THE DEVELOPMENT OF A MATHEMATICAL MODEL OF DIETETIC MEAT PRODUCTS

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SUMMARY

For baby foods, a recommended list of the necessary ingredients having the chemical composition which effects favourably the "metabolic block" of the organism, was established. Medico-biological restrictions of the possible use of the ingredients and the chemical composition of the finished product were determined with account for a probable loss of chemical constituents during processing. The optimal formulation of biologically perfect medicinal products for children was calculated with a computer by a modified simplex-method. Several alternatives were calculated, and the one which provides the maximum of the necessary constituents and determines the quantitative expediency of using individual ingredients, was chosen. The proximate composition (protein, fat, amino acids, vitamins B_1, B_2, B_6, PP) was adjusted to the level required. Protein-to-fat ratio was 1:0.9. The calculated amino acid score approached 1.0. The experimentally prepared product was organoleptically satisfactory and met chemically the medico-biological requirements and the computer data. The results obtained support the view that it is possible to use multi-component formulations in the development of special medicinal products. The optimization of the implementation of this task is accelerated due to the application of computers: the time for data processing and for performing extensive experiments is reduced.

INTRODUCTION

The development of dietetic foods requires the choice of such chemical constituents which are determined with individual consumer's physiological state and at the same time meet the requirements of rational nutrition.

To treat and to prevent the most common at present deseases (e.g. gastro-enterological and metabolic ones), complex therapy is used, one of the factors being properly organized nutrition. Food products for the clients shall be balanced by all the constituents, viz., by proteins, fat, amino acids, vitamins and minerals (1,2).

Using baby foods as an example, a recommended list of the necessary ingredients having the chemical composition which effects favourably the "metabolic block" of the organism, has been established.

In cooperation with the Institute of Nutrition of the USSR AMS, special medico-biological requirements have been developed, among them proximate composition (the level of protein, fat, vitamins, amino acids, minerals), comminution degree, kind and processing procedures of raw materials, the mass fraction of ingredients, the way of using such products.

Relative to the destination of a product, different comminution degrees were considered. When developing products, a necessity of sparing the organism from the mechanical and chemical points of view was taken into account. Thus, to reduce the mechanical irritation of the mucous membrane of the gastrointestinal tract, depending on the desease stage the comminution extent may vary within 50-150 mcm; to eliminate chemical irritation, extractives must be removed.

For medicinal nutrition biologically balanced product are needed, this being possible when multi-component formulations are used. Therefore, as test objects paté and cream were chosen. To prepare them, various raw materials are used (vegetables, animal and plant proteins, fats), maintaining at the same time the inherent characteristics of these products.

The final result can be influenced with many factors, therefore, multi-factorial planning by means of traditional experiments is very time-consuming. That is why we applied a computer to provide a pre-set chemical profile.

MATERIALS AND METHODS

When calculating the optimal formulation, the following task was set: to determine the mass fraction and the list of ingredients which provide the maximum (minimum) value of the optimization criterium (3) and the maintenance of the requirements to the chemical composition and quality of the finished product.

As the optimization criterium, three characteristics were considered: cost, caloric value and food value. The task was realized by the following block-diagram (3).

Choice of efficiency function
↓
Determination of ingredient list
↓
Collection of the actual data on the quantity and characteristics of ingredients
↓
Choice and determination of restrictions
↓
Forming a simplex-table and input into a computer
↓
Calculation and decision-making on the formulation
↓
Preparation of a test batch of a product and its control

Due to difficulties in formalizating the food value of individual ingredients, the first two criteria were used. When analyzing formulations by these criteria, slight variations of the former were noticed, they being due to the relation of ingredients cost to their caloric value. Therefore the basic estimation was carried out with the criterium of raw material cost.

All the ingredients were arbitrarily divided into 3 groups:

Group 1 - the ingredients which provide the basic chemical composition of the product of this class (beef, pork, egg powder);

Group 2 - the ingredients which fortify the product with proteins, vitamins, minerals (Na caseinate, SMP);

Group 3 - the ingredients, which provide the flavour of the product, and replacers of the basic materials (carrots, onions, salt, vegetable oil, butter, water).

In the course of choosing and determining restrictions, a preliminary experiment was performed to outline the ingredient list; as a result, their maximum levels were found which effect favourably the characteristics of the finished product. Restrictions choice was based upon the food value balance of the product proper, as well as upon the maximum levels of its ingredients. The concrete value of such restrictions in each case depended on dietitians' recommendations on a patient's need for any given product and the acceptability of the latter in a certain combination. Special medico-biological requirements to patés and creams for children and dietetic nutrition were taken into account.

Medicinal nutrition requires standardizing many constituents. In addition to lower and upper limits of protein and fat contents, the extreme values of limiting amino acids, vitamins (B_1, B_2, B_6 and PP) and minerals were included into the characteristics of the finished product in order to subsequently satisfy the organism's daily need for a given product. To determine the lower limit need for nutrients (proteins, fat, vitamins, minerals), we used the values indicating 10% satisfaction of a child's need per day; as for the upper limits, we used the data on the nutrient contents in medicinal diets, on the deficiency of these nutrients in children and the values satisfying 20% of the daily need.

The optimization of medicinal products formulations by means of a computer has some peculiarities, involving restriction and adjustment of chemical constituents of the product in question up to the desired level.

For calculations, linear programming methods using the standard programs (4, 5) were used (a modified simplex-method).

The application of a linear programming method is based on that a model uses a system of linear equations in which every function is independent in technological calculations, creates a so-called dilution effect, i.e. the constituents (protein, fat, vitamins, etc.), irrespective of each other, are combined into a new quantity depending on their contents in 100 kg of a product. Though, the amount of a constituent $\sum_{j=1} \alpha_{ji} \cdot x_j$ will range within certain limits:

$$\underline{A}_{ji} < \sum_{j=1}^{n} \alpha_{ji} \cdot x_j < \bar{A}_{ji} ,$$

where $\underline{A}_{ji}$ ($\bar{A}_{ji}$) is the lower (upper) limit of the level of a constituent per 100 kg of the product to be developed; $\sum_{j=1} \alpha_{ji} \cdot x_j$ is the contents of a constituent in 100 kg of the product to be developed. However, a system of linear equations of this type is applicable to the constituents which are not destroyed during processing, i.e. when their "stability coefficient" (K) is equal to 1.

If a constituent changes during processing, the linear relation equation will be as follows:

$$A = \sum_{j=1}^{n} \alpha_{ji} \cdot x_j \cdot K ,$$

where A is the contents of a respective constituent in 100 kg of the product to be developed; K - stability coefficient.

In our calculations neither constituent, except vitamin B_1 (thiamin), is changed during processing to a noticable extent. Therefore, K was used only relative to vitamin B_1.

As is seen from literature (6, 7), the greatest changes occur during heating at above 100°C. Thus, after sterilization the contents of vitamin B_1 in meat paté is reduced by 74-88%, whereas in liver sausage processed at, maximum, 80-90°C, similar changes are insignificant. Besides, a decomposition degree is affected with processing time as well. E.g., when meat products are sterilized in a rotary autoclave (sterilization time is 1.5-1.8 times as short as compared to that in a stationary autoclave), vitamin B_1 is destroyed to a lesser degree. Thus, vitamin B_1 losses depend on the product type, heat processing and processing equipment used. Starting from this, when estimating vitamin B_1, we shall assume its stability coefficient equalling 0.5; then,

$$A_{B_1} = \sum_{j=1}^{n} \alpha_{ji} \cdot x_j \cdot 0.5 .$$

Furthermore, calculations of the formulation accounted for ingredients weight, raw material cost and chemical composition.

Several alternative formulations were calculated which meet the pre-set chemical composition. Sensory evaluation indicated, however, that not all of the products prepared by the calculated formulations were of acceptable organoleptical quality. Therefore we formulated the task with altered limit restrictions on some basic ingredients: beef content from 20-45% to 10-40%; pork content from 10-15% to 5-20%; skim milk powder from 1-2% to 2-5%. Computerized calculations yielded the formulation presented in Table 1.

Table 1

Formulation of paté and cream calculated in a computer

Raw materials and ingredients	Paté	Cream
Beef, Grade 1		+
Pork, semi-lean		+
Beef liver	+	
Beef brain	+	
Beef heart	+	
Egg powder		+
Sodium caseinate		+
SMP	+	+
Butter	+	+
Vegetable oil		+
Carrots	+	+
Onions	+	+
Corn starch	+	+
Spices	+	+
Water	+	+

Under laboratory conditions test samples were prepared. They retained their shape well, were of a tender consistency, their flavour and colour met the requirements claimed to patés and creams. In case tripes were added to paté, it was slightly grainy due to insufficient comminution in laboratory machines; this defect was eliminated when a microcutter was applied under pilot-plant conditions.

Table 2 gives the chemical composition of the manufactured paté and cream and the va-

Table 2. Food value of the test samples of paté and cream destined for children nutrition

	Chemical composition		Extent of meeting medico-biological requirements	
	paté	cream	paté	cream
Proteins, g	11.7	15.3	96.5	126.5
Fats, g	10.0	14.0	83.5	115.5
Protein:fat ratio	1 : 0.85	1 : 0.9		
Amino acids, mg				
tryptophane	153.0	186.0	225.0	270.0
lysine	886.0	1198.0	137.5	185.0
methionine + cystine	461.0	521.0	198.5	225.0
Vitamins, mg				
B_1	0.19	0.13	105.0	72.0
B_2	0.94	0.21	391.5	95.5
B_6	0.33	0.26	137.5	105.0
PP	4.30	2.81	195.0	130.0
Minerals, mg				
Ca	60.0	73.0	30.0	34.5
P	228.0	193.0	100.1	115.5
Mg	24.0	29.0	52.0	61.0
Fe	3.7	1.9	148.0	75.0

lues to which a daily need is met with these products. The constituents of the chemical composition derived with a computer correspond to the suggested system of equations of linear relationship (8):

$$A = \sum_{j=1}^{n} \alpha_{ji} \cdot x_j$$

It is clear from Table 2 that the protein: fat ratio in paté is 1:0.85, in cream 1:0.9; the ratio of the limiting amino acids (tryptophane:lysine:methionine+cystine) 1:5.8:3 and 1:6.4:2.8, respectively. The analysis of the data on the extent the products meet the daily needs indicated that by protein, fat, amino acids, vitamins B_6 and PP and phosphorus cream meets completely the medico-biological requirements. A similar picture was observed for paté as far as amino acids, vitamins, phosphorus and iron are concerned. The following deviations were noted: for protein and fat within 4.5-16.5%, for vitamins within 4.5-28% ; for minerals they reach higher ranges.

When making corrections in the formulations and testing processing technologies under commercial conditions, the attention will be mainly given to the substantiation of the processing parametres which ensure better retention of vitamins and the incorporation of extra ingredients to fortify paté and cream with minerals.

RESULTS

The application of mathematical methods and a computer allowed to reduce labour consumption for large-scale experiments and to improve the quality of meat products due to
- accelerating calculations through applying formalized algorythms;
- yielding more economical formulations with maintaining the pre-set quality;
- reducing the number of formulations to be tested experimentally.

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