MATHEMATICAL SIMULATION OF THE EMULSIFYING PROCESS IN THE PREPARATION OF PROTEIN-FATTY EMULSIONS WITH COMBINED PROTEIN PREPARATIONS

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INTRODUCTION

The use of non-meat raw materials (mostly protein preparations of various origins) has already been accepted as a steady practice in the production of meat products, cooked sausages mainly. In this relation some additional problems have come forth: on one hand, to find protein preparation with composition and functional properties suitable for the particular meat product, and, on the other, to find technology for combined processing of the meat and non-meat raws. The common practice is first to prepare the protein-fatty emulsions that are afterwards added to the meat raw materials during their processing (2,3,4).

There has been a growing interest lately towards developing of combined protein preparations based on animal and vegetable proteins possessing both functional properties and more favourable chemical compositions from the standpoint of the physiology of nutrition (5,6).

The formation of combined protein preparations requires specific information about the functional properties of these products, and about their emulsifying properties in particular, that will influence the quality of the filling mass in relation to the protein-fats-water system behaviour (1).

The emulsifying properties of the proteins as related to the cooked sausages technology can be determined by studying the emulsifying ability and stability of the resultant emulsion (2).

For the needs of meat industry a combined protein preparation has been developed containing lactic-protein concentrate (7) and wheat gluten to be added to meat raw materials during the production of cooked sausages.

The aim of the present work was to optimize the emulsifying process in preparation of protein-fatty emulsions from the combined protein preparation, and to determine the optimal proportion of the components.

MATERIALS AND METHODS

Lactic protein, obtained from sour buttermilk by our own method (7), wheat gluten and lard were used to prepare the protein-fatty emulsions. The results obtained for the model system can be completely applied in industrial systems.

The emulsions were prepared in a laboratory mixer at a speed of 3000 min^{-1} of the bladed roller. The most acceptable protein-fat ratio was 1:5 established during preliminary studies. The emulsifying properties of the combined protein preparation were studied in relation to the following factors bearing the greatest influence:

1. Amount of added water
2. Emulsion processing time (emulsification)
3. Lactic-protein concentrate : gluten ratio.

The absolute amounts of the components used in the emulsion were 20 g proteins (contained in the respective amounts of lactic protein and gluten), and 100 g lard.

The emulsifying ability of the protein preparation and the influence of the above factors were established by means of a complex factor experiment (8), where the emulsion stability was determined by Kozin's method (10), i.e. by measuring the volume of the centrifugally separated liquid phase.

The influence of the added water was studied at two levels, at 20 and 40 cm3; processing time at 3 and 7 min; and added gluten at 30 and 50 g.

In order to establish the values for the studied factors giving a stable emulsion, we programmed the experiments by full factor experiment, and optimized the emulsifying process by Box-Wilson's method (8,9).

RESULTS AND DISCUSSION

Full factor experiment: We selected as the experiment's programming center a point with the following meanings: amount of added water - 30 cm3; emulsion processing time - 5 min; gluten amount - 40 g.

The added water factor was marked x_1, emulsion processing time - x_2, and gluten amount - x_3. The variation intervals were respectively:

$\Delta x_1=10$; $\Delta x_2=2$; $\Delta x_3=10$

The following theoretical matrix was used in the experiment programming (Table 1):

Table 1

No	x_o	x_1	x_2	x_3
1	1	1	1	1
2	1	-1	1	1
3	1	1	-1	1
4	1	-1	-1	1
5	1	1	1	-1
6	1	-1	1	-1
7	1	1	-1	-1
8	1	-1	-1	-1

The experimental operating matrix was developed on the basis of the theoretical matrix (Table 2):

Table 2

No	1	2	3	4	5	6	7	8
x_1, cm3	40	20	40	20	40	20	40	20
x_2, min	7	7	3	3	7	7	3	3
x_3, g	50	50	50	50	30	30	30	30

The results (cm3 liquid phase separated during emulsion centrifugation) obtained from the actual experiments are given in Table 3. The number of duplicate experiments is y_1,y_2, y_3.

Table 3

No	x_0	x_1	x_2	x_3	y_1	y_2	y_3	$\bar{y}$	Si^2	$\sum(y_{in}-\bar{y}_{in})^2$
1	1	1	1	1	7,5	7,2	7,4	7,4	0,0234	0,0468
2	1	-1	1	1	6,3	6,3	6,2	6,3	0,0034	0,0068
3	1	1	-1	1	8,2	8,0	8,1	8,1	0,0100	0,0200
4	1	-1	-1	1	6,9	7,1	6,8	6,9	0,0233	0,0467
5	1	1	1	-1	5,2	5,1	5,0	5,1	0,0100	0,0200
6	1	-1	1	-1	3,9	3,8	4,0	3,9	0,0034	0,0068
7	1	1	-1	-1	5,6	5,5	5,5	5,6	0,0049	0,0098
8	1	-1	-1	-1	4,2	4,3	4,3	4,3	0,0034	0,0068

The results obtained were used to calculate the following regression coefficients: b_0=5,93; b_1=0,60; b_2=-0,28; b_3=1,23; b_{12}=-0,016; b_{13}=-0,037 b_{23}=-0,068; b_{123}=0,006.

After establishing the experiment's dispersion, we verified the coefficient significances and found all, but b_{12} and b_{123} to be significant.

The calculated aspect of the "y" function, i.e. the amount of centrifugally separated liquid phase, is the following:

$$y=5,93+0,6x_1-0,28x_2+1,23x_3-$$
$$-0,037x_1x_3-0,068x_2x_3$$

The verification indicated that the simulation model thus developed is adequate, so next we proceeded with optimization of the process of emulsification. As basic factor of the optimization we chose x_3 with step $H_{b.f.}$=10. The corresponding steps of the other two factors (Table 4) were calculated using the basic factor step. Table 4 also shows the results from the imaginary experiments required by Box-Wilson's method.

Table 4

No	x_1	x_2	x_3	x_2x_3	x_1x_3	y (min)	x_1 (cm^3)	x_2 (min)	x_3 (g)
0	0	0	0	0	0	5,92	30	5	40
1	-0,48	0,22	-1	-0,22	0,48	4,33	25,1	5,45	30
2	-0,97	0,45	-2	-0,91	1,94	2,74	20,2	5,91	20
3	-1,45	0,68	-3	-2,06	4,37	1,16	15,4	6,37	10
4	-1,94	0,91	-4	-3,67	7,77	-0,44	10,5	6,83	0
5	-2,43	1,14	-5	-5,74	12,15	-2,03	5,7	7,20	-10

The results obtained indicate that after the third step the "y" value becomes negative. That is why we made additional imaginary experiments between third and fourth steps with step $h_{xi}=\frac{h.xi}{5}$.

The results are given in Table 5. It is obvious that the best result is at c_1=12,5 cm3; c_2= 6,6 min; and c_3=4 g.

Table 5

No	x_1	x_2	x_3	x_2x_3	x_1x_3	y (min)	c_1 (cm3)	c_2 (min)	c_3 (g)
1'	-1,5	0,73	-3,2	2,35	4,97	0,84	14,4	6,47	8
2'	-1,6	0,78	-3,4	2,65	5,61	0,52	13,4	6,56	6
3'	-1,7	0,82	-3,6	2,97	6,29	0,32	12,5	6,65	4
4'	-1,8	0,87	-3,8	3,31	7,01	-0,12	11,5	6,74	2

For these values of the factors studied the emulsion is most stable because the volume of the liquid phase centrifugally separated is minimum.

The tendency witnessed during the imaginary experiments entirely agreed with the subsequent actual experiments at factor levels as pointed before (Table 6).

Table 6

No	x_1 (cm3)	x_2 (min)	x_3 (g)	y_1	y_2	y_3
1	12,5	6,6	4	0,4	0,4	0,5
2	12,5	6,6	4	0,5	0,3	0,3
3	12,5	6,6	4	0,3	0,4	0,3

The statistical analysis of the results from the actual experiments established that t_{cr}= 2,306. Since for t_{obs}=2,08 the inequality $t_{cr} < t_{obs} < t_{cr}$, it can be concluded that the optimization is efficient.

The results obtained for the emulsifying process optimization indicated that the ratio between the lactic protein concentrate and gluten should be 5:1.

CONCLUSIONS

The results obtained from the present study give reason to draw the following conclusions:

1. On the basis of a full factor experiment (x_1: amount of added water, cm3; x_2: emulsion processing time, min; x_3: amount of added gluten to the lactic protein concentrate, g) it has been established the following relation for the amount of unbound liquid phase (y, cm3) separated during the emulsion centrifugation:

$$y=5,93+0,6x_1-0,28x_2+1,23x_3-0,037x_1x_3-0,068x_2x_3.$$

2. The following optimal values were established for the factors resulting in stable emulsion:

- amount of added water: 12,5%
- emulsion processing time: 6,6 min
- lactic protein concentrate to wheat gluten ratio: 5:1.

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