Correlation between rheological parameters and microstructure of sausages of Bologna type

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Introduction

The organoleptic properties of sausages of Bologna type are determined by the composition and the structure of the product, this in turn depends on the properties of the finely minced, spiced mixture of pulped beef and pork bacon. The finely minced meat, bacon, water and salt (NaCl + $Na_4P_2O_7$) mixture forms a complex colloid system consisting of three phases. One phase in an aqueous solution of the salt and water-soluble proteins, another phase is comprised of the muscle and connective tissue particles, while the third phase is the minced fat tissue. The connection between the microstructure and the rheological behaviour of these products can really be understood only if it is taken into consideration that they possess thixotropic properties /1/. In the systems of this type, the dispersed particles are bound to one another by coagulation forces resulting from the excess of their surface energy. Accordingly, the strength and durability of the structure of the meat pulp are directly proportional to the strength of the binding forces developing between the three phases /2/. In the continous phase, which is in effect an electrolyte solution, globular and fibrillar proteins form a loose, elastic thixotropic framework /3/. Examination of the rheological properties of the mass has revealed that, as a consequence of the rapid increase in the degree of dispersity in the initial stage of the cutting, considerable decreases occur in the viscosity and the limiting shear value.

Subsequently, as the degree of dispersity continues to increase, these rheological properties begin to increase, reach a maximum, and then decrease again. This is evidence of the formation of a new structure /4/. In the course of our work, we sought a correlation between the microstructure and the rheological behaviour of sausages of Bologna type.

Materials and methods

The products studied in the experimental series were prepared in the Hungarian Meat Research Institute, and had the following composition:

beef	50.0 kg
industrial bacon	20.0 kg
water	36.0 kg
white pepper	0.2 kg
ascorbic acid	0.014 kg
nitrite salt mixture	1.74 kg
soluprate ($Na_4P_2O_7$)	o.3 kg
total	108.25 kg

The final product therefore contained 10,4±1 % protein, 16,7±2 % fat and 70±1 % water. Three different procedures were employed in our experiments for preparation of the raw mass of sausages of Bologna type:

Procedure "A": The mixed components were minced for 3.min. in an L5-FKN 50 cutter, and the pulp was then passed through a Stephan MCH-D 30 microcutter.

Procedure "B": The product was minced in the "continuous line cutter" now undergoing testing in the Development Section of the Research Institute.
Procedure "C": The mass prepared by prodedure "B" was further minced in the Stephan MCH-D 30 microcutter. For the rheological examinations, samples were taken from the raw mass prepared by the three technologies, and final products were obtained in a standard manner with constant parameters (filling with the same machine, smoking, Cooking), the microstructures of the products were examined by optical microscope.
For the microstructural studies, the products were allowed to stand for 24 hr, after which 3 μ thick sections were cut and then stained with haematoxylin-eosin and Mallony's stain for the muscle and connective tissue observations. Oil Red O staining was used to establish the distribution of the fat in the product and to determine the dimensions of the fat drops. In each case, five visual fields were evaluated in a transverse direction in sections taken from various sites in the product.
The rheological measurements were performed on a Haake rotation viscosimeter, with the use of an SV measuring system. The scale values were determined from 10 measured points, and multiplication by the potential factor (z) of the instrument gave the shear value (τ). The apparent viscosity was calculated from this via the folliwing relation:

$$\eta = \frac{\tau}{D_r}$$

Measurements were made 8 hr after the production, the mass being stored during this period at +5 ^{o}C. To describe the rheological properties of the meat pulps, we used the Casson equation /5/, which we had previously found effective for this purpose. It was established that the following linear relation holds between $\sqrt{D_r}$ and $\sqrt{\tau}$:

$$\sqrt{\tau} = K_o + K_1 \cdot \sqrt{D_r}$$

where τ is the shear value (N m^{-2}), D_r is the velocity gradient (s^{-1}), K_o is the Casson flow limit (τh_{Ca}) and K_1 is the Casson viscosity (η_{Ca}).
When the equation was applied to meat pulps, it was observed that, at a definite temperature, the behaviour of the mass can be described by a linear equation in the shear velocity interval 1.5-44 s^{-1}. The Casson equation and the values of the regression coefficients were determined from the experimental results with a Hewlett-Packard 97 computer.

Results and discussion

In the experimental work, the microstructures of 15 sausages of Bologna type were compared with their rheological characteristics. The 15 samples were made up from 5 parallel runs on products prepared from the same basic material by methods "A", "B" and "C". On sections of each sample, the numbers of vacuoles were counted with diameters of 1-10 μ, 10-50 μ and 50-150 μ. Table 1 presents the distribution of the vacuoles 10-50 μ in diameter.
The tabulated data were utilized to perform analysis of variance calculations /6/. The mean values of the parameters for the 5 parallel runs (on product prepared by the same technology) were calculated, and are given in Table 2 together with the standard errors /7/.

Table 1.

Statistical evaluation of the number of vacuoles with diameters of 10-50 μ to be found on 1 mm^2 of the sections in the products prepared by the different technologies.

Procedure	Number of vacuoles (n/mm^2) 1.	2.	3.	4.	5.	$\bar{n}$	s^2	s
A	34,5	40,5	66	57	63	52,50	195,08	13,97
B	25	30	29,5	26	41	30,30	4,05	6,36
C	24	45,5	54	34	42	39,90	130,49	11,42

Table 2.

Statistical evaluation of the parameters for the products prepared by technologies "A", "B" and "C", determined by means of the Casson equation.

Procedure	K_o values $\bar{K_o}$	s^2	s	K_1 values $\bar{K_1}$	s^2	s	∝
A	14,14	0,40	0,63	1,13	0,01	0,1	48°30'
B	13,08	2,49	1,58	1,068	0,002	0,046	46°50'
C	13,66	1,37	1,17	0,88	0,04	0,2	41°20'

If the data in the Table are compared with Fig. 1, it may be seen that the highest intercepts K_o and the highest slopes K_1 are clearly exhibited by the samples prepared by procedure "A": these are also the samples which contain most vacuoles with diameters of 10-50 μ.

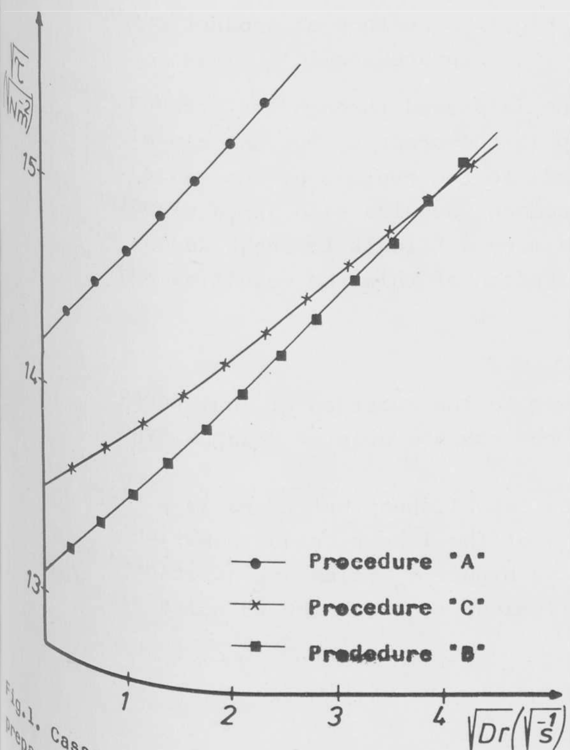

Fig.1. Casson equations for products prepared by procedures "A", "B" and "C"

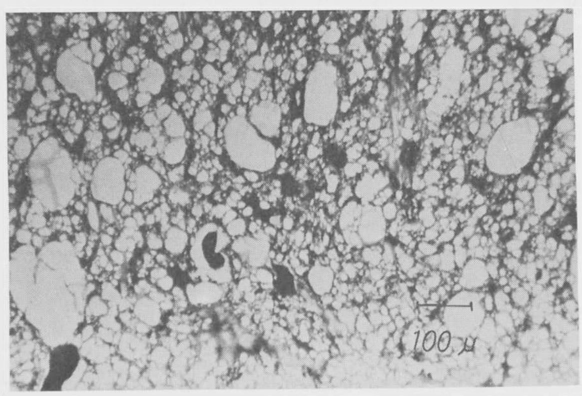

Fig.2. Structure of product prepared by procedure "A"

The photos of the sections clearly demonstrate the differences between the products prepared with the different equipment.

A product with perfect structure is attained with this technology: this is shown not only by the maximum in the number of vacuoles 10-50 μ in diameter, but also by the uniform distribution of the vacuoles. In all cases the inner wall of these vacuoles is covered by macromolecular proteins, which are regarded as very good surfactant materials: these proteins participate in the emulsification of the fats. We have not yet succeeded in establishing exactly what proportions of the vacuoles are occupied by water, fat and air, but it is certain that the distribution of these components in the 1-50 µ diameter interval is responsible for the development of a rheologically and organoleptically perfect product.

The "continuous line cutter" currently undergoing experimentation in the Research Institute could not yield a product of similar quality to the previous one either rheologically or organoleptically. This is well demonstrated by the structure. The number of vacuoles 10-50µ in diameter is far lower, and hence the product is much more compact.

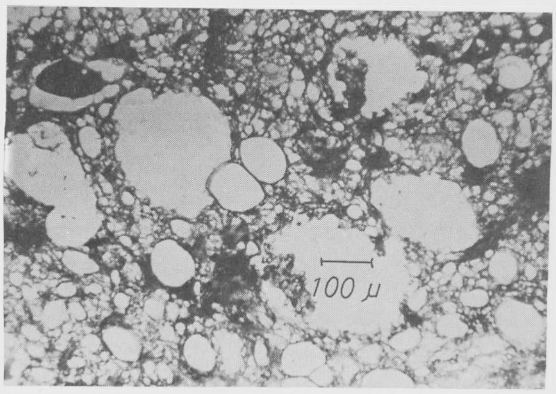

Fig.3. Structure of product prepared by procedure "B"

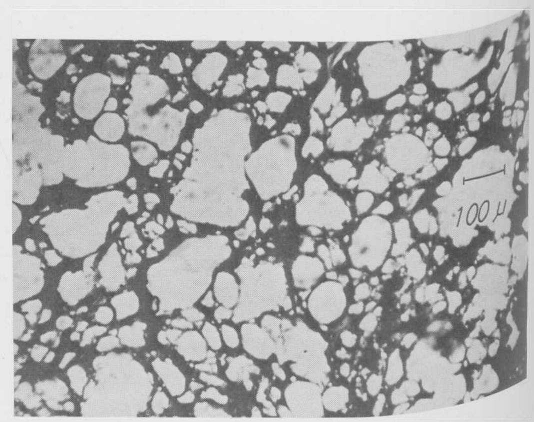

Fig.4. Structure of product prepared by procedure "C"

When the product obtained on the continuous line is passed through the Stephan cutter, this enhances the development of a "foamy" structure in the product, but one can also readily observe the phenomenon that the new mincing leads to the rupture of the walls of the already existing vacuoles and to the formation of common vacuoles with large diameters. This is to be seen in curve "C" of Fig. 1 too: it is more difficult to break down a structure that has already developed, but after the elimination of this the resulting mass flows more easily.

Conclusion

In our series of experiments, we sought an answer to the question of what correlation can be found between the rheological properties of raw sausage pulp of Bologna type and the microstructure of the ready product.

From an investigation of 5 parallel runs, it was established that there is a close correlation between the slope (K_1) and intercept (K_0) of the linear Casson equation and the microstructure of the product. In every case, the higher K_0 value was associated with an extremely uniform structure with ordered distribution, in which the vacuoles with diameters of 10-50 µ predominated.

References

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