A STUDY ON THE FUNCTIONAL PROPERTIES OF A SUNFLOWER PROTEIN CONCENTRATE IN VIEW OF ITS APPLICATION IN COOKED SAUSAGES. II. EMULSIFYING ABILITY AND EMULSION STABILITY.

KOSTADIN WASSILEV, NONKA MARINSKA and NIKOLAI KAMBEROV

Higher Institute of Food and Flavour Technologies,
26 Lenin Blvd., Plovdiv 4002, Bulgaria.

SUMMARY: Non-meat protein concentrates are used in meat products to improve the nutritive balance and nutritive value of sausages, and to promote the formation of the meat stuffing properties, and, eventually, to influence the quality of the end product. That is why it is necessary to study their functional properties. The subject of the present work is the emulsifying ability of a sunflower protein concentrate in relation to a number of factors. The effect of these factors was studied at three levels. The process of emulsification was purposefully optimized by full-factor experiment in order to determine those factor values where the emulsions are stable. The following relationship for the amount of unbound liquid phase (y, cm^3) separated during emulsion centrifugation was established as well as the optimum values of the studied factors giving stable emulsions: $y=10.52+0.47x_1-0.094x_2-3.72x_3-0.29x_1x_2-0.14x_1x_3-0.11x_2x_3-0.65x_1x_2x_3$.

INTRODUCTION: It is well known that non-meat protein additives used in the production of sausages should possess a number of functional properties that influence the water-holding capacity and emulsifying ability of meat raw materials (Tornberg E., 1977), (Marcus F.K., 1978) and (Scheid D., 1977). That is particularly important for vegetable protein preparations which, as regards their composition and properties, often differ from meat raw materials. It is also known that proteins (animal and vegetable), being surface-active substances, can form emulsions in a water-fat-protein system, and decrease the surface stress of the phase interface (Hutton et al., 1977).

The emulsifying properties of the protein preparations mentioned above are important when the latter are used as nutritive components. They assist the formation of water-fatty emulsions, and stabilize the emulsions already formed, and play the role of a protective barrier around the fatty droplets preventing their fusion. In this way protein preparations exert immediate influence on the organoleptic properties and yield of the finished product. That is particularly obvious in meat products whose technologies necessitate preliminary addition of water followed by heat treatment.

MATERIALS AND METHODS: The studies were carried out with a sunflower protein concentrate that was obtained from sunflower seeds after oil separation. The product that remained after the oil separation was milled to grain size 190-275 μ. The concentrate had the following composition: water - 8.1%; protein (for absolutely dry matter) - 45.5%;

crude oil (absolutely dry matter) - 2.1%; nutritive fibres (absolutely dry matter) - 13.1%.

The above concentrate was used to prepare protein-fatty emulsions with protein:fat (pork fat) base ratio 1:5. The emulsifying ability of the concentrate and the stability of the emulsions were tested in relation to the effect of the following factors: amount of added water, amount of sunflow er concentrate, and emulsion treatment (emulsification) time. The emulsions were prepared in a laboratory mixer at 3 000 min^{-1}.

The effect of the amount of added water was studied at three levels: 25, 30 and 35 cm^3. The effect of the amount of sunflower concentrate was also studied at three levels: 5,6 and 7 g; and the treatment time factor was studied for 3, 5 and 8 min.

The emulsifying ability of the protein preparation and the effect of each of the above factors were established by a single-factor analysis of variance (Bondar A.G. et al., 1976), and the emulsion stability was determined by Kosin's method (Kosin N.I., 1966).

In order to find out the factor values where the emulsions will be stable, we made full factor experiment planning and optimization of the emulsifying process by Box-Wilson's method (Schwart D., 1969).

RESULTS AND DISCUSSION: 1. Effect of the amount of added water. As already mentioned, this factor was studied at three levels. The results are given in Table 1.

Table 1

Amount of added water (cm^3)	25		30		35	
No	x_1	x_1^2	x_2	x_2^2	x_3	x_3^2
1	11.0	121.0	12.4	153.8	14.3	204.5
2	11.0	121.0	12.4	153.8	14.3	204.5
3	11.3	127.7	11.6	134.6	13.6	185.0
4	11.3	127.7	11.6	134.6	13.6	185.0

x_1, x_2, x_3 = the amount of liquid phase separated at emulsion centrifugation.

$\sum Rj=148.4$; $\sum Pj=1\ 852.9$; $\sum Rj^2=7\ 406.8$

p=factor number; q=number of parellel tests

$\alpha=0.05$ - confidence level

$SS=17.71$; $SS_b=16.49$; $SS_w=1.22$

$MS_b=8.24$; $MS_w=0.14$; $F_{studied}=60.62$

$F_{crit.}\ /\alpha;\ p-1;\ p(q-1)/ = 4.26$

$F_{studied} > F_{crit.}$ i.e. the studied factor influences the emulsifying process. The additional verification proved that this factor influences the process at any level.

2. Effect of the amount of the sunflower concentrate. The results for the effect of this factor are given in Table 2.

Table 2

Amount of Sunflower Concentrate (g)	5		6		7	
No	x_1	x_1^2	x_2	x_2^2	x_3	x_3^2
1	11.0	121.0	10.4	108.2	11.5	132.25
2	11.0	121.0	10.4	108.2	11.5	132.25
3	11.3	127.7	10.1	102.1	11.9	141.61
4	11.3	127.7	10.1	102.1	11.9	141.61

$$F_{studied} = 37.11; \quad F_{crit.} = 4.26$$

$F_{studied} > F_{crit.}$ i.e this factor also has an effect on the emulsification process. The additional verification also established that this factor is expressed at all levels.

3. Effect of emulsion treatment (emulsification) time. The results are given in Table 3.

Table 3

Emulsification Time (min)	3		5		8	
No	x_1	x_1^2	x_2	x_2^2	x_3	x_3^2
1	11.0	121.0	12.0	144.0	12.7	161.3
2	11.0	121.0	12.0	144.0	12.7	161.3
3	11.3	127.7	11.8	139.2	12.3	151.3
4	11.3	127.7	11.8	139.2	12.3	151.3

$$F_{studied} = 57.19; \quad F_{crit.} = 4.26$$

$F_{studied} > F_{crit.}$ i.e. the factor influences the emulsifying process, and its influence is expressed at all levels.

4. Full factor experiment. After we had established the effect of the studied factors we proceeded towards a full factor experiment. The center of the experiment planning as selected by us was a point with the following factor values: amount of added water - 30 cm^3; amount of sunflower concentrate - 7 g; emulsification time - 6 min.

x_1 was the amount of added water, x_2 - the amount of sunflower concentrate, and x_3 - emulsification time. We accepted corresponding factor variation intervals that were marked as follows: $\Delta x_1 = 5$ cm^3, $\Delta x_2 = 3$ g, $\Delta x_3 = 3$ min.

For experiment planning we used the following theoretic matrix (Table 4).

Table 4

NO	X_0	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

Based on the above we worked out the experiment working matrix (Table 5).

Table 5

No	1	2	3	4	5	6	7	8
X_1, cm^3	35	25	35	25	35	25	35	25
X_2, g	10	10	4	4	10	10	4	4
X_3, min	9	9	9	9	3	3	3	3

The following Table 6 gives the results (cm^3 liquid phase separated during emulsion centrifugation) from the actual experiments with two parallel tests:

Table 6

No	X_0	X_1	X_2	X_3	Y_1	Y_2	$\bar{Y}$	$\sum(Y_{in}-\bar{Y}_{in})^2$	S^2_{in}
1	1	1	1	1	6.6	6.5	6.55	0.005	0.0025
2	1	-1	1	1	6.8	6.5	6.65	0.045	0.0225
3	1	1	-1	1	14.9	15.0	14.95	0.005	0.0025
4	1	-1	-1	1	13.7	13.4	13.55	0.045	0.0225
5	1	1	1	-1	7.4	7.4	7.40	0.000	0.0000
6	1	-1	1	-1	6.8	6.4	6.60	0.080	0.0400
7	1	1	-1	-1	15.0	15.1	15.05	0.005	0.0025
8	1	-1	-1	-1	13.4	13.4	13.40	0.000	0.0000

The results obtained were used to calculate the following coefficients:

$b_0=10.52$; $b_1=0.47$; $b_2=-3.72$; $b_3=0.094$; $b_{12}=-0.29$; $b_{13}=-0.14$; $b_{23}=-0.11$; $b_{123}=-0.65$

Having determined the experiment dispersion, we verified the significance of the coefficients and found out that all coefficients are significant.

The calculations gave us the following model for Y - the amount of the liquid phase liberated during emulsion centrifugation: $y=10.52+0.47x_1-3.72x_2-0.094x_3-0.29x_1x_2-0.14x_1x_3-0.11x_2x_3-0.65x_1x_2x_3$.

The verification proved that the model thus composed is adequate and we could go on with optimization of the emulsification process with optimization base factor x_2 with step $H_{base\ factor}=3$. The results from the imaginary experiments required by Box-Wilson's method are presented in Table 7.

Table 7

No	X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3	$X_1X_2X_3$	y	C_1 cm^3	C_2 g	C_3 min
0	0	0	0	0	0	0	0	10.52	30.0	7	6.00
1	0.6	1	0.03	0.6	0.018	0.03	0.018	6.89	31.1	10	6.08
2	1.2	2	0.06	2.4	0.072	0.12	0.144	2.83	32.1	13	6.16
3	1.8	3	0.09	5.4	0.162	0.27	0.810	-1.95	33.2	16	6.24

It can be seen that after step 3 the result for y becomes negative. For more accurate determination of the optimum where the outcome of the emulsification process will be most favourable (y will approximate 0) we carried out additional imaginary experiments between steps 3 and 4 with a new step $h_{xi}=\frac{h\ .\ x1}{5}$. The results are given in Table 8.

Table 8

No	X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3	$X_1X_2X_3$	y	C_1 cm^3	C_2 g	C_3 min
1	1.32	2.2	0.066	2.9	0.09	0.145	0.191	1.96	32.22	13.2	6.16
2	1.44	2.4	0.072	3.5	0.10	0.173	0.249	1.06	32.34	13.4	6.17
3	1.56	2.6	0.078	4.1	0.12	0.203	0.317	0.15	32.46	13.6	6.18
4	1.68	2.8	0.084	4.7	0.14	0.235	0.395	-0.78	32.58	13.8	6.18

It is obvious that the best result for y is at $C_1=32.46$ cm^3, $C_2=13.6$ g, and $C_3=6.18$ min, and this is the result that can be accepted as the most favourable outcome of the emulsification process.

So we can assume that the values previously indicated for the studied factors will give stable emulsions because the liquid phase separated during their centrifugation will be of minimum amount (0.15 cm^3).

The tendency manifested at the imaginary experiments was entirely confirmed by later actual experiments at the established optimum values of the studied factors.

CONCLUSIONS: The results from our studies make possible to conclude the following: 1. On the basis of a full factor experiment (x_1=the amount of the added water, cm^3; x_2=the amount of sunflower concentrate, g; x_3=emulsion treatment time, min) it was established the following relationship for the amount of the unbound liquid phase (y, cm^3) that is separated during emulsion centrifugation: $y=10.52+$ $+0.47X_1-3.72X_2-0.094X_3-0.29X_1X_2-0.14X_1X_3-0.11X_2X_3-0.65X_1X_2X_3$

2. There were established the following optimum values for the studied factors giving a stable emulsion with the sunflower protein concentrate used by us:

- amount of added water - 26.5 %
- amount of sunflower concentrate - 11.2 %
- emulsion treatment time - 6.2 min.

REFERENCES:

- Tornberg E., Hermanson A. (1977) J. Food Sci. 42, 2, 468-472.
- Mareus F.K. (1978) Die Fleischerei, 29, 2, 42-45.
- Scheid D. (1977) Die Fleischwirtschaft, 57, 10, 1761-1769.
- Hutton C.W., Campbel A.M. (1977) J. Food Sci., 42, 2, 457-460.
- Bondar A.G., Statjuha G.A. (1976) Wishashola, Kiew.
- Schwart D. (1969) Methodes Statistiques a l'usage des medieines et des biologistes, Paris.
- Kosin N.I. (1966) Primenenie emulsii v pistevoi promishlenosti, Pisht. prom., Moscow.