EFFECT OF ADDITIVES ON THE ELASTIC AND PLASTIC PROPERTIES OF BREAD-CRUMB

II. EFFECT OF MILK

By

L. TELEGDY KOVÁTS, R. LÁSZTITY and L. SUSITZKY

Institut of Food Chemistry, Polytechnic University, Budapest

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Among the physical properties of bread-crumb elasticity is of special importance in qualifying bread. In the first article of the present series [12] the theoretical considerations concerning elasticity and its measurement were discussed.

In our present investigations, changes in the plastic and elastic properties of bread-crumb due to the influence of added milk varying as to fat content, are examined.

Milk is one of the most frequently employed additives in the baking industry. It can be used as full-cream milk, skimmed milk, partly skimmed milk, milk powder, skimmed milk powder etc. The effect of these milk-additives on the quality of bread was studied by several authors. One part of the investigations deals with changes in the nutrition value of bread [1, 2], the other more considerable part, with the variation of baking quality owing to added milk. Most of the investigations involve volume tests. In connection with skimmed milk and skimmed milk powder, most research workers point out, that the addition of these substances results in the diminution of the bread volume [3, 4, 5]. Some authors state that the volume increases [6], others have found that depending on the flour employed and the circumstances of production, expansion or diminution occur [7, 8]. Upon addition of full-cream milk or of milk and fat, volume increase was ascertained in every case. Regarding the physical properties of bread-crumb, fewer data are to be found in the literature. According to these data, the addition of full-cream milk, or milk and fat makes the crumb finer to the touch and more elastic, its colour is lighter and the pores are more evenly distributed. When skimmed milk or skimmed milk powder is used, bread-crumb is less liable to crumble and its colour is lighter [7]. As shown by the studies of EDELMANN, CATHCART and BERQUIST [9], the crumb of bread prepared with milk powder is softer than that of bread prepared without milk powder, and during storage firming of the crumb is of a lesser degree. In the literature no data are available concerning the elastic and plastic properties of bread-crumb prepared with milk or milk powder.

Our investigations were performed with a view to obtaining more detailed information about these properties.

Experimental

Raw materials used: Our investigations were carried out with two kinds of "Fbl" type wheat flour*; their baking quality was B_2, and their water absorbing capacity amounted to 60.3%, and 64.2%, respectively. Four kinds of milk was used : skimmed milk, partly skimmed milk containing 0.4% or 2.0% fat, and full-cream milk containing 4.1% fat.

Testing methods: The experimental breads were prepared according to the standard prescriptions [10]. Different quantities of milk were used to prepare the dough and enough water to make it assume the farinographic consistency of 500. The properties of the crumb were tested with an apparatus

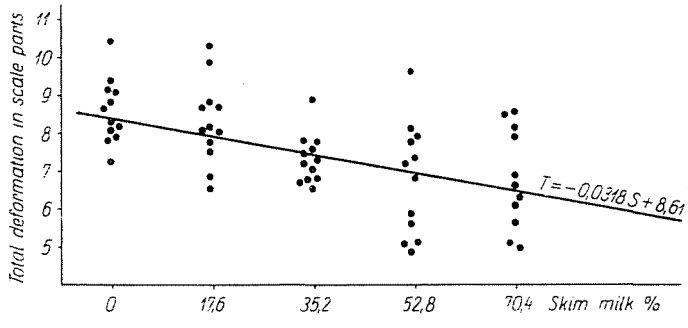


Diagram 1

described in our previous publications [11, 12]. Total deformation, elastic and plastic deformations, as well as relative elasticity were determined [12]. Moreover, the volume of the test breads was determined with the standard method [10].

The results obtained by investigation of crumb from breads prepared with skimmed milk are summarized in Table 1 and in Diagrams 1, 2, 3 and 4. The data were elaborated with mathematical statistical methods and the equations of the regression lines as well as the correlation coefficients were determined. The obtained regression equations are as follows :

Total deformation :	$T = -0.0318\,S + 8.61$
Permanent deformation :	$P = -0.0024\,S + 2.12$
Relative elasticity :	$Re = -0.0556\,S + 75.13$
Elastic deformation :	$E = -0.0293\,S + 6.55$

where S = % quantity of skimmed milk used to prepare the dough.

* Wheat flour with 0,95% ash content.

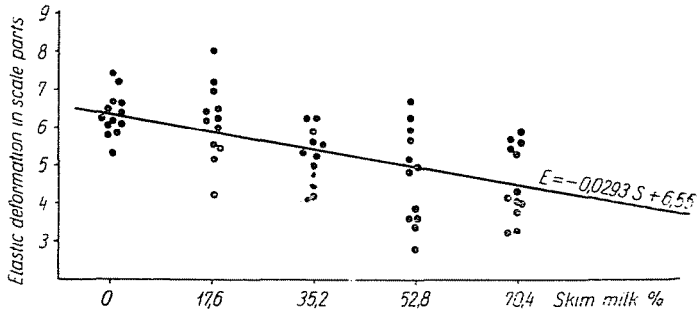


Diagram 2

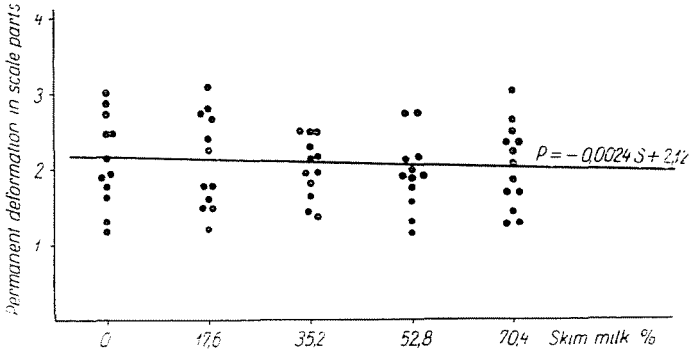


Diagram 3

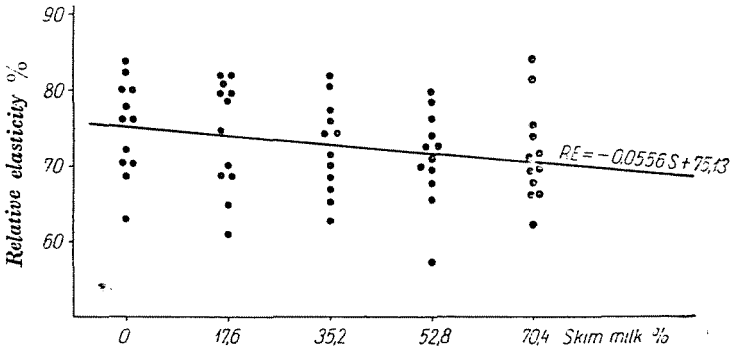


Diagram 4

Table 1

Physical properties of crumb from breads prepared with addition of skimmed milk

Series	Total deformation					Permanent deformation					Elastic deformation					Relative elasticity				
	Skimmed milk, per cent of flour																			
	0	17,6	35,2	52,8	70,4	0	17,6	35,2	52,8	70,4	0	17,6	35,2	52,8	70,4	0	17,6	35,2	52,8	70,4
1	8,1	8,8	6,8	7,7	7,8	1,8	2,8	1,8	2,7	2,6	6,3	6,0	5,0	5,0	5,2	78	68	74	65	67
2	10,4	10,3	8,9	9,5	8,5	2,9	3,1	2,5	2,7	3,0	7,5	7,2	6,4	6,8	5,5	72	70	72	72	65
3	7,2	7,6	6,8	5,0	5,1	1,2	1,6	2,5	1,3	1,8	6,0	6,0	4,3	3,7	3,3	83	79	63	94	84
4	8,2	8,1	7,5	5,5	5,5	2,1	1,2	2,1	1,9	1,6	6,7	5,6	4,9	3,9	4,4	76	82	70	69	73
5	8,8	6,8	7,0	5,8	6,0	1,3	1,5	1,6	2,1	1,4	6,6	6,3	5,5	2,8	4,1	84	81	77	57	75
6	7,9	7,8	7,1	4,9	5,5	2,5	1,8	2,3	1,9	2,6	6,5	8,0	4,2	5,9	5,9	71	82	65	76	69
7	9,2	9,8	6,5	7,8	8,5	1,7	1,8	1,4	2,1	2,3	6,1	7,0	6,3	4,8	5,5	78	80	82	70	81
8	7,8	8,8	7,7	6,9	6,8	3,0	2,8	2,5	2,0	2,2	5,3	5,1	5,3	5,0	4,0	63	65	68	71	62
9	8,3	7,9	7,8	7,0	6,5	2,5	2,7	2,2	1,8	2,3	6,2	4,2	4,5	6,2	4,1	71	61	67	78	66
10	8,7	6,9	6,7	8,0	6,4	1,8	2,3	1,9	1,5	2,3	7,3	6,4	5,3	5,7	5,7	80	74	74	79	71
11	9,1	8,7	7,2	7,2	8,0	2,8	2,4	1,4	1,2	1,3	6,6	5,6	5,9	3,5	3,4	70	70	81	74	72
12	9,4	8,0	7,3	4,7	4,7	1,9	1,5	1,9	1,8	1,7	6,3	6,6	5,6	3,7	3,8	77	81	75	67	70

The corresponding correlation coefficients are as follows:

$$r_t = -0.589$$
$$r_p = -0.119$$
$$r_{te} = -0.198$$
$$r_e = -0.630$$

The data reveal that the compressibility of crumb from breads prepared with skimmed milk decreases with increase of the skimmed milk content. Permanent deformation only slightly changes, so that the decrease of total deformation is chiefly the result of diminished elastic deformation. Most probably the decrease of compressibility is not due to strengthening of the crumb skeleton by the proteins of skimmed milk, but to the volume of bread (see Table 2) diminished by the addition of skimmed milk. The pore walls

Table 2

Volume of breads prepared with different kinds of milk

Type of bread	% of the added milk	Volume* ml.
Prepared with skimmed milk	0	950
	17,6	945
	35,2	903
	52,8	892
	70,4	860
Prepared with milk containing 0,4% fat	0	860
	19	860
	38	876
	57	920
	76	922
Prepared with milk containing 2,0% fat	0	940
	18,3	975
	36,6	982
	54,9	1025
	73,2	1040
Prepared with full-cream milk	0	870
	19	905
	38	943
	57	990
	76	1040

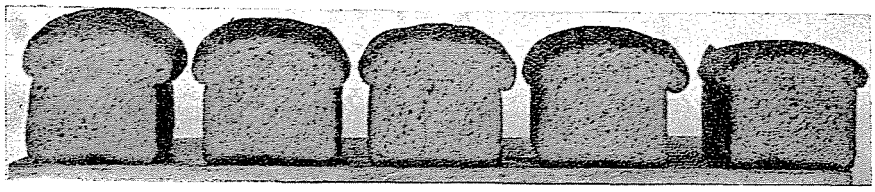
*The volumes refer to averages of 5 breads.

Table 3

Physical properties of crumb from breads prepared with milk of 0.4% fat content

Series	Total deformation					Permanent deformation					Elastic deformation					Relative elasticity				
	Milk (0,4% fat), per cent of flour																			
	0	19	38	57	76	0	19	38	57	76	0	19	38	57	76	0	19	38	57	76
1	6,8	8,6	7,0	7,2	9,0	2,1	2,5	2,5	1,5	4,0	4,7	6,1	4,5	5,7	5,0	69	74	64	79	56
2	6,3	8,3	8,6	7,2	8,6	1,1	2,8	2,1	2,5	3,3	5,2	5,5	6,5	4,7	5,3	83	66	76	65	62
3	5,7	7,0	7,6	8,1	9,0	1,0	1,8	1,8	3,5	2,3	4,7	5,2	5,8	4,6	6,7	83	74	76	57	74
4	8,0	7,0	7,5	8,5	10,5	3,6	2,5	2,6	1,7	5.6	4,4	4,5	4,9	6,8	4,9	55	64	65	80	47
5	6,2	7,1	8,2	7,5	8,5	1,7	3,6	1,9	2,5	3,6	4,5	3,5	6,3	5,0	4,9	73	49	77	67	58
6	7,5	8,0	6,0	7,3	7,8	2,0	3,5	1,0	2,6	2,3	5,5	4,5	5,0	4,7	5,5	73	56	83	64	71
7	6,6	6,5	5,3	7,8	7,3	1,3	1,6	1,1	3,0	3,0	5,3	4,9	4,2	4,8	5,3	80	75	79	62	64
8	7,5	6,2	5,8	6,7	7,6	2,7	2,0	1,8	1,5	2,3	4,8	4,2	4,0	5,2	5,3	64	68	69	78	70
9	6,7	11,0	7,2	7,3	9,5	1,2	4,0	1,3	2,1	4.2	5,5	7,0	5,9	5,2	5,3	82	64	82	71	56
10	8,0	10,1	9,5	7,0	7,0	2,6	1,0	3,0	1,8	1,0	5,4	9,1	6,5	5,2	6,0	63	90	68	74	86
11	7,6	9,1	9,0	5,7	8,6	1,4	3,1	2,0	1,9	3,3	6,2	6,0	7,0	3,8	5,3	82	66	78	67	62
12	6,2	5,8	7,6	9,5	7,7	1,5	1,3	2,3	3,0	1,5	4,7	4,5	5,3	6,5	6,2	76	77	70	68	81

in the crumb of bread decreased in volume are thicker, the bread itself is more compact, and its crumb is less readily formed (see Photograph 1). Marked



Photograph 1

decrease of elastic deformation as compared to plastic deformation is the result of the milk proteins built into the skeleton of the crumb being inferior in elasticity to the gluten proteins.

Table 3 and Diagrams 5, 6, 7 and 8 contain test data of crumb from breads prepared with skimmed milk containing 0.4% fat. Cross-sections of

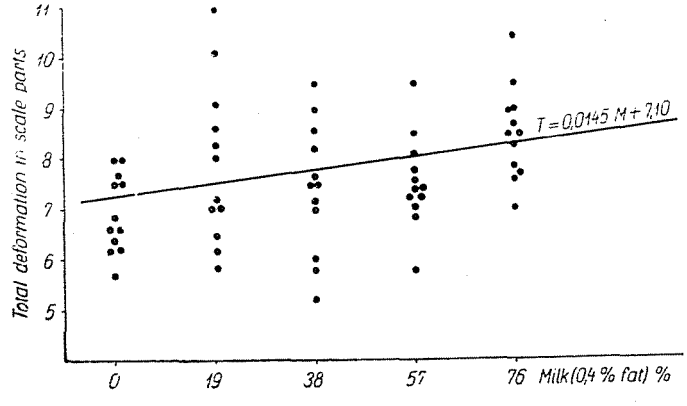


Diagram 5

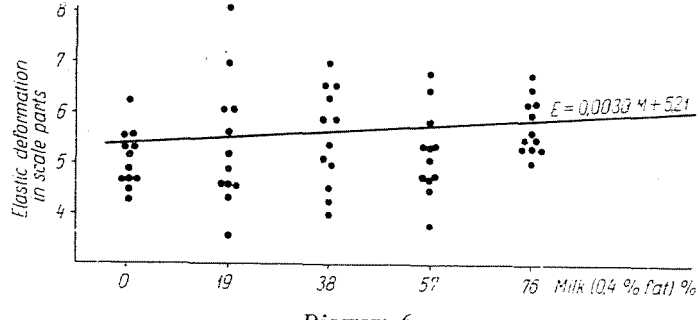


Diagram 6

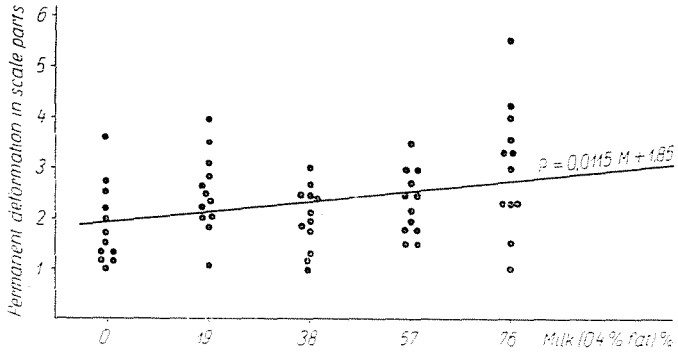


Diagram 7

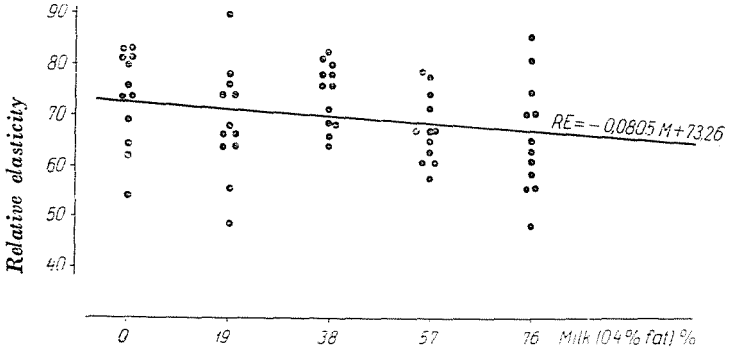


Diagram 8

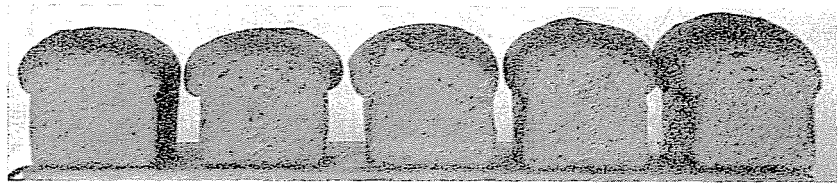
a series of test breads are shown in Photograph 2. The equations of the regression lines corresponding to the data, and the respective correlation coefficients are as follows :

$$T = 0.0145\,M + 7.10 \qquad r_t = 0.299$$
$$P = 0.0115\,M + 1.85 \qquad r_p = 0.345$$
$$RE = -0.0805\,M + 73.26 \qquad r_{re} = -0.233$$
$$E = 0.0030\,M + 5.21 \qquad r_e = 0.087$$

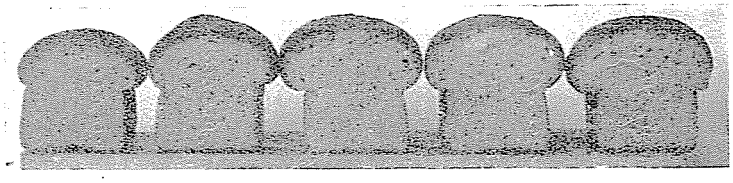
where M = % quantity of milk with 0.4% fat content used to make the dough.

Photograph 2

The data show considerable variances. It can be stated that total and permanent deformations display a slowly increasing tendency, while elastic deformation remains practically almost unchanged and correlation with the milk content is not significant. Relative elasticity shows a slow decrease.



Photograph 3



Photograph 4

The test data of crumb from breads prepared with milk containing 2% fat are presented in Table 4 and Diagrams 9, 10, 11 and 12. A series of the breads are to be seen in Photograph 3.

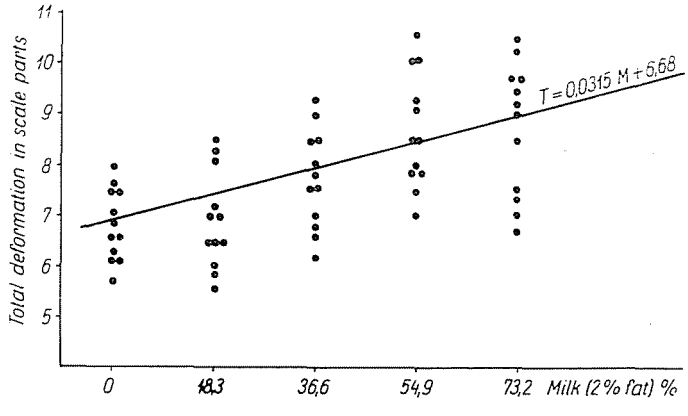


Diagram 9

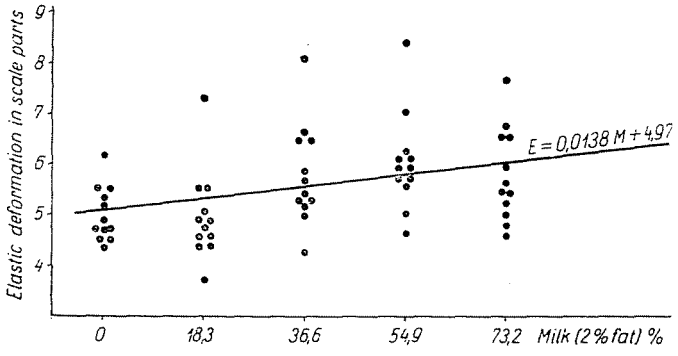


Diagram 10

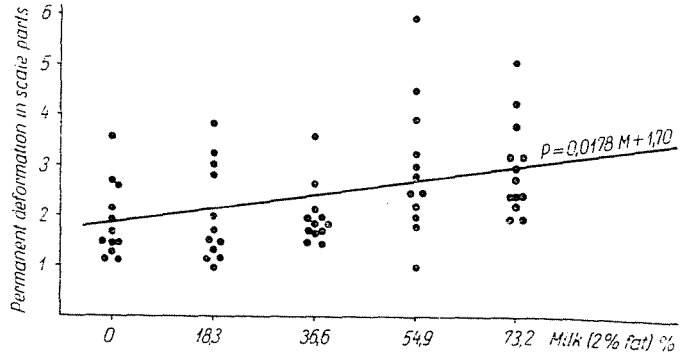


Diagram 11

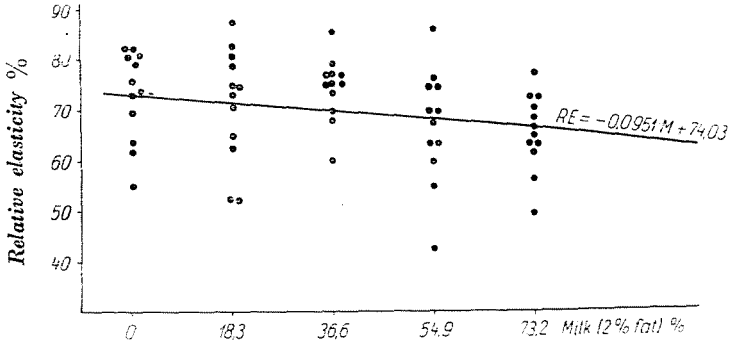


Diagram 12

The equations of the regression lines corresponding to the data, and the respective correlation coefficients are as follows :

$$\begin{aligned} T &= 0.0315\,M + 6.68 & r_t &= 0.613 \\ P &= 0.0178\,M + 1.70 & r_p &= 0.434 \\ RE &= -0.0951\,M + 74.03 & r_{re} &= -0.272 \\ E &= 0.0138\,M + 4.97 & r_e &= 0.333 \end{aligned}$$

where M = % quantity of milk with 2.0% fat content used to prepare the dough.

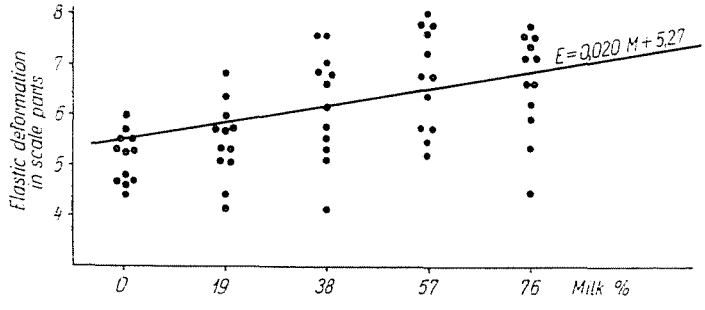


Diagram 13

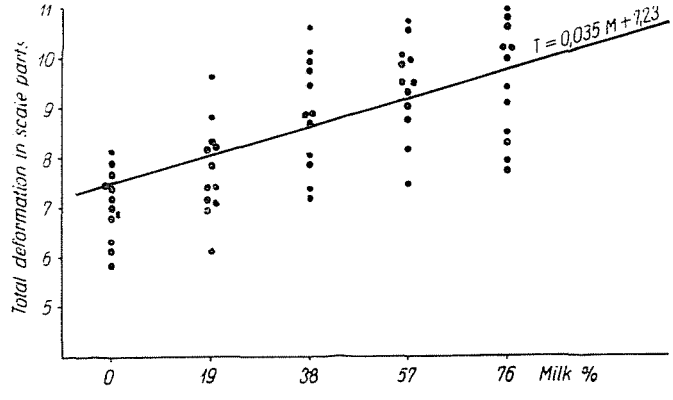


Diagram 14

The results show that total deformation increases with the quantity of added milk, and correlation with the quantity of added milk is quite good. A similar increase can be observed in permanent and elastic deformations too. The change is more marked in permanent deformation than in elastic deformation ; consequently relative elasticity decreases also in this case.

Table 5 and Diagrams 13, 14, 15 and 16 contain test data of breads prepared with full-cream milk containing 4.1% fat. Photograph 4 presents the cross-sections of a series of such breads. The equations of the regression

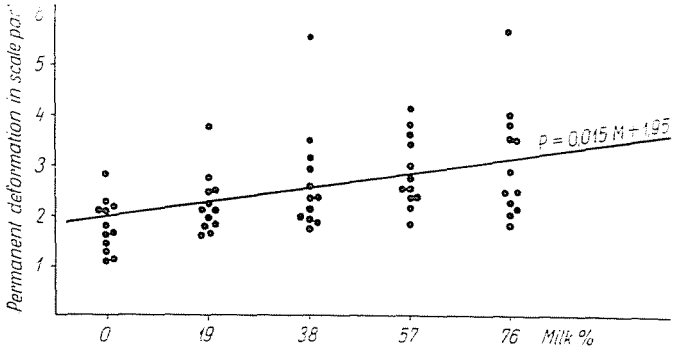


Diagram 15

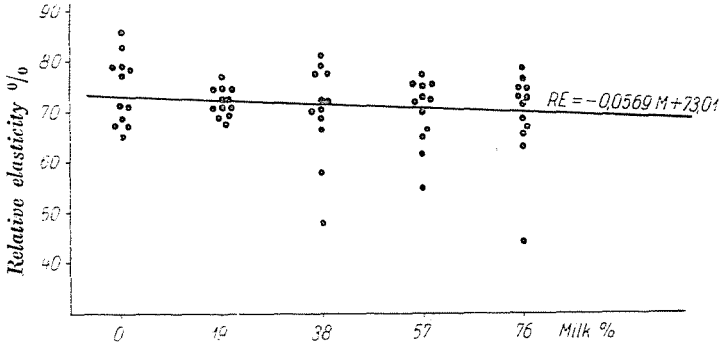


Diagram 16

lines corresponding to test data and the correlation coefficients, are as follows :

$$\begin{aligned} T &= 0.0350\,M + 7.23 & r_t &= 0.691 \\ P &= 0.0150\,M + 1.95 & r_p &= 0.473 \\ RE &= -0.0569\,M + 73.01 & r_{re} &= -0.204 \\ E &= 0.0200\,M + 5.27 & r_e &= 0.542 \end{aligned}$$

where M = % quantity of milk with 4.1% fat content used to make the dough.

The data show that total, elastic, and permanent deformations grow with the increase of the milk content. Although in this case the absolute value of increase in elastic deformation is higher than in plastic deformation increase

Table 4

Physical properties of crumb from breads prepared with milk of 2,0% fat content

Series	Total deformation					Permanent deformation					Elastic deformation					Relative elasticity				
	Milk (2,0% fat), per cent of flour																			
	0	18,3	36,6	54,9	73,2	0	18,3	36,6	54,9	73,2	0	18,3	36,6	54,9	73,2	0	18,3	36,6	54,9	73,2
1	6,8	8,1	8,5	10,6	7,4	2,1	3,8	2,0	6,0	2,7	4,7	4,3	6,5	4,6	4,7	69	53	77	43	64
2	6,3	7,2	7,8	9,1	9,7	1,1	2,7	2,5	3,3	4,2	5,2	4,5	5,3	5,8	5,5	83	63	68	64	57
3	5,7	6,5	9,3	7,8	6,7	1,0	1,1	1,3	2,8	2,1	4,7	5,4	8,0	5,0	4,6	83	83	86	64	69
4	6,2	7,0	7,0	7,0	10,5	1,7	3,3	1,7	1,0	5,2	4,5	3,7	5,3	6,0	5,3	73	53	76	86	51
5	8,0	8,3	9,0	8,5	7,0	3,6	1,0	3,6	2,6	2,0	4,4	7,3	5,4	5,9	5,0	55	88	60	69	71
6	7,5	6,5	6,8	10,1	8,5	2,0	1,6	1,6	4,0	3,1	5,5	4,9	5,2	6,1	5,4	73	75	77	60	64
7	6,6	8,5	8,5	8,0	7,5	1,3	3,0	2,0	2,5	2,0	5,3	5,5	6,5	5,5	5,5	80	65	77	69	73
8	7,5	7,0	7,6	10,1	9,0	2,7	2,0	1,8	4,5	3,1	4,8	5,0	5,8	5,6	5,9	64	71	76	55	66
9	6,7	6,0	6,7	8,5	10,3	1,2	1,5	1,6	2,6	3,8	5,5	4,5	5,1	5,9	6,5	82	75	76	69	63
10	6,0	6,5	6,2	8,0	9,2	2,6	1,7	2,0	2,0	2,5	4,4	4,8	4,2	6,0	6,7	63	74	69	75	73
11	7,6	5,6	8,0	7,5	9,7	1,4	1,2	1,7	1,9	2,3	6,2	4,4	6,3	5,6	7,6	82	79	79	75	78
12	6,2	5,9	7,5	9,2	9,5	1,5	1,1	1,8	2,2	3,0	4,7	4,8	5,7	7,0	6,5	76	81	76	76	68

Table 5

Physical properties of crumb from breads prepared with full-cream milk

Series	Total deformation					Permanent deformation					Elastic deformation					Relative elasticity				
	Full-cream milk, per cent of flour																			
	0	19	38	57	76	0	19	38	57	76	0	19	38	57	76	0	19	38	57	76
1	7,2	8,3	10,7	9,5	9,5	1,2	2,3	5,6	3,7	2,3	6,0	6,0	5,1	5,8	7,2	83	72	48	61	76
2	6,8	8,2	10,0	9,3	10,2	2,2	3,8	3,1	4,1	5,7	4,6	4,4	6,9	5,2	4,5	68	54	69	56	44
3	7,0	8,9	9,8	10,1	10,9	1,5	2,5	2,2	3,5	4,0	5,5	6,4	7,6	7,6	6,9	79	72	76	75	63
4	6,2	6,2	7,2	8,2	7,8	1,4	2,0	3,0	2,8	2,4	4,8	4,2	4,2	5,4	5,4	77	68	58	66	69
5	8,2	9,7	10,2	10,8	10,8	2,9	2,8	3,5	3,8	3,6	5,3	6,9	6,7	7,0	7,2	65	71	66	65	67
6	7,6	7,4	8,7	10,6	8,6	1,8	2,1	2,6	2,9	1,9	5,8	5,3	6,1	7,7	6,7	76	72	70	73	78
7	7,4	7,2	8,1	8,8	11,0	1,7	1,9	2,3	2,4	3,9	5,7	5,3	5,8	6,4	7,1	78	74	72	73	65
8	7,9	8,2	8,9	9,5	10,2	2,3	2,5	1,9	2,7	2,9	5,6	5,7	7,0	6,8	7,3	71	70	79	72	72
9	5,8	7,0	7,3	9,0	8,0	1,1	1,8	2,0	2,2	2,0	4,7	5,2	5,3	6,8	6,0	86	74	73	76	75
10	6,9	7,1	8,8	10,0	9,2	2,2	1,8	1,9	2,5	2,5	4,7	5,3	6,9	7,5	6,7	68	75	78	75	73
11	6,3	7,5	8,0	7,5	8,4	1,8	1,7	2,4	1,9	2,2	4,5	5,8	5,6	5,6	6,2	71	77	70	75	74
12	7,5	7,9	9,5	9,9	10,3	2,1	2,2	1,9	2,6	3,0	5,4	5,7	7,6	7,3	7,6	68	72	80	74	74

of plastic deformation is relatively still greater ; hence in this case too, relative elasticity is diminished by growing volumes of milk.

Summary

The authors investigated the physical properties of crumb from breads prepared with the addition of different kinds of milk varying as to fat content. Total, permanent, and elastic deformations as well as relative elasticity were determined. It has been proved that total, permanent, and elastic deformations of crumb from breads prepared with skimmed milk decrease as the skimmed milk content increases.

Total plastic and elastic deformations of crumb from breads prepared with milk containing 0.4%, 2.0% or 4.1% fat increase in the presence of growing milk content. The measure of growth increases with augmentation of the fat content. Relative elasticity decreases whichever kind of milk is used as additive. This fact furnishes evidence that the building in of milk proteins into the gluten skeleton of bread decreases its elasticity.

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Prof. L. TELEGDY KOVÁTS
R. LÁSZTITY
L. SUSITZKY

Budapest XI., Műegyetem rakpart 3.
Hungary