FOOD ALLOWANCE OPTIMIZATION MODEL

Viesturs Rozenbergs[1] Dr.sc.ing., Mg.ed.; **Imants Skrupskis**[1] Dr.habil.sc.ing.
Dace Skrupska[1] Mg.paed.; **Ērika Rozenberga**[2]
Latvia University of Agriculture[1], NGO ,,Visikuma muizas fonds"[2]
roze@llu.lv[1]; erika.rozenberga@gmail.com[2]

Abstract: Possibility of food allowance optimization by using MS Solver tool is analysed in the research. The model is developed by balancing 22 food products and 30 constraints – 8 nutrients and 22 minimum amounts of food products. The new method differs from the applications of linear programming described in the special literature on nutrition science not only with increased nutritional constraints, but also the minimum amount of every product is introduced as constraints, which does not essentially change costs, but provide quality, for example, for tea or coffee it is recommended to define not $x \geq 0$, but $x \geq 3$. By modifying minimum amounts of tea, coffee, sugar, spices, it is possible to obtain up to 70% economy from the initial rate. Application of the model is approbated in the computer class during practical classes for students of nutrition science.

Keywords: Constraint functions, allowance, constraint, linear programming, nutrients, food costs.

Introduction

One of the most essential components of the state food safety is individual food safety status of every household (Wood, 2006), provided by both self-supply (Perpar, Udovč, 2010) and market relations, determined by money link between a city and country, which is provided by available amount of money means (Abdullah, Kalim, 2012). In case for food purchase there is not sufficient amount of money means for critical number of population, there is great possibility of strikes, as well as anarchy and global migration of people (Falvey, 2011). While there is limited amount of money means, it is important to get nutrients with minimum means, which are not lower than scientifically based rates. On the other hand, according to the Bologna process in the higher education, it is defined, that from the quality of educational material we should move to the quality of training results (Perez-Montoro, Tammaro, 2012), at the same time also from the quantity of academic knowledge and different regularities, conceptually we should move to the approach – know-how, which is accumulated during hundreds of years, as well as during the recent decades and which directly is concerned with economic activity nowadays,- better deliver to students, in order to obtain the level of user skills as soon and efficient as possible. The aim of the article is to check optimization feasibility of food allowance formed by food products with cost function tending to reach the minimum, using Solver supplement of Microsoft Office Excel (Bezerra, Fraga, Dias, 2013) with certain constraints, which are the minimum set amount of food products and nutrients.

Methodology

Application of linear programming for compiling a menu is considered. After survey of literature data an Excel file was developed with calculated daily allowance, nutrition rates were taken as a pattern (LR MK not.nr.1022 no 19.12.2006). For compiling food allowance the set problem is formulated as a minimum of cost purpose functions with certain constraints, which are formed by nutrients of the food products in the allowance, rates of which must not be lower than fixed in the legislation or scientific literature. The study is based on the researches in applied mathematics of Nobel Prize winner in economics George Stigler and B. Dantzig, which are based on Milton Friedman`s school of economics (Dantzig, 1990), and researches of French nutrition scientist Nicole Darmon (Darmon, 2009). The model developed by the authors of this publication is used in the classes of nutrition studies for bachelor and master students of catering and hotel management bachelor study programme and food science master students during the study years 2011/2012 and 2012/2013.

Results and discussion

According to the data in literature, food allowance optimization model was developed, formed by 22 food products and 8 nutrients – totally 30 constraints. According to the given rates shown in the Figure

1, in the cells C7:C28 daily allowance costs are calculated in the cell C3. Average prices of food products per kilo are given in the cells D7:D28, but in the cells D7:28 the price is recalculated for 100 g, because the particular nutritional values in the cells F7:F28 are given per 100 g of the food product (Figure 1).

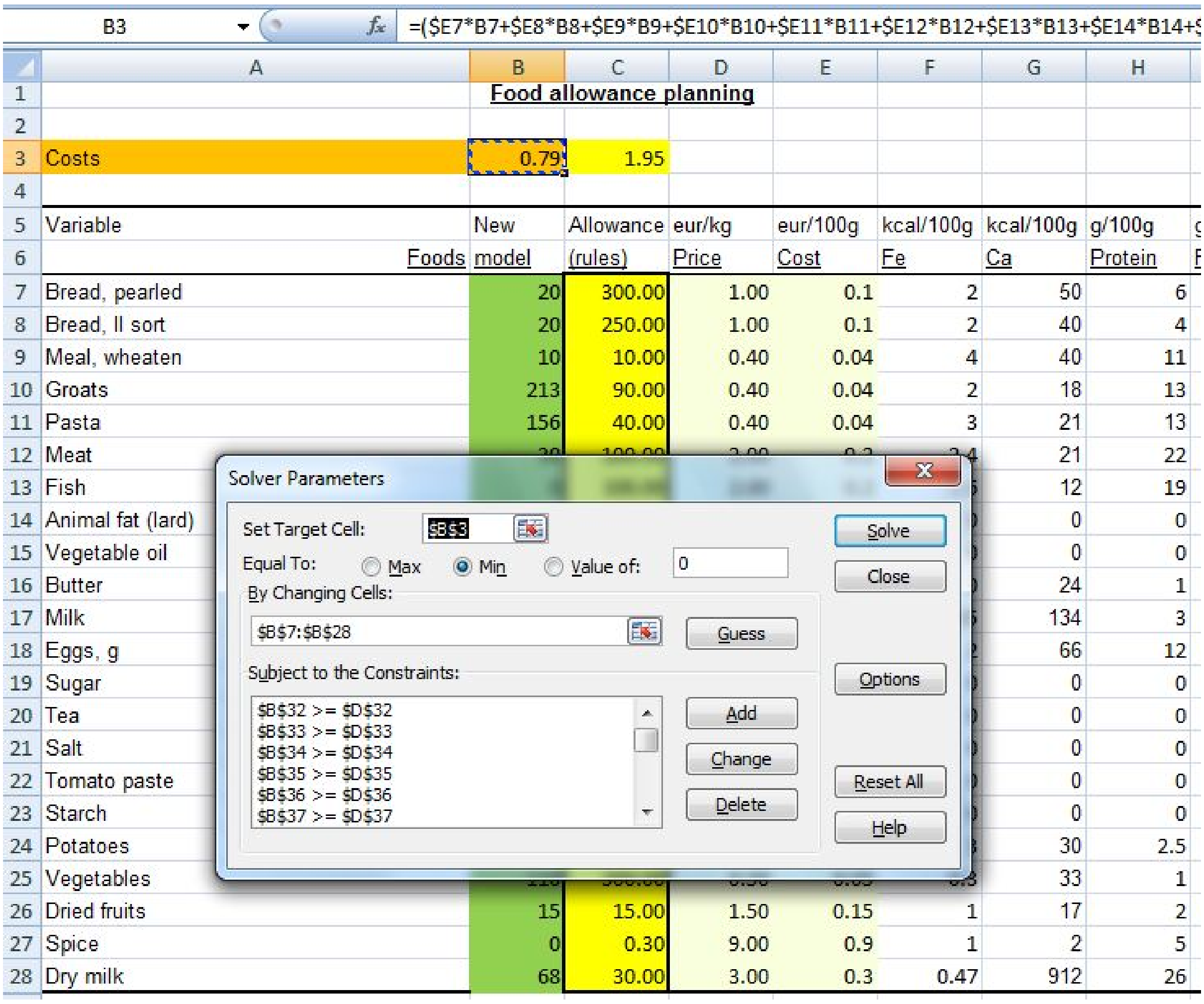

Figure 1. Solver parameters: target cell, changing cells.

The cell B3 is indicated in the window of Solver parameters *Set target cells*, where is searched the minimum of linear programming function at changeable cells B7:B28, indicated in the window By Changing cells. Subject to the Constraints are indicated all constraints $B32 > = $D32 ... $B60 > = $D60 according to the linear programming tasks.

Minimize $Z=Ax_1+Bx_2+Cx_3+Dx_4+Ex_5+Fx_6+Gx_7+Hx_8+Ix_9+Jx_{10}+Kx_{11}+Lx_{12}+Mx_{13}+Nx_{14}+Ox_{15}+Px_{16}$ $Qx_{17}+Rx_{18}+Sx_{19}+Tx_{20}+Ux_{21}+Vx_{22}$, where A...V – food price and $x_1 ... x_{22}$ – quantity of food products, by the following constraints:

1) 2x1+2x2+4x3+2x4+3x5+2,4x6+1,6x7+0,1x8+0,1x9+0,1x10+0,1x11+2x12+0,1x13+0,1x14+ 0,1x15+ 0,1x16+0,1x17+3x18+0,1x19+1x20+1x21+0,5x22≥15;
2) 2)$50x_1+40x_2+40x_3+18x_4+21x_5+21x_6+12x_7+0{,}1x_8+0{,}1x_9+24x_{10}+134x_{11}+66x_{12}+0{,}1x_{13}+0{,}1x_{14}+ 0{,}1x_{15}+0{,}1x_{16}+0{,}1x_{17}+30x_{18}+33x_{19}+17x_{20}+2x_{21}+912x_{22}\geq 800$;
3) $6x_1+4x_2+11x_3+13x_4+13x_5+22x_6+19x_7+0{,}1x_8+0{,}1x_9+1x_{10}+3x_{11}+12x_{12}+0{,}1x_{13}+0{,}1x_{14}+0{,}1x_{15}+0{,}1x_{16}+0{,}1x_{17}+2.5x_{18}+1x_{19}+2x_{20}+5x_{21}+26x_{22}\geq 80$;
4) $1x_1+1x_2+2x_3+3x_4+2x_5+15x_6+14x_7+100x_8+100x_9+82x_{10}+3x_{11}+10x_{12}+0{,}1x_{13}+0{,}1x_{14}+0{,}1x_{15}+ 0{,}1x_{16}+0{,}1x_{17}+0{,}1x_{18}+0{,}2x_{19}+0{,}2x_{20}+0{,}2x_{21}+26x_{22}\geq 80$;
5) $44x_1+48x_2+75x_3+71x_4+74x_5+1x_6+1x_7+0{,}1x_8+0{,}1x_9+0{,}1x_{10}+4x_{11}+2x_{12}+100x_{13}+20x_{14}+0{,}1x_{15}+ 25x_{16}+25x_{17}+12{,}5x_{18}+8x_{19}+10x_{20}+10x_{21}+38x_{22}\geq 360$;

6) $209x_1+217x_2+362x_3+363x_4+366x_5+227x_6+206x_7+900x_8+900x_9+742x_{10}+55x_{11}+146x_{12}+400x_{13}+80x_{14}+0{,}4x_{15}+100x_{16}+300x_{17}+60{,}9x_{18}+37{,}8x_{19}+49{,}8x_{20}+61{,}8x_{21}+490x_{22}\geq 2480$;

7) $2x_1+2x_2+0{,}1x_3+0{,}1x_4+0{,}1x_5+100x_6+160x_7+0{,}1x_8+0{,}1x_9+2500x_{10}+180x_{11}+410x_{12}+0{,}1x_{13}+0{,}1x_{14}+0{,}1x_{15}+0{,}1x_{16}+0{,}1x_{17}+0{,}1x_{18}+2000x_{19}+1500x_{20}+10x_{21}+930x_{22}\geq 12$;

8) $0{,}1x_1+0{,}1x_2+0{,}1x_3+0{,}1x_4+0{,}1x_5+0{,}1x_6+0{,}1x_7+0{,}1x_8+0{,}1x_9+0{,}1x_{10}+6x_{11}+2x_{12}+0{,}1x_{13}+2x_{14}+0{,}1x_{15}+6x_{16}+1x_{17}+15x_{18}+20x_{19}+20x_{20}+1x_{21}+0{,}1x_{22}\geq 70$;

9) $x_1\geq 20$;
10) $x_2\geq 20$;
11) $x_3\geq 10$;
12 $x_4\geq 10$;
13) $x_5\geq 10$;
14) $x_6\geq 10$;
15) $x_7\geq 10$;
16) $x_8\geq 5$
17) $x_9\geq 5$;
18) $x_{10}\geq 5$;
19) $x_{11}\geq 20$;
20) $x_{12}\geq 0{,}5$;
21) $x_{13}\geq 20$;
22) $x_{14}\geq 2$;
23) $x_{15}\geq 5$;
24) $x_{16}\geq 3$;
25) $x_{17}\geq 1$;
26) $x_{18}\geq 100$,
27) $x_{19}\geq 100$;
28) $x_{20}\geq 5$;
29) $x_{21}\geq 1$;
30) $x_{22}\geq 5$.

where coefficients at variables – amount of a nutrient per 100 g of the food product, for example, the coefficient in the equation 8 at x_{18} indicates that for the calculations assumed average content of vitamin C in potatoes is 15 mg/100, which is assumed so low taking into consideration the average amount per year by seasons and average losses of thermal treatment; constraints 1-8 in the equation indicate the minimum nutrition rates of nutrients, for example, in the equation eight the minimum rate of vitamin C is 70 mg per day; in its turn in the equation 9–22 (Figure 2, cell D32:D38) the minimum rate of certain food products are indicated, for example, in the equation 22 the set constraint for tea is ≥2 g per day, but theoretically all the equations 9-10 could have set constraint $x\geq 0$, which is mathematically correct, but is not practically applicable.

	A	B	C	D	E
24	Potatoes	110	400.00	0.50	0.05
25	Vegetables	110	300.00	0.50	0.05
26	Dried fruits	15	15.00	1.50	0.15
27	Spice	0	0.30	9.00	0.9
28	Dry milk	68	30.00	3.00	0.3
32	Iron	15	31.74	15	
33	Calcium	800	1147.22	800	
34	Proteins	80	115.94	80	320
35	Fat	80	116.03	80	720
36	Carbohydrates	360	483.65	360	1440
37	Kcal	2480	3442.62	2480	2480
38	Vit. A	3595	7729.13	12	12.90323
39	Bread, pearled	20	20	0	29.03226
40	Bread, II sort	20	20	0	58.06452
41	Meal, wheaten	10	10	0	100
42	Groats	213	20	0	
59	Spice	0	0.3	0	
60	Dry milk	68	0	0	
61	Tea of coffee minimum:		5		
62					

• Figure 2. Parameters for constraints.

The initial food allowance price is 1.95 euro, but after optimization it has decreased up to 0.79 (Figure 1, cell B3). Mutually replaced food products will be different in every country – it is determined by the price level of different food products. This model shows that bread has a very high added value, which possibly could be replaced by flour. If the constraints $x_1\geq 20$ and $x_1\geq 20$ would be fixed theoretically allowable $x_1\geq 0$ and $x_1\geq 0$, then bread would be generally excluded. If such situation is allowable in relation to bread, then it is not allowable concerning tea or coffee, what mathematically, as being the most expensive products, are first excluded, but which in terms of money make only a very little part of the daily food allowance and which have a big influence on quality of the menu by meeting the customer`s requirements.

Also during the last year several articles have been published, where application of linear programming for compiling a menu is described. Following the recent tendencies, in one of the publications (Macdiarmid, 2012) is analysed possibility to limit greenhouse gas emissions by consuming in nutrition more those food products, for growing of which climate changing gasses are not emitted. In its turn German researchers (Jati, Vadivel, Nohr, Biesalski, 2012) have applied linear programming by using POM-QM for Windows – computer programme, which is planned to be used for quantity methods, operation management and science management. In this research improved Indonesian people`s daily menu is analysed and modelled with the aim to avoid micronutrient deficiency. Researches on nutrition balance also touch upon economic issues. The essence of the issue – how to reduce resources and increase amount of nutrients to be consumed (Gingule B., Rucins M., Rozenbergs, 2011). The group of researchers working on development of ready-to-eat therapeutical food (Dibari, 2012), have used linear programming for optimum balance of soya, sorgo, maize, vegetable oil and sugar in ready food, in order to obtain optimum mixture of basic nutrients. Although food pyramid formally is already withdrawn since 2005 (Rozenbergs, 2008), still food pyramid is being applied for developing food models by applying linear programming, for example, a group of researchers at Public Health school, Washington University, has developed a model for balancing sugar and fat, in order to reach the aims set by the food pyramid (Mailot, Drewnowski, 2011).

Issues of this research field are surveyed not only in the scientific journals of nutrition science, but also in the journals of information technology and mathematic sciences. The researchers group from Sri Lanka (Piyaratne, 2012) has worked out a model for optimum fattening of broilers by using, as mentioned in the publication, even 1800 constraints. In its turn mathematicians from Malaysia (Mamat, 2012) have tried to compile a menu by applying irregular (fuzzy) linear programming approach.

The greatest research on this field is carried out by the French scientist of nutrition science Nikola Darmon, who has several publications with many co-authors (Darmon, 2009; Rambelson, 2008; Darmon, 2008; Ferguson, Darmon, Briend, Premachandra, 2004; Briend, Ferguson, Darmon, 2001), from which as the first research could be considered the one published already in 1999 (Darmon, 1999).

From the aspect of pedagogical and particularly IT training, the essential issues are when, what and in what context to teach (Straesser, 2007), especially it concerns elementary school, where is huge students` potential for training mathematical intellect, although in reality it is not often developed, but on the grounds of good intentions, it is even hindered (Espinoza, Barbe, Galvez, 2011). Quite many publications are devoted to training Excel, one of the latest is on Excel training and use in operation guidance (He, 2012).

There are certain things in different education programmes and study subjects, which have to be studied – it could be either to learn how to solve a quadratic equation or to know exactly which year a certain war has started and which year it has finished. Nutrition studies are very wide and often scientifically and socially contradictory; moreover, the acquired knowledge has to be taken into consideration in daily life. Frequently it is pointed out, that nutrition studies, which could be both, a component of health education and housekeeping study subjects, are not to be taught theoretically, but by the teacher`s pattern, besides, the headmaster should have good figure without overweight, non-smoker, etc., who could deliver the positive message through himself to formal and non-formal school leaders (Schee, 2009).

There is still an open question about what has to be taught at the university, for example, should students of economics be taught mathematics at all (Mallik, Basu, 2009). Certainly, if the study programme is developed so, that after finishing the study programme the student receives the qualification of economist, then mathematics is necessary and on a very high level with certain specialization; if the student is granted a degree of social sciences in economics, then they could do also without mathematics.

In the context of nutrition studies the question is – what does a pupil of the 7th form needs to acquire in the nutrition studies, and specifically, calculating with paper and pencil, calculator or Excel worksheet? Not only bureaucratically formulating, that by finishing elementary school the pupil „is able to compile and considers healthy menu" (LR MK not.nr. 1027 no 19.12.2006). Yes, by finishing elementary school the pupil „is able to compile and consider healthy menu". Then why the resources of state and private persons have to be wasted by studying for several years? Several professions are defined in the profession classificatory, which correspond with the skill „to compile (or plan?) a menu" – nutrition specialists, specialists in nutrition science, specialists in art, culture and cookery. Besides, there is no demand for the profession „cook" to compile a menu (LR MK not.nr. 461 no 18.05.2010). What does it mean „to compile a healthy menu"? It can be only calculation of basic nutrients and energy value; it can also be calculation of definite number of vitamins and minerals. Several authors attach a special importance even to particular microelements, especially – iodine (Bobiniene, Gudavičiute, Miškiniene, 2010), content of which is defined as a quality indicator of meat (Čepuliene, Bobiniene, Sirvydis, Gudavičiute, Miškiniene, Kepaliene, 2008), with this also as a provision of balanced food allowance.

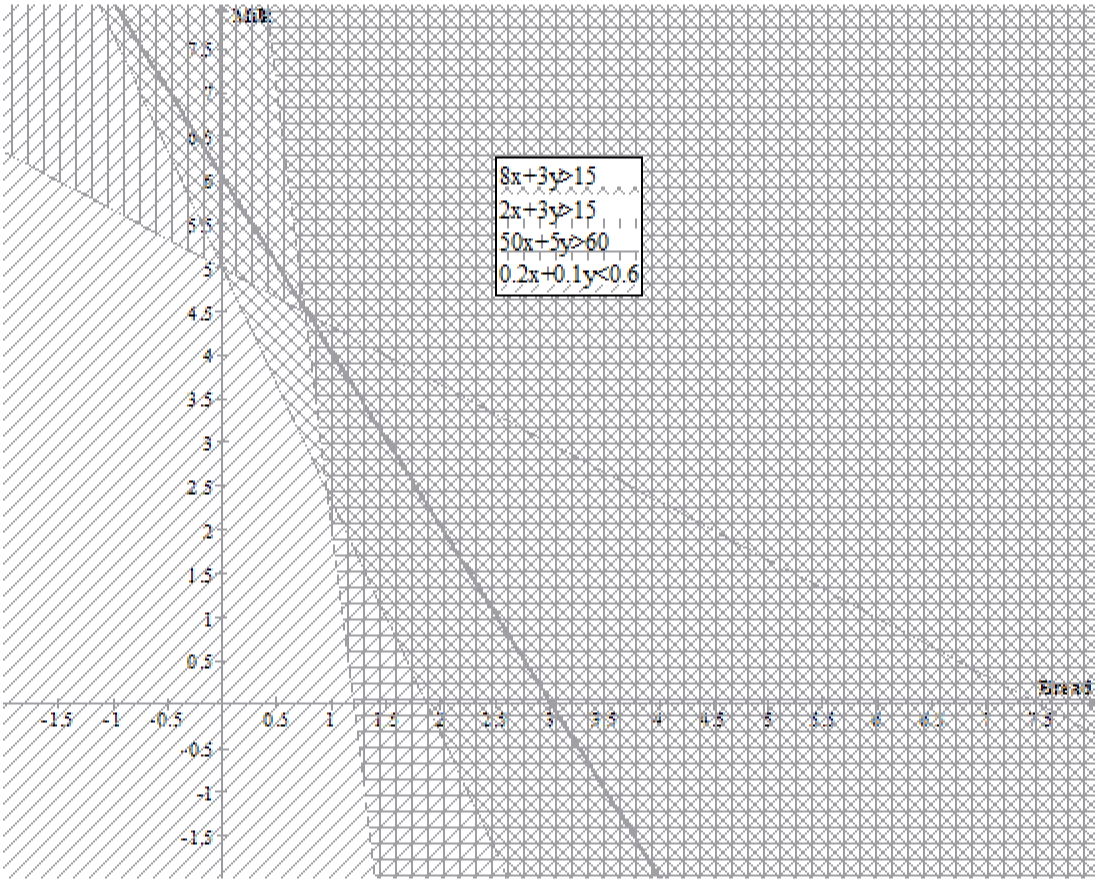

Figure 3. Two-dimension graphical model for nutrient balance.

When approbating the developed model during classes of nutrition studies, it was concluded, that it is possible to consider and analyse the particular model during one academic hour. For development of a new model several hours would be necessary, which are not planned in the curricula, but for an individual work there is no necessary preliminary knowledge in mathematics and computing. On the other hand, such sample could be used at school to acquire deeper knowledge in particular subjects, for example, developing two-dimension or three-dimension model, which can be shown also graphically, for example,

1) two-dimension model for bread with milk– x1>0, x2>0, 8x1+3x2≥15, 3x1+3x2≥15, 50x1+5x2≥60 (Figure 3);
2) three-dimension model for bread with butter and milk x1>0, x2>0, x3>0; 4x1+0,85x2+4x3≥15, 4x1+82x2+4x3≥15, 50x1+0,01x2+5x2≥60.

The figures illustrate mathematical essence of constraints. The two-dimension model, although simple, graphically shows the essence of constraints. It would be recommended to start explanation of menu optimization model to students with the graphical model. The three-dimension model is less graphical and more complicated to be formed, what does not justify the applied effort for the development of this graphical model. This approach is approbated during training classes.

Conclusions

1. With the linear programming methods by using MS Solver tool, it is possible to balance the daily allowance, consisting of 22 food products.
2. For practical calculations as constraints have to be set not only nutrients within the range of their daily rate and food products, each more than a null, but certain minimum amounts have to be used for food product constraints, that could meet the customer`s requirements.
3. The developed model is approbated during the classes of nutrition studies and it is concluded, that during one academic hour it is possible to consider and analyse the particular model.
4. The model developed by authors can be used not only for optimization of food allowance, but also in the study process of nutrition classes.

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