints are represented by the inequalities imposing a maximum and a minimum value for energy, protein and sodium. In the option menu, click on "Options" of the solver function. It is important to mention that "All variables are supposed positive". Now, by clicking the "Solve" function, a new screen appears with the solution immediately displayed in the recipe column (Figure 5, page 39). The least expensive option is obtained with 84 g of rice and 33 g of beans for a cost of 0.15 CU. This corresponds indeed to one of the corners of the feasible area, where the lines representing the constraints for minimum protein and energy cross each other.

Figure 3

	A	B	C	D	E	F	G
1	FOOD COMPOSITION TABLE						
2							
3							
4			Cost	Energy	Proteins	Sodium	
5			per Kg	(Kcal/100g)	(g/100g)	(mg/100g)	
6	Rice		1	350	8	80	
7	Beans		2	320	25	50	
8							
9							
10	RECIPE	g					
11							
12	Rice	50	0.05	175	4	40	
13	Beans	50	0.10	160	13	25	
14							
15	Total	100	0.15	335	17	65	
16							

Figure 4

	A	B	C	D	E	F	G
1	FOOD COMPOSITION TABLE						
2							
3							
4			Cost	Energy	Proteins	Sodium	
5							
6	Rice						
7	Beans						
8							
9							
10	RECIPE	g					
11							
12	Rice	50					
13	Beans	50					
14							
15	Total	100					
16							
17							

Solver Parameters

Set Target Cell: $C$15
Equal To: ○ Max ● Min ○ Value of: 0
By Changing Cells: $B$12:$B$13

Subject to the Constraints:
$D$15 <= 600
$D$15 >= 400
$E$15 >= 15
$F$15 <= 100

Linear programming in real life

In real life, designing a diet for the complementary feeding period represents a much more complex problem than the examples discussed. First, diets are never designed with only two foods, but at least 10 or 20 depending on local resources, and infant and young child feeding practices. Unfortunately, this makes graphic representation of constraints compatibility impossible. Yet, the basic principles remain the same.

In practice also, constraints have to be added to the model to make sure the obtained recipes are acceptable and realistic. This is done by setting a maximum limit for each food which should be obtained from key informants. This limit corresponds to the maximum amount of each food which can reasonably be recommended in the considered age group.

Although the full theory behind linear programming was developed more than 50 years ago, it has gained popularity with the advent of low cost, powerful, small computers. Now, even the most complex nutritional problems involving hundreds of different foods with nutritional and acceptability constraints can be solved in a few seconds once the data have been properly displayed on a spreadsheet. Easy to use linear programming programmes incorporating the nutrient composition of most foods available in developing countries are now available on the Internet (*www.nutrisurvey.de*) and are better to use for this purpose than Excel.

Practical applications of linear programming

Very practical questions regarding complementary feeding have been debated over many years with no clear solution achieved. Without the help of linear programming, even for an expert, it is impossible to use intuition and guessing alone to arrive at solutions to problems which require solving hundreds of equations simultaneously. Further, conflicts of opinion on these issues are difficult to avoid as long as opinions are based on guesses. Linear programming should clarify these issues.

Everyone agrees that nutrient recommendations formulated by different expert committees are difficult to use in practice. So far, few practitioners have succeeded in providing recommendations that are realistic and consistent with recommended nutrient intakes. Very often recipes or diets based on current food recommendations do not provide all nutrients at the recommended level. Linear programming should lead to major progress in this area.

Figure 5

	A	B	C	D	E	F	G
1	FOOD COMPOSITION TABLE						
2							
3							
4			Cost	Energy	Proteins	Sodium	
5			per Kg	(Kcal/100g)	(g/100g)	(mg/100g)	
6	Rice		1	350	8	80	
7	Beans						
8							
9							
10	RECIPE	g					
11							
12	Rice	84					
13	Beans	33					
14							
15	Total	117	0.15	400	15	84	
16							

In conclusion, linear programming is a powerful tool that could help formulate sound nutritional advice, especially in the context of complementary feeding in poor countries. Coupled with behaviour change communication strategies, it has the potential to improve infant and young child nutrition. This rigorous method has been used for years in industry and animal nutrition. Its introduction into human nutrition is long overdue.

Further readings

Briend A, Darmon N, Ferguson E, Erhardt JG Linear programming: a mathematical tool for analyzing and optimizing children's diets during the complementary feeding period. *Journal* of *Paediatric Gastroenterology and Nutrition*. 2003, 36(1):12-22.

Briend A, Ferguson E, Darmon N. Local food price analysis by linear programming: a new approach to assess the economic value of fortified food supplements. *Food Nutrition Bulletin*. 2001, 22(2):184-9. Avialable at: *www.unu.edu/unupress/food/fnb22-2.pdf* Accessed 17 September 2003.

Linear programming module of Nutrisurvey. Available at: *www.nutrisurvey.de/lp/lp.htm* Accessed 17 September 2003.

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