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Economic-Mathematical Model of the Structure of Nutrition of Population in the Region

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Abstract

The problem of food security has traditionally been at the centre of attention of domestic and foreign economic science and practice. It was connected with the challenges of world development and the growth of global contradictions. One of the most important areas of study of food security is the modelling of this socio-economic process. When making management decisions, not only expert, but also mathematical methods are used. The most common form of mathematical methods is economic and mathematical modelling. It is generally accepted, that mathematical model is a representation of certain processes, which occur in a real object, and are described using mathematical theorems, formulas and symbols. The essence of economic and mathematical modelling consists in the description of socio-economic systems and processes, in the form of economic and mathematical models. Based on the linear programming methods, the economic-mathematical model of food security has been developed in this paper, taking into account the specifics of the region, gender of the subject, his type of activity, lifestyle and age characteristics. This model helps to determine the optimal nutrition structure, which is a determining factor of food security. Cost minimization is the objective function in this model. Developed model of the structure of nutrition of population in the region is considered on the example of the Republic of Tatarstan of the Russian Federation.

Keywords: Food security, Economic; Mathematical model.

1. Introduction

One of the acute problems of our time, which is constantly solved by the world community, as well as by the representatives of national governments and local authorities, is the problem of food security of population. It should be noted that food security presupposes the creation of appropriate favourable conditions for solving the food problem. It is also necessary to maintain the situation in the food sector, when a risk of a food problem would be minimal (Antamoshkina, 2014; Krass and Chuprynov, 2006).

Economic and mathematical modelling is a branch of economic science, which studies the problems of development and investigation of different economic and mathematical models, as well as their applications. Economic and mathematical modelling is based on the development of various models and is one of the system-wide methods of research. It allows to identify the factors, affecting changes in the object; to find the patterns of the process of changing and its consequences; to determine the possibilities and expenses of influence on the course of changes. The finding of optimal nutritional structure of different population groups is the determining factor of food security, not only for the country as a whole, but also for a particular region (Naydanova and Tushkaeva, 2015). To this end, the formalized economic-mathematical model was developed in this paper. Its application was considered on the example of the Republic of Tatarstan of the Russian Federation (Antúnez and Ganga, 2017; Larichev *et al.*, 2003) .

2. Methodology

Linear programming methods were used to develop the model of the optimal structure of population nutrition in the region. In order to formalize and to develop the model of the structure of nutrition of various groups of population in the region, we introduce the following variables and designations:

x_1 – is a daily consumption of bread and bread products (in terms of flour) (in grams);
x_2 – is a daily consumption of potatoes (in grams);
x_3 – is a daily consumption of vegetables, melons and gourds (in grams);
x_4 – is a daily consumption of fruits and berries (in grams);
x_5 – is a daily consumption of meat and meat products (in grams);
x_6 – is a daily consumption of milk and milk products (in terms of milk) (in litres);
x_7 – is a daily consumption of eggs (in pieces);
x_8 – is a daily consumption of vegetable oil, margarine (in grams);
x_9 – is a daily consumption of sugar and confectionery products (in grams);

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x_{10} – is a daily consumption of fish and fish products (in grams);

i – is the type of a product, included in the main list ($i = \overline{1,10}$);

c_i – is the cost of a product of the i-th type for 1 kg, with the exception of eggs and milk. (The cost of eggs is given for a dozen, and the cost of milk - per litre);

b_1 – is the norms of calories consumption per day, recommended by the World Health Organization (WHO), per day, taking into account the gender, type of activity, lifestyle and age characteristics of a person;

b_2 – is the norms of proteins consumption per day, recommended by WHO, taking into account the gender, type of activity, lifestyle and age characteristics of a person;

b_3 – is the norms of fats consumption per day, recommended by WHO, taking into account the gender, type of activity, lifestyle and age characteristics of a person;

b_4 – is the norms of carbohydrates consumption per day, recommended by WHO, taking into account the gender, type of activity, lifestyle and age characteristics of a person;

a_{i1} – is the content of calories in 100 g of product of the i-th type ($i = \overline{1,10}$);

a_{i2} – is the content of proteins in 100 g of product of the i-th type ($i = \overline{1,10}$);

a_{i3} – is the content of fats in 100 g of product of the i-th type ($i = \overline{1,10}$);

a_{i4} – is the content of carbohydrates in 100 g of product of the i-th type ($i = \overline{1,10}$);

N_i – is the medical norms of consumption of a product of the i-th type per day, recommended by WHO, taking into account the gender, type of activity, lifestyle and age characteristics of a person ($i = \overline{1,10}$).

For this task, the goal is to form an optimal daily diet with minimal cost. The objective function is as follows:

$$F = \frac{1}{1000}\sum_{\substack{i=1 \\ i\neq 6,7}}^{10} c_i x_i + c_6 x_6 + \frac{1}{10} c_7 x_7$$

The first type of restrictions is imposed on the norms of consumption of calories, fats, proteins and carbohydrates per day, recommended by WHO, taking into account the gender, type of activity, lifestyle and age characteristics of a person. Given that the average weight of 1 egg is 60 grams, and the fat content in a litre of milk is 2.5% - 3.2% - 1.027 kg, these restrictions will take the form:

$$\frac{1}{100}\sum_{\substack{i=1 \\ i\neq 6,7}}^{10} a_{ij} x_i + \frac{60}{100} a_{6j} x_6 + \frac{1027}{100} a_{6j} x_6 \geq b_j \quad (j = \overline{1,4})$$

or

$$0{,}1\sum_{\substack{i=1 \\ i\neq 6,7}}^{10} a_{ij} x_i + 0{,}6 a_{6j} x_6 + 10{,}27 a_{6j} x_6 \geq b_j \quad (j = \overline{1,4}).$$

The second type of restrictions is imposed on the norms of products consumption, recommended by WHO, taking into account the gender, type of activity, and lifestyle and age characteristics of a person. So,

$$x_i \geq N_i \quad (i = \overline{1,10}).$$

Thus, we obtain the following formalized economic and mathematical model of food security, taking into account the specifics of the region, gender, type of activity, lifestyle, and age characteristics of a person. It is necessary to find the optimal set of products, consumed by a person, taking into account the peculiarities of his life activity. The cost of this set should be minimal.

$$F = \frac{1}{1000}\sum_{\substack{i=1 \\ i\neq 6,7}}^{10} c_i x_i + c_6 x_6 + \frac{1}{10} c_7 x_7 \to \min \quad (1)$$

$$\begin{cases} 0{,}1\sum\limits_{\substack{i=1 \\ i\neq 6,7}}^{10} a_{ij} x_i + 0{,}6 a_{6j} x_6 + 10{,}27 a_{6j} x_6 \geq b_j \quad (j = \overline{1,4}). \\ x_i \geq N_i \quad (i = \overline{1,10}) \end{cases} \quad (2)$$

3. Results

The model (1) - (2) is considered on the example of the Republic of Tatarstan. According to the Federal State Statistics Service, in order to preserve normal human life, a person must consume at least 105 grams of protein per day, not less than 104 grams of fat, not less than 426 grams of carbohydrates, and the average daily nutrition should contain at least 3126 kilocalories. Table 1 provides information on the energy value and content of proteins, fats and carbohydrates in 100 grams of the main types of products (Babaee *et al.*, 2018; Hwang and Yoon, 1981).

Table-1. Energy value and content of proteins, fats and carbohydrates in 100 g of main types of products

Food products	Energy value, kcal.	Proteins, g	Fats, g	Carbohydrates, g
Bread and bread products (in terms of flour)	229	8.6	1.3	45.2
Potatoes	77	2	0.4	16.3
Vegetables, melons and gourds	37	1.2	0.1	7.7
Fruits and berries	96	1.5	0.5	21.7
Meat and meat products (in terms of meat)	166	15	11.7	0.2
Milk and dairy products (in terms of milk), pasteurized whole drinking milk, 2.5-3.2% fat	58.8	2.82	3.2	4.7
Eggs	157	12.7	11.5	0.7
Vegetable oil, margarine	899	0	99.9	0
Sugar and confectionery products	399	0	0	99.8
Fish and fish products	130	15	6	4.1

According to the Territorial Body of the Federal State Statistics Service of the Republic of Tatarstan, average consumer prices for certain types of food products in the Republic of Tatarstan at the end of the year, in rubbles per kilogram, with the exception of milk and eggs are presented in Table 2 for 2010-2014. Prices for milk are per 1 litre, prices for eggs – per a dozen.

Table-2. Average consumer prices for certain types of food products at the end of the year for 2010-2014 in the Republic of Tatarstan

Food products	Average consumer prices for certain types of food products at the end of the year (rubles per kilogram)				
	2010	2011	2012	2013	2014
Bread and bread products (in terms of flour)	35.08	38.11	40.48	50.27	57.09
Potatoes	27.54	10.91	11.73	18.95	22.76
Vegetables, melons and gourds	96.31	108.24	102.55	110.54	124.13
Fruits and berries	52.25	54.5	52.57	53.5	61.81
Meat and meat products (in terms of meat)	171.25	223.35	240.16	240.47	260.51
Milk and dairy products (in terms of milk), pasteurized whole drinking milk, 2.5-3.2% fat	25.28	25.87	27.89	35.81	36.79
Eggs	34.69	36.29	38.1	53.58	56.29
Vegetable oil, margarine	67.3	72.83	73.67	73.61	73.23
Sugar and confectionery products	38.16	27.81	29.7	30.78	44.95
Fish and fish products	213.98	213.5	222.62	220.16	276.97

Medical norms of consumption of the main types of products, recommended by WHO, in kg per year per capita are given in Table 3.

Table-3. Medical norms of consumption of the main types of products, recommended by WHO, in kg per year per capita

Food products	Recommended medical norms, kg/year/person
Bread and bread products (in terms of flour)	95 - 105
Potatoes	95 - 100
Vegetables, melons and gourds	120 - 140
Fruits and berries	90 - 100
Meat and meat products (in terms of meat)	70 - 75
Milk and dairy products (in terms of milk), pasteurized whole drinking milk, 2.5-3.2% fat	320 - 340
Eggs	260
Vegetable oil, margarine	10 - 12
Sugar and confectionery products	24 - 28
Fish and fish products	18 - 22

Using the data of Tables 1-3 and the formalized economic-mathematical model (1) - (2), we solve the problem of the optimal daily food consumption, with minimization of costs for meals. The results are presented in Table 4.

Table-4. The optimal daily food consumption per capita in the Republic of Tatarstan

Food products	Optimal daily food consumption per capita, in grams
Bread and bread products (in terms of flour)	292.65
Potatoes	260.27
Vegetables, melons and gourds	328.77
Fruits and berries	246.58
Meat and meat products (in terms of meat)	191.79
Milk and dairy products (in terms of milk), pasteurized whole drinking milk, 2.5-3.2% fat	0.88
Eggs	0.71
Vegetable oil, margarine	45.44
Sugar and confectionery products	120.71
Fish and fish products	49.32

4. Discussion

The results, obtained in Table 4, were compared with medical norms of consumption of the main types of products, recommended by WHO, (Table 3) and the data of the Territorial Body of the Federal State Statistics Service of the Republic of Tatarstan on per capita consumption in kg/year in the Republic of Tatarstan for 2010-2014 (Table 5) (David and Luenberger, 2008).

Table-5. Annual per capita food consumption in the Republic of Tatarstan for 2010-2014

Food products	Recommended medical norms, kg/year/person	Per capita food consumption in the Republic of Tatarstan, kg/year					Optimal consumption per capita, kg/year
		2010	2011	2012	2013	2014	
Bread and bread products (in terms of flour)	95 – 105	123	122	123	123	122	106.8157
Potatoes	95 – 100	151	162	169	167	166	95
Vegetables, melons and gourds	120 - 140	80	82	87	88	92	120
Fruits and berries	90 - 100	52	56	63	70	70	90
Meat and meat products (in terms of meat)	70 - 75	73	74	78	80	80	70
Milk and dairy products (in terms of milk), pasteurized whole drinking milk, 2.5-3.2% fat	320 - 340	368	367	367	364	364	320
Eggs	260	289	288	293	280	280	260
Vegetable oil, margarine	10 - 12	16	16	17	17	17	16.586
Sugar and confectionery products	24 - 28	41	41	42	42	42	36.6142
Fish and fish products	18 - 22	8.5	9.1	10.5	9.8	9	18

According to the data from Table 5, per capita consumption of certain types of food products, such as vegetables, melons and gourds, fruits and berries, fish and fish products does not correspond to optimal values. Solving the problem (1) - (2) with the data from Tables 1-3, we obtain the following expenditures for food products, during 2010-2014 (Table 6).

Table-6. Minimum expenditures for food products in the Republic of Tatarstan for 2010-2014

Year	Minimum expenditures for the main types of food products, rubles per day	Minimum expenditures for the main types of food products, rubles per month	Minimum subsistence level (average per capita), rubles per month	The ratio of minimum expenditures for the main types of food products, with the minimum subsistence level, %
2010	137.94	4138.26	4574	90.4
2011	148.50	4455.18	5001	89.1
2012	152.92	4587.59	5622	81.6
2013	168.64	5059.19	6020	84
2014	187.63	5629	6988	80.6

5. Summary

The economic-mathematical model (1) - (2), considered on the example of the Republic of Tatarstan of the Russian Federation, shows that per capita consumption of the certain types of food products, such as vegetables, melons and gourds, fruits and berries, fish and fish products does not correspond to the optimal values. Minimum expenditures for food products during 2010-2014 amount to 80% - 90% of the minimum subsistence level. Thus, low real incomes do not allow the residents to buy food products in the amount, necessary for normal life (Abikhanova *et al.*, 2018; Matousek, 2007).

6. Conclusion

Food provision of the population is one of the components of economic security of the region. The criterion of sustainability of food supply in the region includes the degree of satisfaction of physiological needs for the components and the energy content of food ration. The level of economic availability of food for various categories of population is one of the determining factors of food security. The proposed economic and mathematical model of the optimal structure of nutrition of different categories of population helps to determine the optimal structure of nutrition at the lowest costs. This is the determining factor of food security. Developed economic-mathematical model (1) - (2) is universal, since it takes into account the specifics of the region, gender of the subject, his type of activity, lifestyle and age characteristics (Igor et al., 2009).

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