Development of creating computer programs method for multivariate optimization of functional meat product recipes

A S Miroshnik, M I Slozhenkina, I F Gorlov, D A Mosolova and A L Ishevskyi
Volga Region Research Institute of Manufacture and Processing of Meat-And-Milk Production, Volgograd, Russia

E-mail: niimmp@mail.ru

Abstract. The article presents the results of development and testing of new computer program for calculating functional meat products based on Microsoft Office Excel 2010. The paper describes methodology of its creation, including method and formulas of calculation, presentation type of input data and calculation results, as well as possibility of increasing accuracy and efficiency of optimization when using programs of this type. The necessity of developing software for optimizing functional food products, based on a full search algorithm, is substantiated. The ways of using the program and ways of its further development are presented. The key advantages and disadvantages of using the created computer program are identified. The computer program at the end of its work provides the user a list of formulations optimized according to the general optimality criterion, which is an undeniable advantage. This is important because it is very difficult to predict organoleptic indicators at the current level of technological development. It was revealed that in the current form, amount of computing a computer program directly depends on the size of database used. An idea of identifying a logical function that organoleptic properties with respect to parameters of raw materials in a recipe is proposed.

1. Introduction
Profitability growth is the main task of any food industry enterprise. Faced with low purchasing power of consumers, as well as the growing demand of functional products and a variety of offers in market of raw ingredients, meat producers are constantly forced to update the range of products. This process involves operational correction and development of new recipes. Using of existing recipes may be unacceptable, in particular due to fluctuations in parameters of raw materials, changes in product requirements and market conditions [1, 2].

Task of designing functional food products with desired properties has remained relevant for decades [3]. The key problem which scientists and food technologists, who solve this problem, faced by is the difficulty of optimizing ingredient composition of food [3-5]. There are often a lot of optimization criteria, in some cases even more than 10 [6-10]. In addition, composition of product, depending on its functional orientation and characteristics of technological processing, must satisfy different requirements for each individual case [4]. All this together leads to a large number of calculations that are difficult or impossible to perform with acceptable accuracy without using of modern information technologies.

In this regard, to solve this type of problems, numerous software products are being developed that mainly use multi-criteria optimization with scalar ranking. Such programs currently developed a lot, but
descriptions of algorithms their action is extremely small, and there is practically no source codes [10, 11]. Lack of information about the algorithm of one or another program for optimization can significantly reduce effectiveness of its optimization. Also, due to the peculiarities of technological processing of meat products, calculation algorithms must be adapted to each specific type of product.

Thus, at present, due to the lack of such software, creation of fundamental scientific foundations for development of computer programs for optimizing meat product recipes, including functional ones, is particular relevance. We believe that this is necessary both for further researches in the field of development of functional nutrition, but also for creation of computer models predicting physicochemical parameters of the finished product subsequently. The introduction of such technologies in meat production will allow us to abandon direct production of undesirable products, which will significantly reduce cost of meat products.

Thus, the aim of our study is to develop a methodology for compiling computer programs for multifactor optimization of recipes for functional meat products, which can be adapted to various types of meat products subsequently.

2. Materials and methods
The computer model is based on software Microsoft Office Excel 2010. The subject of the study was software products for optimization of meat products and scientific articles on topic of our research. The work was performed on the basis of ITMO University laboratory. When compiling a computer model, we were guided by generally accepted methods for calculating the performance of meat products [12]. The development is oriented for use by personnel of meat enterprises, students of specialized training and teachers of the corresponding departments. When compiling a computer model, we were guided by generally accepted methods for calculating of meat product parameters [12]. The development is oriented for use by meat processing technologists, students and teachers of corresponding departments.

3. Results and discussion
In the case of optimizing the recipes of functional meat products, it is difficult to predict organoleptic indicators and it is necessary to work with a large number of options for optimized recipes to obtain the best result. A brute force method can provide such an opportunity. However, an analysis of literature data showed that among developed programs for optimizing recipes of meat products there are very few that use a brute force method as an optimization algorithm. This can be explained by the absence until recently of high-performance personal computers and computing clusters and, due to low computing power, mainly less technologically sophisticated heuristic optimization algorithms, for example, the simplex-method, were used. That is why, when developing our program, we used the brute force algorithm.

As part of the research goal, at initial stage of our work, we developed a computer model characterizing component composition of meat product. It involved the calculation of up to seven optimized mixture parameters based on data of raw materials used and their mass fraction in the formulation. The formula for calculating optimization parameters is given below:

\[ A = \sum_{i=0}^{n} c_i \cdot b_i \]  

(1)

where \( c_i \) - parameter value of the \( i \)-th component;
\( b_i \) - mass fraction of \( i \)-th component.

Further were created: a matrix containing all possible combinations of ratio of components in the recipe of five ingredients in 10% increments and a matrix with combinations of database ingredients with the grouping of the latter into groups of five. According to the results of testing, it was found that an increase in the number of ingredients in the calculated formulation does not cause a significant increase in the accuracy of the results with the accepted number of optimization criteria.
The program calculates the parameters of each recipe for each combination of database ingredients. The methodology for calculating the general optimality criterion is to determine the length of the vector of deviations of the parameters from their optimal value and is calculated by the formula (2):

\[ L = \sqrt{\sum_{i=0}^{n} \left( \frac{c_i - c_{iH}}{c_{iH}} \right)^2} \]

where \( c_{iH} \) - preset optimal value of i-th parameter.

The presence of a denominator in the formula is necessary to obtain uniformity of deviation of the indicators from the optimum. You can also add a factor to it that determines the weight of the parameters.

Optimal results can be considered those in which generalized optimality criterion has the lowest values. The number of results in ascending order of this criterion in the program is expressed as a table (table 1).

| available raw materials | raw material characteristics (unit of measure) | parameter weight | param. 1 | param. 2 | param. 3 | param. 4 | param. 5 | param. 6 | param. 7 |
|------------------------|---------------------------------------------|------------------|---------|---------|---------|---------|---------|---------|---------|
| ingredient 1           | 30                                           | 1,0              | 0       | 0       | 0       | 0       | 0       | 0       | 0       |
| ingredient 2           | 0                                             | 1,0              | 50      | 0       | 0       | 0       | 0       | 0       | 0       |
| ingredient 3           | 0                                             | 1,0              | 0       | 10      | 0       | 0       | 0       | 0       | 0       |
| ingredient 4           | 0                                             | 1,0              | 0       | 0       | 20      | 0       | 0       | 0       | 0       |
| ingredient 5           | 0                                             | 1,0              | 0       | 0       | 0       | 40      | 0       | 0       | 0       |
| ingredient 6           | 0                                             | 1,0              | 0       | 0       | 0       | 0       | 35      | 0       | 0       |
| ingredient 7           | 0                                             | 1,0              | 0       | 0       | 0       | 0       | 0       | 2       | 0       |
| ingredient 8           | 4                                             | 1,0              | 42      | 0       | 0       | 0       | 0       | 0       | 0       |
| ingredient 9           | 0                                             | 1,0              | 57      | 0       | 0       | 0       | 0       | 0       | 0       |
| ingredient 10          | 0                                             | 1,0              | 0       | 0       | 0       | 0       | 60      | 10      | 0       |
| ingredient 11          | 0                                             | 1,0              | 0       | 0       | 0       | 0       | 32      | 3       | 0       |

| parameter optimum      | 10                                            | 11               | 8       | 27      | 8       | 5       | 1       |

Optimal results can be considered those in which generalized optimality criterion has the lowest values. The number of results in ascending order of this criterion in the program is expressed as a table of results. Its form is shown in table 2. Structure of the developed program is shown in figure 1.

| absolute deviation | recipe | param. 1 | param. 2 | param. 3 | param. 4 | param. 5 | param. 6 | param. 7 | component 1 | component 2 | component 3 | component 4 | component 5 |
|-------------------|--------|---------|---------|---------|---------|---------|---------|---------|-------------|-------------|-------------|-------------|-------------|
| -0,230            | -0,230 | 0,038   | 0,084   | 0,114   | 0,164   | 0,060   | 0,010   | 0,0000  | 10% -40%    | 20% -20%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,252            | -0,252 | 0,030   | 0,050   | 0,114   | 0,184   | 0,060   | 0,010   | 0,0000  | 10% -10%    | 20% -10%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,222            | -0,222 | 0,030   | 0,100   | 0,114   | 0,164   | 0,060   | 0,010   | 0,0000  | 10% -20%    | 40% -20%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,256            | -0,256 | 0,034   | 0,042   | 0,114   | 0,184   | 0,060   | 0,010   | 0,0000  | 10% -50%    | 10% -50%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,242            | -0,242 | 0,060   | 0,050   | 0,114   | 0,164   | 0,060   | 0,010   | 0,0000  | 10% -10%    | 40% -20%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,240            | -0,240 | 0,008   | 0,084   | 0,114   | 0,184   | 0,060   | 0,010   | 0,0000  | 10% -50%    | 20% -50%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,236            | -0,236 | 0,004   | 0,092   | 0,114   | 0,184   | 0,060   | 0,010   | 0,0000  | 10% -50%    | 10% -50%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,246            | -0,246 | 0,004   | 0,042   | 0,114   | 0,164   | 0,060   | 0,010   | 0,0000  | 10% -20%    | 10% -20%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,232            | -0,232 | 0,000   | 0,100   | 0,114   | 0,184   | 0,060   | 0,010   | 0,0000  | 10% -20%    | 50% -20%    | 20% -10%    | 20% -10%    | 10% -20%    |
| -0,212            | -0,212 | 0,060   | 0,100   | 0,114   | 0,144   | 0,060   | 0,010   | 0,0000  | 10% -20%    | 30% -20%    | 20% -10%    | 20% -10%    | 10% -20%    |
In our opinion, the presence of an extensive database in this kind of program, although desirable, but not necessary. Creation of such database is time-consuming and in conditions of limited availability of raw materials and changes in its parameters will constantly require correction. It should be noted that required computing power of the program in its current form correlate with size of the database. The use of existing databases of raw ingredients in presented program requires the inclusion of an additional method of selecting raw materials.

A significant deviation of the optimized parameters in raw material is critical in multi-criteria optimization. It is logical to assume that the best result can be achieved by selecting the raw materials by correlating the parameters of the available ingredients accordance with truth table from mathematical logic, where one is shift value of the parameter up, and zero, respectively, shift value of the parameter down from the required optimum. Each column except the last will meet the optimization criterion, and the row will correspond to the database ingredient. Each column except the last will meet i-th optimization criterion, and the row will correspond to the database ingredient. In this case, provided that there is a correlation between the optimization criteria and the organoleptic characteristics of the product, if the right column is filled in according to the principle of satisfying or not satisfying the organoleptic indicators - one and zero, respectively, then on the basis of such a truth table it is possible to identify a logical function describing organoleptic characteristics of meat product.

4. Conclusion
As a result of the work, a software product for optimizing recipes of functional meat products based on Microsoft Office Excel 2010 was developed. It, due to differences in parameter values during technological processing and the interaction of micronutrients, can be used to achieve required characteristics of minced meat, or to predict product parameters that do not undergo significant changes during technological processing. Subsequently, results of the study can also serve as basis for creating new programs for predicting both organoleptic characteristics and rheological parameters of meat products.

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