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AUTOMATED CONSTRUCTION OF OPTIMAL MEAL PLANS FOR PRESCHOOL

The article describes and analyses the current state of the meal provision in preschools. The task of nutrition optimization is accomplished and sample meal plan calculations for a preschool are presented. Software for solving this problem is developed.

Keywords: *optimization; model; meal plan; preschool school.*

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АВТОМАТИЗАЦІЯ ПОБУДОВИ ОПТИМАЛЬНИХ ПЛАНІВ ХАРЧУВАННЯ У ДОШКІЛЬНИХ НАВЧАЛЬНИХ ЗАКЛАДАХ*

У статті розглянуто та описано сучасний стан харчування в дошкільних навчальних закладах. Поставлено задачу оптимізації раціону, проведено як приклад розрахунки планів харчування у дошкільних навчальних закладах та розроблено програмний засіб для розв'язання даної задачі.

Ключові слова: *оптимізація; модель; план харчування; дошкільний навчальний заклад.*
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АВТОМАТИЗАЦИЯ ПОСТРОЕНИЯ ОПТИМАЛЬНЫХ ПЛАНОВ ПИТАНИЯ ДЛЯ ДОШКОЛЬНЫХ УЧЕБНЫХ ЗАВЕДЕНИЙ

В статье рассмотрено и описано современное состояние проблемы питания в дошкольных учебных заведениях. Поставлена задача оптимизации рациона, приведен пример расчета планов питания в дошкольных учебных заведениях и разработан программный продукт для решения данной задачи.

Ключевые слова: *оптимизация, модель, план питания, дошкольное учебное заведение.*

Problem setting. Children are our future. This phrase has become quite trivial but it never loses its actuality. Parents are taking care of their children and trying to give them only the best to grow them up healthy and successful. Nutrition is one of the most important factors which secures normal child growth and development, resistance to unfavorable conditions, high functional level of all body systems. Nutrition should not only cover the energy used by a child but also secure the essential elements for growth and development of all organs and systems. Children's metabolism is more intensive than the adult one since they move and walk intensively and this causes lots of energy spending.

The question about the nutrition in preschools is of vital importance since most illnesses begin to form at this age. These are chronically gastrointestinal illnesses: chronicle gastrooydenits, clocustolangits and even ulcerous illnesses.

Nutrition of children in a family is a matter of budget and tastes of parents and much also depends on the nutrition of children in preschools.

Latest research and publications analysis. S.V. Kotlyk, M.P. Mardar and A.V. Yljanyckiy (2008) in their work "The program modelling of optimal prescribing

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of nutrition in the conditions of ecological situation worsening" denote the most actual task at the modern stage of development is the elaboration and realization of algorithms, programming methods and database, with the use of balanced and component formulas for preparing nutrition products. High effectiveness and the opportunity to choose the optimal ingredients could be realized with the use of the right mathematical tools and programmes. The programming product "RACION" is based on the principle of food combinatorial analysis and quantitative selection of raw materials and processing additives which all together ensures the formation of the required organoleptic and physical-chemical properties of a final product with the certain level consumer value (nutrition, biological) and nutritional value. The drawback of this system is the usage of Monte Carlo (Metropolis and Ulam, 1949), the method of random optimization algorithm with its high demands to computable capacity, significant time spent on compulations, high complexity of models and the high risk of getting inadequate models.

A.A. Krukova, T.D. Andrianova and L.V. Matysevic (1999) developed the automated system ("pitanie" stands for nutrition in Russian) with the use of database management system (DBMS) MS Access. The system includes a complex of programming means, which are defined by the parameters: protein (animal and plant), fats (animal and plant), carbohydrates, minerals (potassium, calcium, magnesium, phosphorus, and iron), vitamins (A, B1, B2, PP i C, and beta-carotene), and the nutrition value. The authors developed the database "Chemical composition of nutrition products" (350 nutrition products), "Technological cards" (425 recipes of dishes); the opportunity of their unlimited extension is foreseen. There are no methods of compiling menu; in this system it is developed only for the calculating the chemical compound of products.

In 2008 there appeared the configuration "DS: public nutrition + diet nutrition" by the company "1C-Tellur. Business strategy", with its use a price of a dish could be calculated in daily and holiday prices, along with costs of meals of any complexity, automatical recalculation of dishes cost in the case of a change in a warehouse, resettled calculations of a dish with a given output. The main elements of this system providing automatic interconnection are special documents: "Calculation card", "The order from the bar", "The chef's order". This configuration gives an opportunity to a consumer to form a menu, keep track of industrial wastes according to the season. Configuration "DS: public nutrition + diet nutrition" is designed for the automation of industrial and commercial activities in nutrition for cafes, bars, restaurants, canteens etc.

In 2001 the system "Calories counter" was designed by O. Lebedeva to calculate the nutrition value (calories) of the ration. Several operations are realized in this program: storage and export of rations in different formats for conducting "The nutrition diary"; adding own products and ready dishes (it is enough to insert the components of a dish and its weight); to calculate the percentage of fats, proteins and carbohydrates correlation in the ration, the amount (volume) of liquid consumed and the amount of pieces of bread in grams along with the measurement of volume (teaspoon, tablespoon, cup) for some products; search in the database for a product. This system doesn't make the ration menu, doesn't include the number of necessary substances for normal body function.

The goal of the paper is to develop computer methods for calculating, recording and analysing nutrition in preschools.

Unresolved issues. At present, the issues of creating optimal menus for preschools and elementary schools for providing children organisms with necessary amount of nutrients under the minimum costs of a ration still remain unresolved.

Key research findings. Child's nutrition should be full, with plenty amounts of protein, fats and carbohydrates, and also microelements and vitamins. Nutrition should vary, dishes should look nice, and they should provoke appetite. Some products should be used every day (meat, dairy products, fruits and vegetables) and other, for example, egg or fish should be served seldom.

The standards for one child nutrition are set according to the Cabinet of Ministers "Decree approval of the nutritional standards in education units and health centers". Daily ration should consist of: proteins, fats, carbohydrates and minerals. It is convenient to present the case in Tables 1 and 2, which show the 50 key ingredients.

Table 1. **The norms of nutrition s in preschools**

The name of a product	The norm for one child	Calories	Proteins	Fats	Carbohydrates	Retail prices, as of 01.06.2013, UAN/kg
Crop bread	100	220	4.9	1.0	46	5.05
Grain bread	130	239	7.9	1.0	48.1	5.98
Flour	30	334	10.3	1.1	68.9	4.50
Starch	3	327	0.1	0	79.6	16.20
Cereals:						
- buckwheat		335	12.6	3.3	62.1	7.50
- rice	45	330	7.0	1.0	71.4	7.00
- oat		303	11.0	6.1	49.7	11.5
Beans		314	23.0	1.6	50.8	6.25
Macaroni		337	10.4	1.1	69.7	9.20
Potatoes	300	80	2.0	0.4	16.3	5.5
Fresh vegetables:						
- cabbage		27	1.8	0.1	4.7	3.50
- carrot		30	1.3	0.1	7.2	5.00
- cucumbers	350	11	0.7	0.1	1.9	4.50
- beetroot		42	1.5	0.1	9.1	2.20
- tomatoes		23	1.1	0.2	3.8	12.00
- green onion		19	1.3	–	3.5	9.00
- radish		21	1.2	0.1	3.8	8.00
Fresh fruits:						
- apple		45	0.4	0.4	9.8	8.00
- pear		42	0.4	0.3	9.5	10.00
- apricot		41	0.9	0.1	9.0	20.00
- cherry	250	50	1.1	0.4	10.6	22.00
Citruses:						
- oranges		40	0.9	0.2	8.1	11.00
- lemon		33	0.9	0.1	3.0	14.00
- tangerine		40	0.8	0.3	8.1	15.00
Juices:						
- grapes		54	0.3	0	13.8	8.90
- pomegranate	150	64	0.3	0	14.5	38.00
- apple		38	0.5	0	9.1	8.80
- plum		66	0.3	0	16.1	8.90
Dried fruits:						
- prunes	20	242	2.3	0	58.4	26.00
- raisins		262	1.8	0	66.0	30.00

Continuation of *Table 1*

The name of a product	The norm for one child	Calories	Proteins	Fats	Carbohydrates	Retail prices, as of 01.06.2013, UAN/kg
Confectionary:						
- biscuits	30	436	7.5	11.8	74.4	25.00
- waffles		350	3.2	2.8	80.1	38.50
Sugar	50	379	0	0	99.8	5.00
Honey, honey products	3	314	0.8	0	80.3	43.00
Cream butter	40	661	0.8	72.5	1.3	60.00
Oil	12	899	0	99.9	0	13.40
Fat	2	897	0	99.7	0	26.00
Eggs, piece	1	157	12.5	11.5	0.7	0.70
Milk	500	58	2.8	3.2	4.7	7.00
Sour-milk products (kefir)		56	2.8	3.2	4.1	11.40
Sour-milk cheese	40	232	14.0	18.0	2.8	22.00
Cheese	12	360	23.0	29.0	–	68.00
Sour cream	15	206	2.8	20.0	3.2	8.00
Veal meat	125	97	19.7	2.0	–	62.50
Poultry		241	18.2	18.4	0.7	21.50
Sausages	25	252	11.7	22.8	–	24.75
Fish, fish products:	75					
- carp		112	16.0	5.3	–	27.00
- silver hake		86	16.6	2.2	–	27.00
Cereals coffee, sugar	2					55.45
Cocoa	2	380	24.2	17.5	27.9	100.00

Table 2. **Standards on energy values in preschools for children between the age of 3 to 6**

Chemical composition	Daily standard for one child, grams
Proteins	74
Including animal	37
Fats	67
Including plant	24
Carbohydrates	355
Energy value, Kkal	2319

Different nutrition products are digested in different parts of the intestine and for the digestion of different products different time is needed; besides, products should be combined. For example, cereal dishes are well combined with milk and dairy products; meat products can be combined with vegetables, as a result garnish should be cooked with vegetables, meat products are not well combined with potatoes, and among those cutlets with mashed potatoes, or goulash with potatoes, or chicken, baked in the oven with potatoes – very common dish. For good ration it is necessary to abandon such combinations of products.

When there is no product compatibility, the digestion is not complete. Then may occur intestine fermentation, toxins poisoning etc.; increased flatulence and bloating are observed and a person suffers from flatulence.

To ensure a child gets full-value nutrition, a menu is made for two seasons of the year: summer autumn and winter spring. It is important to keep the optimum ration. It refers to the number and the sequence of meals during a day. The routine of nutrition differs according to the main principles of ration, especially in industrial activi-

ties. According to the current physiological grounding 3–4 meals per day is the optimal choice.

The distribution of daily nutrition on separate meals is conducted, depending on the nature of work activity and daily routine. At 4 times nutrition it is recommended as breakfast – 25%, for lunch – 35%, for noon – 15% and for dinner – 25% of the daily ration energy value. At 3 times nutrition the value should be 25–30, 40–45 and 20–25% accordingly.

The formalization of software systems. Let's form the task about nutrition for children between 3 to 6. The main output data are shown in Table 1. x_1 is the amount of 1 type products, x_2 is the amount of 2 type products, ..., x_n is the amount of n type. Than, having the amount of products and prices for certain products, we can write the price-purpose function according to the optimal criteria – the cost. It is needed to find such variables x_1, x_2, ..., x_{50}, in order to provide the minimum of price-purpose function (for the 50 ingredients):

$$\min f(x) = 5.05x_1 + 5.98x_2 + 4.5x_3 + \ldots + 100.0x_{50}. \quad (1)$$

Conducting the limitation:

- proteins $4.98x_1 + 7.9x_2 + 10.3x_3 + \ldots + 24.2x_{50} \geq 74;$ (2)
- animal proteins $0.8x_{35} + 99.7x_{37} + 11.5x_{38} + \ldots + 16.6x_{48} \geq 37;$ (3)
- fats $1.0x_1 + 1.0x_2 + 1.1x_3 + \ldots + 17.5x_{50} \geq 67;$ (4)
- plant fats $1.0x_1 + 1.0x_2 + 1.1x_3 + \ldots + 17.5x_{50} \geq 24;$ (5)
- carbohysrates $46.0x_1 + 48.1x_2 + 68.9x_3 + \ldots + 27.9x_{50} \geq 355.$ (6)

The solving of the tasks (1–6) are conducted by means of the modified simplex method.

In nutrition and for children especially, a very important part is vitamins and microelements, and as a result for more effective nutrition it is important to take into consideration this, so it is needed to ensure the minimum of the purpose-oriented function (1) and to conduct the limitation for (2–6) and vitamins (A, B1, B2, PP, C):

$$0{,}01x_5 + 0{,}01x_8 + 0{,}02x_{10} + \ldots + 0{,}01x_{48} \geq 500; \quad (7)$$

$$0{,}09x_1 + 0{,}11x_2 + 0{,}17x_3 + \ldots + 0{,}12x_{48} \geq 0{,}9; \quad (8)$$

$$0{,}03x_1 + 0{,}03x_8 + 0{,}04x_4 + \ldots + 0{,}1x_{48} \geq 1{,}1; \quad (9)$$

$$0{,}68x_1 + 0{,}92x_8 + 1{,}2x_4 + \ldots + 1{,}3x_{48} \geq 12; \quad (10)$$

$$20x_{10} + 45x_{11} + 5x_{12} + \ldots + 3{,}2x_{48} \geq 45. \quad (11)$$

Microelements (Na, K, Ca, Mg, P, Fe):

$$0{,}42x_1 + 0{,}499x_2 + 0{,}003x_3 + \ldots + 0{,}14x_{48} \geq 3{,}5; \quad (12)$$

$$0{,}143x_1 + 0{,}102x_2 + 0{,}122x_3 + \ldots + 0{,}335x_{48} \geq 2; \quad (13)$$

$$0{,}18x_1 + 0{,}02x_2 + 0{,}018x_3 + \ldots + 0{,}03x_{48} \geq 500; \quad (14)$$

$$0{,}02x_1 + 0{,}014x_2 + 0{,}016x_3 + \ldots + 0{,}035x_{48} \geq 60; \quad (15)$$

$$0{,}092x_1 + 0{,}065x_2 + 0{,}086x_3 + \ldots + 0{,}24x_{48} \geq 400; \quad (16)$$

$$0{,}0029x_1 + 0{,}0011x_2 + 0{,}0012x_3 + \ldots + 0{,}0007x_{48} \geq 7. \quad (17)$$

For the solving the task (1–17), in the same way, a modified simplex complex is used.

As the result, the aim of the tasks (1–17) is to calculate correctly and quickly and order the necessary amount of products for nutrition of children in preschools, and form according to the requirements the orders and all the reporting documents. The next stage is to form portions, for this it is needed to solve the task of integer programming.

Designing of the database. The first stage in the projecting is to design a database, in which there are several tables "Product", "Meal", "Food_value", "Microelement", "Vitamin", "Receipt", "Ingredient", "Group", "Product_group", with the help of it in Table 3 "Selected_meal" are written down all of possible options of dishes on the basis of products available. In the table "Product" there is a list of products. The table "Meal" consists of receipts, which comply with children's nutrition. In the table "Food_value" there is information on the contents of proteins, fats, carbohydrates and energy value of dishes. In the table "Microelement" there is information on microelements in every dish. In the table "Vitamin" there is information on contents of the key vitamins in dishes. In the table "Receipt" there are recipes for preparing dishes. In the table "Ingredient" there are ingredients for every dish and the needed amount for preparing a certain dish. In the table "Group" all the dishes are divided between the groups: first meals, dairy meals, garnishes, second meals, salads, snacks, drinks. In the table "Product_group" products are sorted between types: grocery, vegetables, fruits, dairy products, meat, fish, herbs, supplements, fats, drinks.

On the base of these tables all the possible variants of dishes are formed. With the help of linear and integer programming, dishes are divided into days, considering the criteria of optimality. Such criteria are:

1. Daily rate of products chemical composition should be in allowable borders.
2. The groups should be repetitive (first dishes, second dishes, dairy products etc.) in the menu.
3. The repetitive dishes should form a two-week menu.
4. Meat and fish dishes should be included in the menu with the certain amount of times (meat – 3 times, fish – 2 times etc. a week).

For filling the table "Meal" the data were put, which one of the preschools in Lviv city gave. This data were technological cards in which the name of the dish was given, ingredients, their amount for preparing one portion, and the amount of proteins, fats, carbohydrates and calories in one portion. The data were filled to the tables of the database.

Features of software development. The designed system includes clients and server parts (Figure 2). The client part is realized as a website. The user sends a request to create a nutrition plan. When the server receives this request, it chooses the right data from the database and does the calculations. After received the result, the server sends an answer. The server part (Figure 3) is realized in Ruby language, exactly framework Ruby on Rails, because this language is designed for web programming and has a lot of tools for creating web services. Server generates html i css, which are the base of client part, and send it to the browser, which displays the received result. The server part uses DBMS MySQL for data saving.

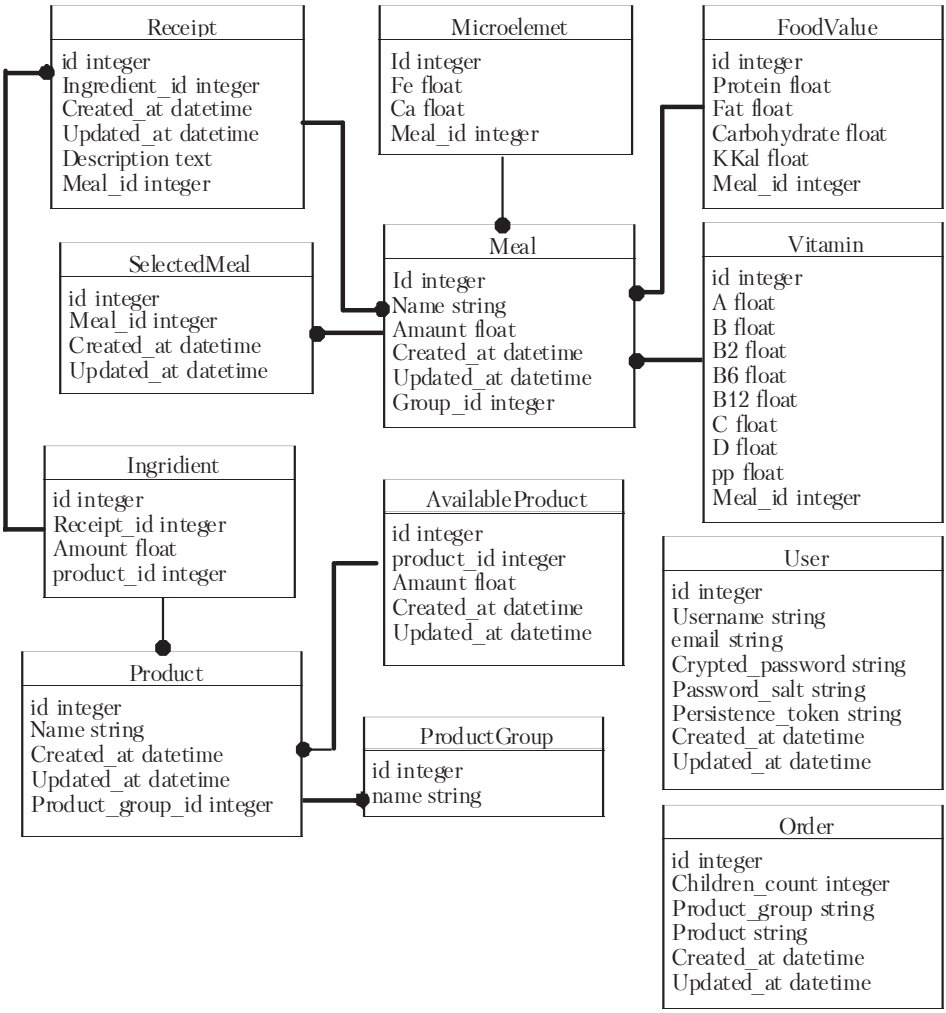

Figure 1. **Designed structure of data base,** *developed by the authors*

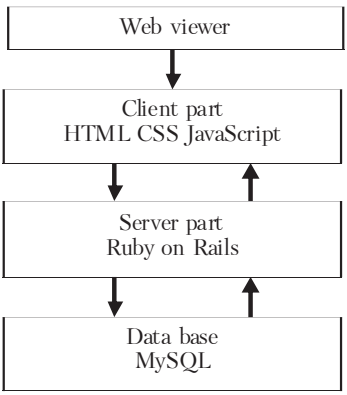

Figure 2. **General structure of system,** *developed by the authors*

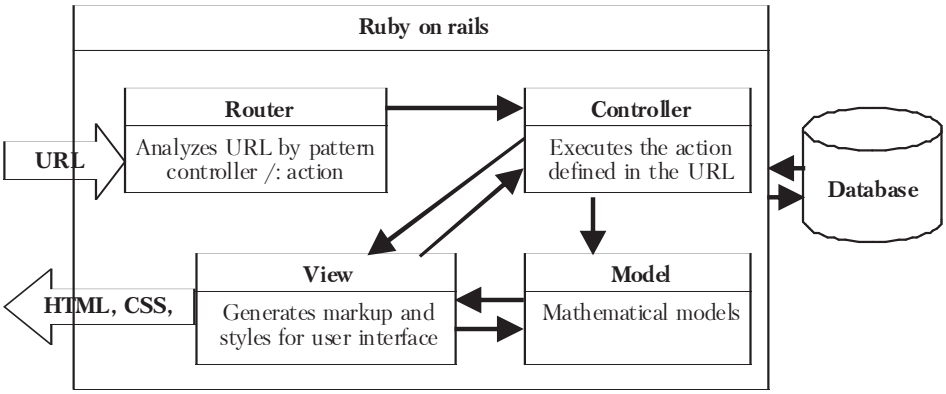

Figure 3. **The structure of the designed server part,** *developed by the authors*

Dishes, which could be prepared are saved in the database and the menu-shedule is generated with the way of solving the task of integer programming. As the result of the automation systems functioning of optimal nutrition plans the menu-schedule is made, the example of which is shown in Figure 4.

	Monday	Tuesday	Wednesday	Thursday	Friday
Breakfast	wheat porrige with milk, tea with lemon	herrcules porrige, tea with lemon	millet porrige, tea with lemon	buckwheat porrige, tea with lemon	milk vermicelli, tea with lemon
Dinner	bean soup with a cast rice porrige, stewed carrorts, fish cutlets	meat soup with meatballs, pasta with butter, vegetable caviar, meat cutlet, stewed apple	vegetables soup casserole, beet salad with white souce, stewed apples	oxalic soup with rice, mashed potatoes, stewed potatoes, meat goulash, stewed rhubarb	rice soup with tomatoes, salad with green peas, milk souce, stewed apples
Snack dinner	Omelette, cocoa with milk	cheese and semolina, pudding	lazy dumplings, cocoa with milk	bread with butter and cheese, cocoa with milk	pancakes with condensed milk, cocoa with milk

Figure 4. **The result of the system's functioning,** *developed by the authors*

Conclusions. The current condition of nutrition problem in preschools is examined in this article. The main normative documents are analyzed. The task of optimization ration was put and solved with the help of modified simplex-method and the methods of integer programming. As the example, the calculations of nutrition plans for preschool are given. The main peculiarities of designed programming system are described.

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