Fighting undernourishment in Ukraine with linear optimization

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Abstract

Using linear optimization we developed diet for people who live at subsistence wage in Ukraine. Proposed diets satisfies all the nutrition needs for adult people.

1 Introduction

According to different researches of International Organizations, percentage of poor people in Ukraine reaches up to 60%. These people live in terrible living conditions and struggle to survive each day. To somehow provide them with minimal necessary basket of good and services Ukrainian government developed subsistence wage.

Subsistence wage is abstract monetary value, that established by Ukrainian government and reconsidered each couple of months. It is widely used to calculate minimal wages and various social benefits – unemployment benefits, pensions, payments to low income families and families with more than 2 children, invalidity benefit.

According to Ukrainian law[1], subsistence wage is enough to provide physical survival as well as social and cultural development to a person. It includes food expenses, non-food expenses (such as clothes, medicine, electronics, furniture) and services (utility expenses and entertainment).

Subsistence wage is calculated for four age groups: small children, teenagers, adults and old people. As at October, 2017, subsistence wage is 1,624 UAH ($\approx$ 61 USD) on average for all age groups[2].

Subsistence wage in Ukraine is highly criticized. It is said to be too low to even cover food costs, forgetting about non-product goods and services.

We are not here to criticize, but try to find a solution. The main aim of this paper is to find daily product basket with minimal value that satisfies all the daily nutrition needs. This basket will be an advice for poor people what products to buy and how to cook them in order to gain all the nutrients needed.

2 Methodology

We chose to develop diet for adult people, but model can be easily updated for each age group – only by changing daily nutrition rates. As at October, 2017, subsistence wage for adult people is 1684 UAH, while food expenses takes share up to 50% of the budget (842 UAH, $\approx$31 USD).

As subsistence wage is the same for men an women, but daily nutrition rates for men are higher, we decided to optimize budget for men. We used nutrition rates for men, 30-60 years old. The solution is applicable to woman diet as they need less.

We chose to collect prices in Lviv city region, but model can be updated to any other regions as well – by changing price vector.

We used United States daily nutrition rates - they are higher than those in Ukrainian sources.

We collected data both on raw and boiled/roasted products because some product change their nutrient composition under thermal processing. Our solution gives optimal product basket as well as the type of thermal processing.

3 Data Description

We collected data on prices of products available in Ukrainian market (in UAH per kilogram), nutrient composition of each product (g/mg of element contained in 1 kg of product), recommended daily intakes for nutrients and maximum daily intakes for some nutrients as well (in the same units of measurement - g/mg).

To prepare data for our model we used 4 types of data sets:

1. Food nutrients information from USDA [3] and AUSNUT [4] datasets;
2. Nutrients recommended and upper limit daily intakes from DRI: Dietary Reference Intakes report by Institute of Medicine of the National Academy of Sciences [5], other publications on NCBI web resource [6], Human energy requirements report by FAO/WHO/UNU [7];

3. Prices on food in Ukraine by State Statistics Service of Ukraine [8], online food store Auchan [9] and grocery market Shuvar [10];

4. Our custom datasets like cooking coefficients, join tables, header lists, units conversion, nutrients unification, translation, etc.

Since USDA database had no information on Iodine, Omega-3 and Omega-6 nutrients, we decided to use additionally AUSNUT database, where these measurements were done. For proper calculations, we joined plain and added nutrients, like in case of vitamin E, which were measured in USDA data set separately.

For final model we selected 51 basic food products (both raw and cooked) and 32 parameters for each product (26 nutrients, 3 macronutrients, energy and price). We didn't use products that cannot be consumed raw (such as meat, eggs, wheat, pasta, mushrooms). We used coefficient to adjust price vector of raw products if product change its weight while cooking.

Nutrient Fluorine was excluded from analysis as we gain Fluorine from water and water is free in Ukraine.

For convenience, we imputed large values in maximum daily intake vector for those nutrients that do not have upper limits.

As a result, we have a product/nutrient pivot table, prices table and RDI table.

4 Mathematical Model

The model is not new. It is widely used to find cheap diet for animals in agriculture [11, 12] as well as for people [13].

Mathematical model is expected to minimize budget spent on products. Model has two constrains - fulfill daily nutrition rates and not exceed maximum safe rates for some nutrients.

Let x_i be the number of units (kg in our case) of food i to be consumed per day and p_i be the price of 1 kg of food i. So the function to minimize is:

$$p_1x_1 + p_2x_2 + ... + p_mx_m \rightarrow min$$

Let a_{ij} be the number of nutrient i that contains in 1 kg of product j. In our model nutrients have various units of measurement. Let b_i be the daily rate for nutrient i and b_i^{max} be the maximum safe amount of nutrient i to be consumed per day.
So the constrains have the following form:

$$b_1 <= a_{11}x_1 + a_{12}x_2 + ... + a_{1m}x_m <= b_1^{max}$$

$$...$$

$$b_n <= a_{n1}x_1 + a_{n2}x_2 + ... + a_{nm}x_m <= b_n^{max}$$

Of course, we need nonnegative x's.

$$x_1, x_2, ..., x_m >= 0$$

Additionally, we added constraints to make diet diverse. Daily consumption of the same product have to be less than 0.25 kg per day.

$$x_1, x_2, ..., x_m <= 0.25$$

At the same time we developed alternative approach for the case when minimal budget amount from the previous model (Diet Problem) will be higher than share of food expense in subsistence wage. In this approach we minimize discrepancies from the daily nutrition rates while budget is fixed.

Let B be the budget to be spent on food. Let x_i, p_i, a_{ij}, b_i, b_i^{max} be as defined in the previous model.
Let d_i be discrepancy - the share of daily rate of nutrient i that is not gained from product basket.

$$d_i = \begin{cases} 0, & if \ \sum_{j=1}^{m} a_{ij}x_j >= b_i \\ 1 - \sum_{j=1}^{m} /b_i, & if \ \sum_{j=1}^{m} a_{ij}x_j < b_i \end{cases}$$

So the function to minimize is:

$$d_1 + d_2 + ... + d_n \rightarrow min$$

With budget constraint:

$$p_1x_1 + p_2x_2 + ... + p_mx_m <= B$$

And upper limit constraints:

$$a_{11}x_1 + a_{12}x_2 + ... + a_{1m}x_m <= b_1^{max}$$

$$...$$

$$a_{n1}x_1 + a_{n2}x_2 + ... + a_{nm}x_m <= b_n^{max}$$

As usual, x's are nonnegative.

$$x_1, x_2, ..., x_m >= 0$$

First model is linear and can be solved by simplex method. Second problem is nonlinear, so it requires other approaches (gradient descent, etc).

5 Results

Initially we started with smaller list of product (about 20), just to check how algorithm works. We were not able to find cheap product basket, so we tried alternative approach - minimize nutrient rate discrepancies. The model helped us to see the problem. There were no cheap products that contain enough Omega-3, Omega-6, Potassium, Calcium and Vitamin D. So we expanded product list by adding cheap products rich in these nutrients.

Finally, we solved standard Diet Problem and found family of baskets that costs about 25-35 UAH (0.9-1.2 USD) per day. Their weight is about 2.2 kg of food per day. Of course, all of them satisfy constrains listed above. See Table 1 for examples of the product baskets.

We set the goal to find not the single solution (the global minimum), but to offer options, so people can choose depends on their tastes. Besides, this approach makes it possible to notice common tendencies.

To solve problem we used *boot* library in R, *simplex* function. To find a set of solutions, we varied price vector - make discrepancies from the initial prices vary according to normal distribution with mean = 0 and standard deviation = 0.25 and each time recalculated global minimum of new problem. This approach makes it possible to change weight of the products in the final solution and find not just the global minimum but some solutions nearby. Final basket prices were calculated in initial prices, of course. As a result we get 1000 distinct solutions. Next, we selected 65 most distinct basket sets by setting euclidean distance between each two baskets at least 0.5. As a result, there is no duplicates or very similar solutions in the final solution family.

We noticed some tendencies. We see that there are many product that not included to any cheap diets among these 1000, such as beef, pork, chicken, butter, oranges. It means that these products is not the source for cheap nutrients. On the other hand there are also products, that occur in most baskets - bread, pasta, sunflower oil, eggs, potato, sugar, oatmeal and herring. These products have to be consumed to satisfy nutrition needs within the low budget (See Table 1).

We analyzed model bottlenecks as well. We noticed that there are still some nutrients, such as Vitamin D, Calcium, Potassium, Carbohydrate and Omega-3, that in most solutions are consumed just at the recommended level (See Table 2). If there were some cheap products with these nutrients, product basket price can be even lower.

6 Conclusions and Future work

Our model is not a cure. It has its limitations.
- Nutrient composition of products in Ukraine may be different from those in United States.
- We restricted consumption of the same product per day to 0.25 kg per day for every product. Better to establish different limits for different products.
- We didn't include some elements in our model (Cobalt, Boron, Sulfur, Chrome) as we could not find data.
- Further consultation with nutritionist is needed. Because we, as data scientists, might forget some important diet rules.

However, results are unexpectedly good. This model, when improved, may solve the problem of undernourishment not only in Ukraine, but in other countries as well. Model could be adjusted for different age groups and people with special nutrition needs. One can develop an application to collect data on products available in the market and their prices and recalculate optimal solution, so price change and seasonality will be taken into consideration.
Our model may be interesting for governments and charity organizations.

7 References

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APPENDICES

APPENDIX A. More resources

You can find additional description and output of our research on the github:
https://github.com/mgontar/NutsPassion

- Initial dataset
- iPython script for processing data
- Final dataset
- R Script for family of solutions
- Excel workbook with 65 the most distinct product baskets
- Solution visualization with Shiny.app

APPENDIX B. Data Tables

Table 1. Solution Examples and Popularity of products

Product Name	Price per kg, UAH	Share of baskets with nutrient	№1	№9	№51	№60
Rice (boiled)	7.04	31%	-	-	-	-
Wheat bread (raw)	12.37	82%	0.25	0.25	0.25	0.20
Rye bread (raw)	12.25	85%	0.07	0.05	0.02	0.07
Beef (boiled)	179.41	2%	-	-	-	-
Beef (roasted)	173.85	0%	-	-	-	-
Pork (boiled)	171.47	0%	-	-	-	-
Pork (roasted)	151.31	0%	-	-	-	-
Chicken (boiled)	73.82	0%	-	-	-	-
Chicken (roasted)	85.17	2%	-	-	-	-
Salo (raw)	60.06	17%	-	-	-	0.06
Salo (roasted)	100.12	0%	-	-	-	-
Pasta (boiled)	4.22	85%	0.25	0.25	-	-
Buckwheat (boiled)	6.11	29%	-	0.25	0.25	0.05
Pork/beef sausage (raw)	72.68	0%	-	-	-	-
Milk (raw)	17.46	25%	0.10	0.21	-	-
Cream (raw)	45.73	0%	-	-	-	-
Butter (raw)	149.2	0%	-	-	-	-
Cottage cheese (raw)	96.12	0%	-	-	-	-
Sugars (raw)	15.58	74%	0.03	0.00	0.08	0.10
Sunflower oil (raw)	32.76	80%	0.03	0.03	0.05	0.01
Eggs (boiled)	19.38	71%	0.25	-	0.25	-

Eggs (roasted)	25.83	48%	-	0.14	-	0.20
Potatoes (boiled)	7.59	49%	0.09	-	0.05	0.20
Potatoes (roasted)	9.13	51%	0.25	0.24	0.25	-
Cabbage (raw)	5.41	60%	0.25	-	0.25	0.20
Cabbage (boiled)	5.88	62%	-	0.25	-	-
Carrots (raw)	7.7	60%	0.05	0.05	-	-
Carrots (boiled)	7.74	40%	-	-	0.05	0.20
Beets (raw)	5.41	49%	-	-	0.25	0.05
Beets (boiled)	5.7	43%	-	0.25	-	0.20
Onions (raw)	5.94	28%	-	-	-	-
Onions (boiled)	8.02	15%	-	-	-	0.20
Salt (raw)	4.35	0%	-	-	-	-
Oranges (raw)	40	0%	-	-	-	-
Green beans (raw)	20	5%	-	-	-	-
Sunflower seeds (raw)	40	31%	-	-	-	-
Pumpkin seeds (raw)	90	2%	-	-	-	-
Walnuts (raw)	220	58%	0.01	0.01	-	0.01
Oatmeal (boiled)	4.85	77%	0.25	0.25	0.25	-
Portabella mushrooms (boiled)	57.2	0%	-	-	-	-
Figs (raw)	110	0%	-	-	-	-
Radishes (raw)	5	38%	0.25	-	-	-
Tomatoes (raw)	22	0%	-	-	-	-
Sweet peppers (raw)	47.5	0%	-	-	-	-
Hot peppers (raw)	25	35%	-	-	0.04	-
Garlic (raw)	34	35%	0.05	-	-	0.16
Parsley (raw)	40	9%	-	-	-	-
Dill weed (raw)	50	5%	-	-	-	-
Herring (raw)	50	97%	0.09	0.11	0.05	0.09
Sardine (oil) (canned)	104	25%	-	-	0.07	-
Sardine (tomato sauce) (canned)	88	12%	-	-	-	-
Basket Price, UAH			28.97	29.95	30.82	33.74
Basket Price, kg			2.26	2.35	2.17	2.00

Table 2. Mean daily nutrition rates, averaged by 1000 optimal baskets.

Nutrient/Vitamin	Recommended daily intake	Mean by optimal baskets	Status
Vitamin A	900	1,508.5	
Vitamin C	90	253.3	
Vitamin D	15	15.0	rare nutrient
Vitamin E	15	25.3	
Vitamin K	120	383.8	
Vitamin B1	1.2	2.5	
Vitamin B2	1.3	2.6	
Vitamin B3	16	32.8	
Vitamin B6	1.3	3.7	
Vitamin B9	400	878.4	
Vitamin B12	2.4	7.2	
Vitamin B5	5	8.7	
Vitamin B4	550	879.7	
Calcium	1000	1,001.1	rare nutrient
Copper	0.9	2.1	
Iodine	150	326.2	
Iron	8	23.3	
Magnesium	420	526.4	
Manganese	2.3	8.5	
Phosphorus	700	1,972.7	
Selenium	55	266.1	
Zinc	11	13.9	
Potassium	4700	4,700.8	rare nutrient
Sodium	1500	2,264.5	
Carbohydrate	410	412.2	rare nutrient
Fibers	38	45.7	
Fats	98	103.2	
Omega-3	1.6	1.6	rare nutrient
Omega-6	17	42.2	
Proteins	102	119.9	
Energy	3000	3,019.4	rare nutrient