Optimization of baby food formulations using spreadsheets

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Abstract. The development of product formulations for the nutrition of young children is a complex and laborious task, the solution of which involves the calculation of the nutritional value of both individual components and the whole product. The article shows a step-by-step way of solving a particular example of designing a product recipe for feeding young children using the standard add-on “Solution Finder” of the Microsoft Excel spreadsheet processor. A special place in the article is given to the formation of a table with the source data. Uncertain factors in the calculation of the formulation are the mass fractions of the raw materials, which should be determined taking into account the objective function and a number of restrictions. Restrictions on the ratio of proteins, fats, carbohydrates and water were used as the main parameters for optimizing the formulations for the nutrition of young children, and the cost of the finished product was determined as a function of the goal. As a result of using the Microsoft Excel spreadsheet editor, the formula for the baby food with the specified properties was calculated taking into account the installed food components of the mixture, a number of limiting factors and the low cost of the finished product, equal to 98.9 RUB per 1 kg which corresponds to 1.4 Euro per 1 kg at the current exchange rate.

1. Introduction

A rational and balanced diet of children is one of the most important conditions that ensures harmonious growth, adequate morphological and functional maturation of various organs and tissues, optimal indicators of psychomotor and intellectual development and the child's resistance to infections and other adverse external factors [1,2].

The industrial production of foods for young children does not aim to replace mother's milk with artificially created mixtures. The composition of these mixtures is trying to bring closer to the composition of human milk. Cow milk is used, as a rule, for the production of substitutes for human milk, since it is the main raw material for the dairy industry. Differences in the composition of human and cow's milk determine the main directions of correction of the composition of the feedstock - cow's milk [3,4,5].

Many factors should be considered when creating food for feeding young children. It is necessary to pay attention to the individual characteristics of the child, such as body mass index, intolerance to individual components of food, but also to a diet balanced by macro- and micronutrient composition [6,7].

One of the most important factors for the proper development and growth of a child is a sufficient amount of protein balanced in amino acid composition. This is complicated by the fact that at all stages
of production and even refrigeration processing, the amino acid composition of the processed protein can vary significantly [8]. It is also often difficult to estimate the baby’s intake of nutrients, as the baby may be breast-fed. But the breastfeeding importance for the child health should be noticed too [9,10].

Mature breast milk is the best nutrition for the baby and contains all the substances necessary to meet the needs of the baby. These are irreplaceable polyunsaturated fatty acids, iron in easily digestible form, milk proteins, etc. In addition, breast milk contains substances that contribute to the adaptation and proper development of intestinal microflora and provide protection against microbial and viral infections. In terms of amino acid composition, it exceeds the composition of the “ideal” protein formed by the FAO / WHO (table 1).

**Table 1.** Comparison of the amino acid composition of mature breast milk and ideal protein [11]

| Amino acid                        | Mass fraction, g · 100 g⁻¹ protein |
|-----------------------------------|-----------------------------------|
| Mature breast milk                | “Perfect” protein                 |
| Valine                            | 5.20                              | 3.90                              |
| Leucine                           | 9.80                              | 5.90                              |
| Isoleucine                        | 4.60                              | 3.00                              |
| Methionine + Cysteine             | 4.00*                             | 2.20                              |
| Threonine                         | 4.60                              | 2.30                              |
| Lysine                            | 7.50                              | 4.50                              |
| Phenylalanine + Tyrosine          | 8.60*                             | 3.80                              |
| Tryptophan                        | 1.50                              | 0.60                              |

* Pairs are summed up, since the need for one amino acid can be covered by the presence of another.

Although the composition of mature breast milk is inconsistent in the process of feeding the baby, it still surpasses substitutes for breast milk of various manufacturers. Therefore, the main goal of the industrial production of food for young children is to maximize the approximation of the composition of the mixture to the composition of breast milk, and not to replace breast milk with artificial mixtures [12,13]. The main type of raw material for the mixtures production is cow’s milk, which composition is adjusted in the production process. It is important that casein is the main component of cow’s milk (about 80 %), whey proteins account for 14-24 % of the total amount of protein, including β-lactoglobulin and immunoglobulins 7-12 %, and α-lactalbumin 2-5 %, serum albumin (serum albumin) 0.7-1.3 % [14,15,16]. First of all, the protein component is corrected: the protein content is reduced to 1.5-2.0 g per 100 ml, the ratio of casein to whey proteins is brought closer to a ratio of 40:60. Some manufacturers do not correct this indicator, so the ratio of casein to whey proteins can remain at the level of cow’s milk in a ratio of 80:20 [17,18,19].

For the nutrition of young children, FAO / WHO 1985, 1990 and 2011 formed the following norms for the consumption of amino acids (table 2).

**Table 2.** Consumption rates of essential amino acids for young children [20,21,22]

| Amino acid                        | Mass fraction as recommended by FAO / WHO, g · 100 g⁻¹ protein |
|-----------------------------------|---------------------------------------------------------------|
|                                   | 1985   | 1990   | 2011   |
| Valine                            | 5.00   | 3.50   | 4.30   |
| Leucine                           | 7.00   | 6.60   | 6.60   |
| Isoleucine                        | 4.00   | 2.80   | 3.20   |
| Methionine + Cysteine             | 3.50   | 2.50   | 2.70   |
| Threonine                         | 4.00   | 3.40   | 3.10   |
| Lysine                            | 5.50   | 5.80   | 5.70   |
| Phenylalanine + Tyrosine          | 6.00   | 6.30   | 5.20   |
| Tryptophan                        | 1.00   | 1.10   | 0.85   |
Modern computer technology approaches play a large role in improving the complex raw materials products and economic analysis methods. In order to develop a multicomponent product, many formulation options are used. However, the task of a specialist in this field is to select a recipe with specified parameters from many options (e.g., with a minimum cost, high quality indicators, maximum use of raw materials).

The primary task at the first stage of creating a new food product is to design the product formulation. The recipe should meet most of the consumers’ needs. It is difficult to realize this task without using computer technologies when developing multi-component food products with a number of limiting factors. This problem is solved by using the Microsoft Excel spreadsheet editor system, which has great potential in the recipe calculations of multicomponent food systems [23].

The purpose of the work was to investigate the possibility of using the Microsoft Excel spreadsheet editor for calculating and optimizing the composition of multicomponent food products in the case of baby nutrition mixtures.

2. Materials and Methods

The most popular tool for solving optimization problems is the standard add-on “Search for a solution” of the Microsoft Excel spreadsheet processor, which is included in Microsoft Office. This add-in allows to effectively solve prescription problems. The results presentation in the table form provides information convenient for accounting and reporting. Moreover, the Excel “Search for Solutions” add-ons are not inferior in their functionality to analogues of special mathematical programs, such as MathCAD. All other things being equal, the recognized advantage of Excel is the simplicity of the interface and accessibility for the general user.

3. Results and Discussion

This article presents an example of using a Microsoft Excel spreadsheet in designing a product formulation for the nutrition of young children. Table 3 presents the initial data for the development of formulations of baby food mixtures, the chemical composition of the recipe ingredients of the mixtures and the standard mixtures for baby food.

| Ingredients              | X<sub>i</sub> | Mass fraction, % | Price, rub·kg<sup>-1</sup> |
|-------------------------|--------------|------------------|-----------------------------|
|                         |              | fat     | protein | carbohydrate | water |                      |
| Skimmed milk            | X<sub>1</sub>| 0,1     | 2,0     | 4,8         | 93,1   | 73,0                  |
| Whey powder             | X<sub>2</sub>| 0,3     | 14,0    | 67,0        | 18,7   | 80,4                  |
| Vegetable oils          | X<sub>3</sub>| 99,9    | 0       | 0           | 0,1    | 62,0                  |
| Lactose                 | X<sub>4</sub>| 0       | 0       | 100,0       | 0      | 160,0                 |
| Prebiotic dietary fiber | X<sub>5</sub>| 0       | 0       | 100,0       | 0      | 91,4                  |
| Probiotic culture       | X<sub>6</sub>| 0       | 75,5    | 22,5        | 2,0    | 113,8                 |
| Vitamin Complex         | X<sub>7</sub>| 0       | 0       | 0           | 0      | 476,3                 |
| Trace elements          | X<sub>8</sub>| 0       | 0       | 0           | 0      | 399,1                 |
| Stabilizer (0,01%)      |              |         |         |             |        |                       |
| Baby foods formula standard |      | 27,7   | 10,6    | 53,9        | 7,8    |                       |

The water content of the infant formula will be:

\[ 100 - (27,7 + 10,6 + 53,9) = 7,8 \% . \]
To solve this problem using Microsoft Excel, a table is created on the worksheet of the spreadsheet editor (Figure 1), which reflects the data of the chemical composition of the mixture formulation components. Uncertain factors are the mass fraction of raw components of the formulation, which had to be determined considering the objective function and several restrictions. The cost price of the finished product is selected as the target function.

The total mass of all components of the mixture is calculated according to the following formula: \( = \text{SUM (C4:C13)} \) in the cell C15. The line 19 carries out input of balance equations, mass fractions of fat, protein, carbohydrates and water in 100 kg of mix for baby food are calculated in the cells D19-G19. For example, the formula in the cell D19 would be:

\[
= \text{SUMPRODUCT (SC4:SC11;D4:D11)/100}
\]

The cells E19, F19, G19 are filled by analogy.

In the cell H18, the cost price of 100 kg of the mixture will be calculated as the sum of the mass products of a raw material at its price. Then the formula in the cell will look like:

\[
= \text{SUMPRODUCT (C4:C11;H4:H11)}
\]

The line 17 indicates the normative indicators of the infant formula, namely the content of fat, protein, carbohydrates, water.

After entering the source table with the record of formulas, the function Search for solutions is launched (Menu → Tools → Search for solutions) (Figure 2).
Figure 2. Screenshot of the Solution Finder window in Excel

The “Search for solutions” dialog box appears on the screen, in which the cell of the objective function (cell H18) is selected — the prime cost of the mixture without considering the cost of the stabilizer — and set to the minimum value. The stabilizer is not considered in the calculation of the mixture cost, since this ingredient is a constant parameter in the production.

Next, the changing cells are selected - these are cells containing the masses of individual types of raw materials (C4: C11).

Then restrictions are added, in this study case:
- the content of skimmed milk in the mixture should be greater than or equal to 15 % (C4>=15);
- the content of certain types of ingredients must be greater than or equal to zero (C4:C11>=0);
- the mass fractions of fat, protein, carbohydrates and water in 100 kg of the finished product should be equal to the standard values (D17=D19; E17=E19; F17=F19; G17=G19).

The “Run” button is activated in the “Search for solutions” window after entering all the parameters and so the calculation of the baby food formula optimized by cost is made (figure 3).
As a result, the lowest cost (9891.5 RUB per 100 kg which corresponds to 140.4 Euro per 100 kg) is calculated in the cell H18, which can be obtained using all the listed food components, considering the indicated restrictions. The “Solution Search” of the Microsoft Excel can be used not only for purposeful and quick calculation of the optimal cost of the baby food mixture under certain limitations of the formula components, but also to calculate its nutritional and biological value.

4. Conclusions

On a particular example of designing a formula for a baby food using Microsoft Excel spreadsheets, the lowest cost formula (98.9 RUB per 1 kg which corresponds to 1.4 Euro per 1 kg at the current exchange rate) for the mixture was calculated taking into account the indicated limitations in component composition.

Thus, the use of spreadsheets, including the Microsoft Excel spreadsheet editor in the calculation and optimization of formulations of multicomponent dairy products is attractive and promising. Intermediate, repeated and new prescription calculations are carried out with minimal time costs (the time required to change the initial data). All optimization settings are saved (when data changes) in the solution search window and do not require re-entry.

Thus, this tool can be widely used for educational and practical purposes in the development of new products, including baby food mixtures.

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