LINEAR PROGRAMMING LOCAL COST NUTRITION OPTIMIZATION MODEL

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Abstract: The aim of this paper is to develop a linear programming optimization model of food consumption to meet daily nutrients needs of the standard woman and the standard man at the minimal cost respecting the World Health Organization (WHO) standards. The cost of food, subject to be minimized, is defined as the objective function in the optimization model. The sample used in this research consists of 59 most frequently used food items as decision variables which are selected based on a survey of 50 households in the capital of Bosnia and Herzegovina. Results are obtained in the form of a minimal cost of daily shopping list that will satisfy micronutrient and macronutrient needs.

Key words: linear programming, optimization, modeling, cost, nutrition

1. INTRODUCTION

Paper (Briend et al., 2001) illustrates how linear programming techniques can be used to determine a nutritionally adequate diet of the lowest cost with an example based on a food price survey performed in Mao, the main city of Kanem Province in Chad for a child aged three to six years. In the analysis, only local traditional food is taken into the model. This research emphasizes benefits of this approach in evaluating the economic benefits of food aid programs.

Study (Maillot et al., 2008) tests the hypothesis how food nutrient profiling ranks may help to identify food with adequate nutrition quality for its price using linear programming model.

Study (Maillot et al., 2009) develops linear programming model which selects an individual weekly diet that meets current nutrient recommendation which approximates person's food intake pattern. Results show that high percentage of adults would need to expand their weekly food repertoire to fulfill nutrient recommendations.

Article (Kopir et al., 2009) shows application of linear programming model to household data in Vihiga district, and determines optimal household consumption bundle of locally available food commodities and the associated expenditures meeting dietary needs. Results show that household incomes are not sufficient to meet nutrient requirements.

Research (Rysiana et al., 2010) investigates the nutrient sufficiency of an adult female in Aceh Besar regency. Results show requirements for minimum food consumption expressed in money value per body mass weekly.

Study (Maillot et al., 2011) develops a linear programming model with age and gender food patterns. The optimized food pattern suggests more vegetables and food intake and lower energy density according to Dietary Guidelines Advisory Committee.

2. RESEARCH METHODOLOGY

In this paper linear programming optimization model is developed with the aim to create optimal food shopping list at the minimal cost while meeting micronutrient and macronutrient constraints defined by WHO including energy requirements.

WHO defines human energy requirement as constraint as well. In order to determine individual energy needs a model of standard male and standard female is used. WHO defines standard male person as 25 years old healthy man with an average weight of 65 kg and low active lifestyle, while standard female person is defined as 25 years old healthy woman with an average weight of 55 kg and low active lifestyle.

Beside the energy provided by macronutrients such as carbohydrates, fats and proteins, needs for certain types of micronutrients such as vitamins A, C, D, folate, iron, calcium and sodium are taken into consideration. These nutrients are taken into account because lack or excess of these nutrients is associated with the most frequent health problems.

WHO suggests recommended (RNI) and upper limit (UL) nutrient intake as well as recommended energy needs.

The food is divided into 7 major groups according to modified Shermann scheme: 1. cereals, bread and pasta (including snacks); 2. sugar and sugar concentrates; 3. fat (including nuts); 4. meat, fish and eggs; 5. milk and dairy products; 6. fruits and 7. vegetables.

Modification of the Shermann scheme is as follows: snacks are included in the first group, nuts are included in the third group and fruits and vegetables are grouped separately. Optimal division of energy intake should be as follows: 35% from group 1, 10% from group 2, 15% from group 3, 10% from group 4, 15% from group 5, 7,5% from group 6 and 7,5% from group 7.

Selection of the food commodities used in this research is obtained from a survey of random sample of 50 households in the capital of Bosnia and Herzegovina in February and March 2011. Based on this survey, 59 food commodities are selected as follows: 11 cereals food items, 4 from sugar group, 8 from fats, 7 from meat, fish and eggs group, 9 from milk and dairy products group, 9 from fruits and 11 from vegetables groups.

Retail prices of selected food commodities are taken from major shopping centers in the capital of Bosnia and Herzegovina. Research of the retail prices was conducted in March 2011. Prices are expressed in local currency convertible mark (KM).

3. MATHEMATICAL MODEL AND RESULTS

Mathematical model is expected to minimize food cost criteria while fulfilling macronutrient and micronutrient requirements.

Objective function in the developed model is defined by equation (1):

$$Minimize\ Z = C_1 x_1 + C_2 x_2 + \cdots + C_i x_i + \cdots + C_n x_n \quad (1)$$

where:
Z = total cost of food identified by model,
$1 \leq i \leq n$,
$n = 59$,

x_i = decision variables representing weight of selected food commodity expressed in grams per day,

C_i = cost of decision variable x_i expressed per unit weight of food commodity.

Constraints in the linear programming model are defined using WHO standards for the recommended and upper limits of daily intake of micronutrients and macronutrients as shown in table 1, and optimal division of energy intake as described above.

Thus the minimization of the objective function is subject to the following constraint nonequalities:

$$a_{j1}x_1 + a_{j2}x_2 + \ldots + a_{ji}x_i + \cdots + a_{jn}x_n \geq (RNI)_j \quad (2)$$

$$a_{j1}x_1 + a_{j2}x_2 + \ldots + a_{ji}x_i + \cdots + a_{jn}x_n \leq (UL)_j \quad (3)$$

$$x_i \geq 0 \quad (4)$$

where:

j = number of a micronutrient or macronutrient shown in table 1, j = 1 to 10

a_{ji} = content of jth micronutrient or macronutrient per unit weight of ith food commodity.

Energy intake, as well as optimal division of energy intake constraints, are prescribed as equality.

A standard software package was used to solve developed linear programming optimization model and generate results of the minimization process.

Model results of daily consumption of food commodities according to modified Shermann scheme are given in table 2.

According to the results of the developed model 3,47 KM for the standard man and 3,38 KM for the standard woman are calculated as a minimum food cost per day while meeting micronutrient and macronutrient requirements.

Optimal solution for the standard man consists of 15,28%, 3,44%, 2,64% 8,04%, 39,14%, 10,92% and 20,54% of food commodities of groups 1-7 respectively. Optimal solution for the standard woman consists of 15,26%, 3,46%, 2,28%, 7,79%, 43,43%, 7,24% and 20,54% of food commodities of groups 1-7 respectively.

Out of 59 food commodities included in the model, optimal solution comprises only 12 for both genders.

Nutrients	Standard Man		Standard Woman	
Energy, kcal/d	=	2590	=	2017
Protein, g/d	≥	63	≥	49
Protein, g/d	≤	95	≤	74
Carbohydrate, g/d	≥	347	≥	271
Carbohydrate, g/d	≤	474	≤	369
Fat, g/d	≥	42	≥	33
Fat, g/d	≤	84	≤	65
Vitamin A, µg/d	≥	300	≥	270
Vitamin A, µg/d	≤	600	≤	500
Vitamin C, mg/d	≥	45	≥	45
Vitamin C, mg/d	≤	1000	≤	1000
Vitamin D, µg/d	≥	5	≥	5
Vitamin D, µg/d	≤	50	≤	50
Folate, µg/d	≥	400	≥	400
Folate, µg/d	≤	1000	≤	1000
Calcium, mg/d	≥	1000	≥	1000
Calcium, mg/d	≤	3000	≤	3000
Iron, mg/d	≥	8	≥	18
Iron, mg/d	≤	45	≤	45
Sodium mg/d	≥	1000	≥	1000
Sodium mg/d	≤	2000	≤	2000

Tab. 1. RNI and UL micronutrient and macronutrient intake

Modified Shermann scheme	Standard Man	Standard Woman
Group 1	249 g/d	194 g/d
Group 2	56 g/d	44 g/d
Group 3	43 g/d	36 g/d
Group 4	131 g/d	99 g/d
Group 5	638 g/d	522 g/d
Group 6	178 g/d	92 g/d
Group 7	335 g/d	261 g/d

Tab. 2. Daily consumption of food commodities

4. CONCLUSION

The results of this research show that for the standard woman and the standard man it is possible to develop reliable linear programming model which minimizes the cost of food commodities as the objective function while meeting the required micronutrient and macronutrient needs as model constraints.

Limitation of the model is that it is developed for daily needs of the standard woman and the standard man and thus doesn't include food variety consumption as a function of time (time series) as natural human need.

Future research, beside considered micronutrients and macronutrients requirements, should also incorporate more goals in the model like: biological values of food commodities with respect to content of fats, carbohydrates and amino acids, content of antioxidants in food commodities and maximum food budget.

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