Mathematical Model - Differentiated Dietary Nutrition Period of Prenatal Development of the Fetus

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A B S T R A C T

The influence of such priority factors as vitamins during fetal development in three trimesters is considered. An analysis of the dynamics of fetal development was carried out, taking into account the saturation of food products with nutrients and vitamins. The main factors influencing the development of the fetus have been studied, the main types of nutrients in products that provide rational nutrition for pregnant women have been identified. A mathematical model of differentiated dietary nutrition during fetal development has been developed.

A R T I C L E I N F O

Article history:
Received 20 January 2022
Received in revised form
22 January 2022
Accepted 09 February 2022

Keywords: vitamins in food products, intrauterine development of the fetus, rational nutrition, mathematical model, differentiated dietary nutrition.

The health status of women during pregnancy and newborns is influenced by a number of factors, the most significant are socio-demographic and medical indicators: the age and lifestyle of the parents, the presence of various occupational hazards, bad habits, the presence of chronic diseases in the parents, the mother's attitude to pregnancy, as well as mother's nutrition during prenatal development of the fetus, during pregnancy and childbirth [1;3].

Simulation of the process of fetal development depending on nutrition. To maintain normal life, a pregnant woman needs to have a certain amount of nutrients. The daily diet of pregnant women should contain the required amount of fats, proteins, carbohydrates, vitamins, get a certain energy value, expressed in calories, necessary for the absorption of food.

The human need for vitamins (physiological need) is an objective value that has developed in the course of evolution and does not depend on our knowledge. On the basis of scientific data on the study of physiological requirements, the recommended intake rate (RNP) of vitamins is established (Table 2). It fully covers the need of any person. The need and, accordingly, the RNP for pregnant women is about 25% higher than for women of childbearing age. Recommended norms of consumption of vitamins (Norms of physiological requirements for nutrients and energy for different groups of the population).

Table 1. Recommended intake (RDA) of vitamins [4]

Vitamin	Women	Pregnant women	Vitamins in food (mg / 100g)
C, mg	70−80	90−100	Rosehip (426), green pepper (127), parsley (133), kiwi (92), broccoli (89), dill (85), strawberry (59), orange (53), lemon (53), pineapple (47)

A, mg	0,8−1,0	1,0−1,2	Beef liver (5), cream (0.4), spinach (0.45), carrots (0.8), butter (0.6), parsley (0.4), cilantro (0.3), apricot (0,1), fish oil (30)
E, mg	8	10	Butter (41), seeds (35), almonds (25), dried apricots (4.3), olives (3.8), turnips (2.8), peanuts (8.3)
D, ME	100	500	(IU / 100g) fish oil (10,000), mackerel (643), egg yolk (218), beef liver (49), salmon (441), whole milk (2)
B1, mg	1,1−1,5	1,5−1,9	Pine nuts (34), beef liver (0.3), buckwheat (0.3), pistachios (1), wheat (0.4), walnut (0.4), oatmeal (0.4), corn (0.4) pasta (0.25)
B2, mg	1,3−1,8	1,6−2,1	Pine nuts (88), liver (2.2), chicken egg (0.4), porcini mushroom (0.3), cottage cheese (0.3), rose hips (0.3), spinach (0.25), processed cheese (0.4), goose (0.23),
B6, mg	1,8	2,1	Pine nuts (124), beans (0.9), walnuts (0.8), sea buckthorn (0.8), garlic (0.6), pomegranate (0.5), millet (0.5), pepper (0.5), chicken (0.5), beef liver (0.7)
PP, mg	14−20	16−22	Peanuts (19), pine nuts (8), turkey (13), beef (8), chicken (12), rabbit (12), wheat (7), goose (8.6), mackerel (11), salmon (9), liver (17), peas (6.5)
Folic acid, mcg	200	400	(mcg / 100g) Peanuts (240), beef liver (240), beans (90), lettuce (48), spinach (80), broccoli (63), porcini mushroom (40), leeks (32), (nine). Folic acid, mcg
B12, mcg	3,0	4,0	(μg / 100g) Beef liver (83), rabbit (7), Swiss cheese (3), lamb (2.3), beef (1.9), cow's milk (0.5), chicken breast (0 , 34).

Even a temporary deficiency of proteins leads to a delay in fetal development and a decrease in its body weight, the weight of the brain, liver, and heart decreases. When the mother is starving, globulins are primarily used to feed the fetus. Violation of the ratio of albumin and globulins in the serum of pregnant women can affect embryogenesis.

The choice of the optimal menu for pregnant women can be carried out by solving the problems of assortment, prescription and assortment-prescription optimization, which determine the choice of optimal cooking strategies depending on the established structure of the product range. Assuming that for each product y_i a certain scheme and food supply uniquely corresponds, the optimal structure of the assortment will determine the optimal set of processed schemes and the corresponding distribution of the product, both by processing stages and by individual technologies within a stage. The following is used as the target function of assortment optimization:

$$\sum_{i=1}^{N}\left(\frac{y_i^o}{\sum_{i=1}^{N} y_{i_1}^o}-\frac{y_i}{\sum_{i_1=1}^{N} y_{i_1}}\right)^2 \to \min \ (1) \text{ или } \sum_{i=1}^{N}\left|\frac{y_i^o}{\sum_{i=1}^{N} y_{i_1}^o}-\frac{y_i}{\sum_{i_1=1}^{N} y_{i_1}}\right| \to \min, \ (2)$$

With restrictions of the form:

$$\sum_{i=1}^{N}\lambda_{ri}y_{ri}=G_r;\ r=\overline{1,R};(3)\sum_{i=1}^{N} y_{ri}=v_r;\ r=\overline{R+1,Q}, \qquad (4\ (3)\ (4)$$

with individual restrictions:

$y_i^{\min} \le y_i \le y_i^{\max}; i = \overline{1, N};\ y_i \ge 0$ (5)

General limitation of material balance by product in the field of parsing

$$\sum_{j=1}^{M}\sum_{n=1}^{v}\sum_{i=1}^{N_n} y_{ij}^{(n)} \le \sum_{j=1}^{M} G_j \ (6)$$

can be supplemented with balance constraints for each processing stage

$$\sum_{j=1}^{M}\sum_{i=1}^{N_n} (y_{ij}^{(n)} + x_{ij}^{(n)}) = \sum_{j=1}^{M} G_j^{(n)}; n = \overline{1, v} \ (7)$$

or material balance equations

$$\sum_{i=1}^{N_n} (y_{ij}^{(n)} + x_{ij}^{(n)}) + \sum_{i=1}^{N_n} (p_{ij}^{(n)} + u_{ij}^{(n)}) = G_j^{(n)};\ j = 1, M;\ n = \overline{1, v},\ (8)$$

The problem is solved by the method of mathematical programming with the determination, under given constraints, of the optimal assortment of products according to the criteria, as well as according to the criteria of maximum profit, minimum cost or maximum output of food in a given structure of the assortment [5]. Standards for structurally complex combined products establish requirements and restrictions on the biological composition that can be provided by various formulations and processing means. In this regard, the problem arises of finding optimal recipes for the development of food products of a given quality with balanced indicators of biological value with rational use of the product. In this case, the formulation of the problem is associated with minimizing the deviation of the elementary composition of the product from the standard normative structure of indicators of the biological value of the product according to the criterion

$$\sum_{k=1}^{m} \left(\frac{z_k^o}{\sum_{k_1=1}^{m} z_{k_1}^o} - \frac{z_k}{\sum_{k_1=1}^{m} z_{k_1}}\right)^2 \to \min,\ (9)$$

subject to restrictions: By the elemental composition of the product

$$z_k^{\min} \le \beta_k \sum_{j=1}^{I} \rho_{jk} x_j \le z_k^{\max};\ k = \overline{1, m},\ (10)$$

by prescription components

$$\sum_{j=1}^{J} x_j = 1;\ (11)\ \ x_j^{\min} \le x_j \le x_j^{\max}\ \ (11)\ (12)$$

The presented mathematical model of prescription optimization of combined differentiated dietary nutrition allows us to find for each structurally complex product the composition of prescription components that meet the physico-biological requirements of the standard and the criterion of the maximum biological value of the product. Further, taking into account all production constraints, the problem of assortment-recipe optimization is solved, which makes it possible to find the optimal set of recipes according to the selected criterion for a given group of products with balanced quality indicators.

The generalized formulation of the problem of assortment-recipe optimization is reduced to minimizing the criteria under the constraints:

By the structure of the assortment and resource provision

$$\sum_{i=1}^{N} y_i = v;\ (13)\ \ y_t^{\min} \le y_i \le y_i^{\max};\ (14)\ \sum_{i=1}^{N} x_{ij} y_i \le G_j;\ j = \overline{1, J}, (15)$$

by prescription components

$$\sum_{j=1}^{N} x_{ij} = 1; i = 1, N; (16) \quad x_{ij}^{\min} \le x_{ij} \le x_{ij}^{\max}; i = \overline{1, N}; \; j = \overline{1, J_i}, \; (17)$$

by elemental composition

$$z_{ik}^{\min} \le \sum_{j=1}^{J_i} \rho_{jk} x_{ij} \le z_{ik}^{\max}, (18)$$

The resulting solution to the optimal set of recipe options *(x_{ij}; $i = 1, N$; $j = 1, J_i$)* and production volumes y_i $i = 1, N$ is the structural basis for drawing up schemes for processing and distribution of material flows in the areas of food acceptance, its preparation and the actual preparation of combined products with the determination of the rational structure of the entire processing system.

Conclusion:

Nutrition is a key modifiable factor that influences the course of pregnancy and has a long-term effect on the health of the offspring. Nutritional characteristics should be assessed at the stage of preliminary preparation or at the earliest stages of pregnancy. The high-risk groups for the development of nutritional deficiency are women with chronic diseases of the digestive system, malnutrition, overweight, obesity, undergoing bariatric surgery, with a high intake of sugars and fats. Women should eat a nutritious diet during pregnancy that includes the consumption of fruits and vegetables, whole grains, low-fat dairy and protein. The use of multivitamin complexes is justified and effective for the prevention of the development of nutritional deficiency during pregnancy and lactation, and may be one of the factors in the prevention of the development of obstetric and perinatal complications.

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