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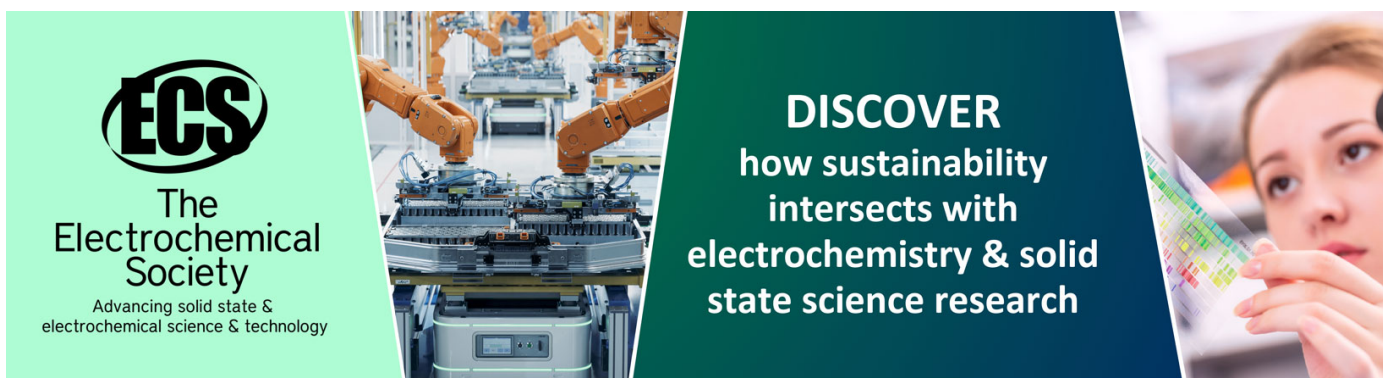
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Statistical methods in food recipes design

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Abstract. A methodology based on statistical methods for optimizing multicomponent compositions is applied for meat product recipes design. Using raw materials of animal and plant origin, virtual arrays of input variables (raw materials) are developed and chemical (protein, fat), mineral and vitamin compositions are calculated for each data array. The calculation of balance and rationality of the amino acid composition in the feedstock is established by clustering method. As a result, the recipe of cooked sausage based on raw materials of plant and animal origin is developed. The optimal recipe for the developed meat product has a high utilitarian coefficient (0.856), the amino acid rate of the limiting amino acid is 0.87. The manufactured prototype is distinguished by high organoleptic characteristics (average organoleptic indicator – 4.8 points). The finished product yield to the unsalted raw materials mass is equal to 120.3%.

1. Introduction

Currently, in accordance with the theory of adequate nutrition in the human body, the main essential components of food (proteins, fats, carbohydrates, vitamins, minerals, etc.) must come in certain proportions and quantities. The protein component of food should be balanced in amino acid composition. Nutrient diet depends on the individual needs of the human body [1–4].

The imbalance and lack of certain ingredients consumption leads to pathological changes in the human body. The increased content of fats, proteins, easily digestible carbohydrates in the diet, lack of dietary fiber, unsaturated fatty acids and vitamins leads to the development of obesity, diabetes mellitus, cardiovascular diseases (including atherosclerosis), digestive organs, cancer, etc. [3, 5–10].

Recently, in dietetics, medical, therapeutic, and other types of functional foods are widely used. These foods make up for the lack of nutritional deficiencies. Functional products contribute not only to prevention, but also sometimes to the treatment of certain diseases. For persons with increased body weight, it is necessary to limit the intake of fat, especially of animal origin. Calorie reduction should be proportional to the excess of the normal body weight [11–13].

An analysis of the available literature allows to identify the raw components of functional recipes for meat products that ensure the deficient nutrients supply (low-fat pork, beef liver, beef grade 1, rice flour, wheat bran, soy protein concentrate). Beef liver includes all essential amino acids, is able to fill the nutritional deficiency of bioavailable iron, water-soluble B vitamins, fat-soluble vitamins A, E and K.



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Soy concentrate used in meat product formulations improves their functional, technological and organoleptic characteristics, helps balance the amino acid composition, enriches the finished product with vitamins A, B1, B2, PP. Rice is a dietary ingredient which enhances not only the functional, technological and organoleptic properties of products, but also enriches them with vitamins, vegetable protein, dietary fiber and micro and macro elements [9, 10].

The use of the drug “Vitacel” is important for regulating the calorie content of finished products. Vitacel is also a source of dietary fiber [14–17].

2. Research methods

The research results were statistically processed in the program Statistic v.10. The chemical composition of cooked sausages samples was determined on a FoodScan analyzer. The finished products yield was calculated according to the generally accepted method. Organoleptic indicators were determined on a 5-point scale according to GOST R 52196-2011. The water-binding ability of minced meat was investigated by the method of R. Grau and R. Hamm. The mathematical model of amino acid composition balance was calculated according to the method of N. N. Lipatov [18–20]. To develop the composition of the original composition, the mixture plan was used. In the planning matrix, the calculations of chemical and amino acid compositions were carried out in EXCEL.

3. Results and discussion

When choosing the most favorable composition, it is necessary to have additional variants of input parameters between the extreme boundaries of the factors. Using Pascal algorithmic language, an array of variables was created. A fragment of 16443 experiments array is presented in table. 1. The functional indicators in the created database (fat, protein, vitamins, mineral and amino acid compounds) were calculated using neural network technologies.

Table 1. Virtual Array.

Experiment No.	Composition ingredients, %						
	Beef grade 1	Low-fat pork	Vitacel	Beef liver	Soy flour	Soy concentrate	Rice
1	2	3	4	5	6	7	8
1	43.0	48.0	0.9	4.1	2.0	1.0	1.0
....							
25	70.4	7.1	0.0	15.0	2.5	2.5	2.5
....							
116	74.0	12.0	1.5	4.2	4.0	4.0	0.3
....							
16442	62.6	4.7	2.5	16.6	2.3	5.0	6.3
16443	47.7	38.0	1.6	9.5	0.2	1.0	2.0

Table 2. Chemical amino acid composition of array.

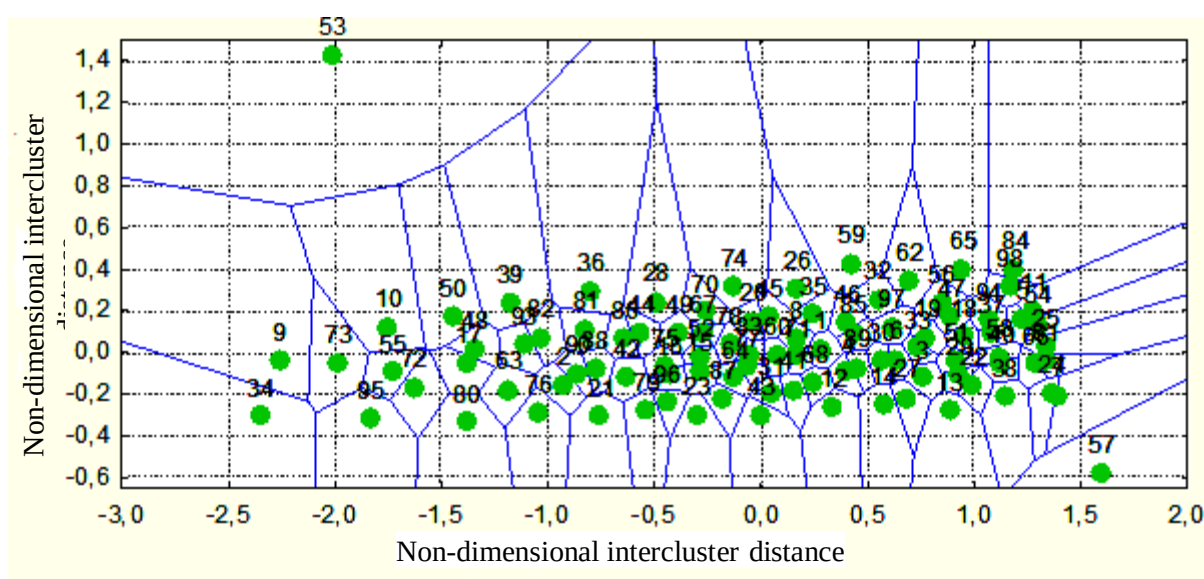
Experiment No.	Mineral composition, mcg/100 g								
	Protein	Fat	Sodium	Potassium	Calcium	Phosphorus	Iron	Magnesium	Zinc
1	9	10	11	12	13	14	15	16	17
1	14.3	12.0	51.0	242.0	7.0	164.0	1.6	21.0	3.0
2	18.0	3.1	63.1	315.5	8.7	182.5	2	21.3	3.1
....									

116	21.3	4.3	111.6	282.2	12.0	197.7	2.6	32.9	3.0
....									
16442	17.3	3.4	91.6	237.0	8.9	164.5	2.4	23.7	2.8
16443	16.9	6.5	72.7	248.7	7.3	154.9	1.9	19.4	2.8

Table 2. Continued.

Experiment No.	Content of vitamins, mcg/100 g						
	B1	B2	B3	B6	B12	E	PP
1	18	19	20	21	22	23	24
1	0.5	0.1	0.5	0.3	2.0	0.5	2.4
2	0.0	0.1	0.4	0.4	2.5	0.5	4.5
....							
116	0.1	11.4	0.5	4.9	5.0	0.5	4.0
....							
16443	0.3	23.7	0.5	9.9	7.8	0.5	3.1

In accordance with the lack of individual nutrients in the diet and in order to develop a balanced amino acid composition of the formulation, the obtained data were clustered (figure 1).

**Figure 1.** Virtual array clustering diagram.

To determine the optimal cluster, reference parameters for amino acid composition (FAO / WHO standard) and the desired characteristics of the chemical composition (including vitamin and mineral) were introduced into the initial data array. The optimization results are shown in table 3.

According to the methodology by Academician N. N. Lipatov, the assessment of the mutual balance and rationality of essential amino acids in the most optimal options was carried out (table 4).

Table 3. Composition variants in the optimal cluster.

Experiment No.	Ratio of components, %						
	Beef grade 1	Low-fat pork	Vitacel	Beef liver	Soy flour	Arcon-S	Rice

1	55.4	7.0	1.0	27.0	2.5	2.7	4.4
2	65.9	0.7	1.1	26.0	1.0	2.6	2.7
3	54.0	10.4	1.7	25.2	2.7	3.0	3.0
4	61.2	0.2	0.0	29.1	3.1	3.2	3.2
5	64.5	0.0	0.5	27.2	0.0	3.9	4.0
6	55.4	8.9	1.2	27.3	1.9	2.8	2.5
7	52.9	8.5	2.5	27.9	3.5	3.3	1.4
8	53.5	6.9	1.1	26.8	4.2	3.6	3.9
9	57.0	8.6	2.2	25.5	0.8	3.8	1.7
10	54.1	9.6	2.0	27.1	2.6	3.8	0.8
11	59.4	6.7	0.4	27.0	3.6	2.8	0.1
12	59.4	3.7	0.4	26.9	2.8	2.5	4.3
13	55.5	4.2	2.4	27.9	5.2	2.2	3.7
14	45.3	21.4	0.2	24.8	4.3	2.0	2.0
15	56.3	9.8	1.1	26.7	1.9	3.2	1.0

Table 4. Balance and rationality of the amino acid composition in the studied options.

Composition No.	Limiting amino acid score (C min), fraction	Utility ratio (U), fraction	Indicator of excess content of essential amino acids (σ_T), g/100g of protein	Indicator of comparable excess content of EAA(σ_C), g	Use of non-essential amino acids for biosynthesis of EAA, (Σ^{BS} EAA), mass fractions	Use of EAA as energetic material (Σ^{EG} EAA), mass fraction
	0.85	0.8352	6.03	7.09	0.0357	0.16477
2	0.85	0.8331	6.07	7.14	0.0363	0.16687
3	0.87	0.8487	6.28	7.18	0.0372	0.15126
4	0.85	0.8415	5.76	6.78	0.0339	0.15846
5	0.85	0.8326	6.14	7.22	0.0364	0.16730
6	0.85	0.8377	5.92	6.96	0.0349	0.16224
7	0.85	0.8376	5.93	6.98	0.0350	0.16233
8	0.87	0.8516	5.66	6.47	0.0363	0.14839
9	0.87	0.8493	5.76	6.58	0.0370	0.15064
10	0.87	0.8543	5.54	6.33	0.0355	0.14560
11	0.87	0.8516	5.66	6.47	0.0363	0.14839
12	0.85	0.8352	6.03	7.09	0.0356	0.16475
13	0.85	0.8400	5.93	6.74	0.0353	0.15606
14	0.87	0.8533	5.59	6.39	0.0358	0.14661
15	0.87	0.8760	5.50	6.25	0.0327	0.14393

The utility coefficient (U) (table 4) ranges from 0.8326 to 0.8560; fraction of essential amino acids (EAA) – predecessors of non-essential amino acids biosynthesis (Σ^{BS} EAA), is 0.0339 – 0.0364, fraction of EAA which are energetic material (Σ^{EG} EAA) is 0.14393 – 0.16687. The results obtained in Table 4 indicate the amino acid composition balance in the studied compositions. The optimal variant in terms of the amino acid composition is experiment 15, since the limiting amino acid score is 0.87, the utilitarian coefficient – 0.8760, which is preferable compared to other compositions, the EAA

redundancy index is low – 5.50 g/100 g of protein. The use of EAA for nonessential amino acids biosynthesis is 0.0327. The mass fraction of EAA used as an energy-generating material is 0.14393.

Table 5. Main qualitative indicators of cooked sausage recipe design, $q \leq 0.05$.

pH	Water-binding and water-retaining properties, % of total moisture	Output, % to weight of non-salted raw materials	Organoleptic assessment, score						Average organoleptic assessment
			Marketable condition	Color	Smell	Consistence	Taste	Juiciness	
6.58	93.7	120.3	5.0	4.8	5.0	4.8	5.0	4.6	4.8

From the data presented in table 5, we can assume that the active acidity (pH) of the finished product is 6.58, this indicator is typical for cooked sausages. The water-binding capacity (WBC) of minced meat is 93.7% of the total moisture. The high WBC value of the minced meat guarantees a good yield, presentation, juiciness and consistency of the meat product.

4. Conclusion

Using modern statistical methods, a methodology of recipes composition design for multicomponent food products has been developed. Basing on the analysis of the chemical, amino acid, mineral and vitamin compositions of the raw materials, the optimal recipe for boiled sausage was determined, in which the maximum proportion of essential amino acids is used for anabolic purposes. The boiled sausage sample had good organoleptic characteristics. The results obtained indicate the effectiveness of modern statistical methods in designing recipe composition for food products.

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