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EFFECT OF AMOUNT AND ORIGIN OF PROTEIN ON THE RHEOLOGIC CHARACTERISTICS OF COOKED SAUSAGES

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The stepwise programmed stress method of evaluation of rheological characteristics of solid foods was used for examination of cooked sausages. Those were differentiated in degree of raw material desintegration, level of hydration and amount of non — meat proteins added. The relationships between the rheological parameters: plasticity, fluidity, elasticity, and protein contents were demonstrated. It was observed that sodium caseinate affected the rheological parameters of sausages. No effect of added TVP was observed.

INTRODUCTION

It is well known that proteins are the basic structure-forming elements of meat products. Depending on the degree of raw material processing and addition of other components, the systems of different mechanical characteristics are formed. Those may be characterized on the base of physical measures using any system of objective units or on the base of sensoric assessment using sensory quality factors. Food technologists are mainly interested in finding the relationship between objective characteristics and sensoric features of products.

The main purpose of the study was to establish the basic principles of sausage structure formation under the conditions of using on large scale the non-meat proteins as meat substitutes.

ESTIMATION OF RHEOLOGICAL PARAMETERS OF SOLID FOODS USING THE STEPWISE PROGRAMMED STRESS METHOD

It is obvious that proper rheological method of texture examination of food products ought to be analytical, what means that it should be able to determine any rheological parameter univocally as well as to detect any structural change occuring in the material under examination. If possible, such method should be also a versatile one, what means that it should be suitable to test material of different mechanical properties. The existing methods are not quite analytical. In most of them only the determination of forces needed for sample destruction in predetermined cutting system is possible. If the measurement is recorded, the graphical recording obtained may be investigated and give some analytical data. However this type of figure is not very characteristic one and it is difficult to be interpreted, mainly due to its stress-strain relations variability. The use of Instron's apparatus has made possible to programm precisely the process of deformation of tested samples with concurrent measure of stresses, but the effects have been unsatisfactory yet, because the elasticity of sample can not be measured. That is why the method elaborated many years ago [1] has been and is being used.

There was used a very simple apparatus, a simple penetrometer equipped with flat-ended punch of circular cross-section. The punch was directly loaded with weights. By this way different normal stress of predetermined value could be obtained. Movings of punch were recorded. The most characteristic feature of this method is the way of stress changes programming. Such programm can be seen in Fig. 1. In the way of loading the punch succesively with weights of the same mass the stepwise increase of stress value is obtained, then kept constant for limited time followed by unloading with coming back the stress value to the first level. Deformations caused by this type of stress changes and plotted against time are differentiated in a characteristic manner accordingly to the rheological properties of sample.

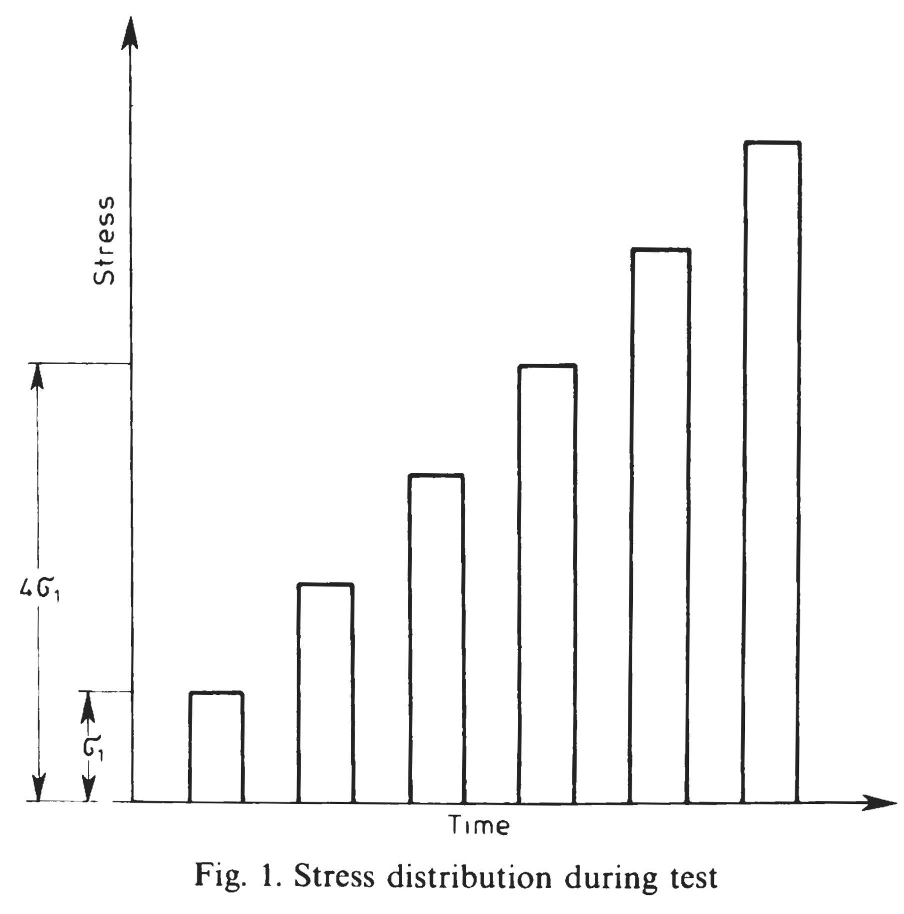

Fig. 1. Stress distribution during test

In Fig. 2 there are presented the deformations for the single viscous element, single elastic element, single plastic element and for the combination of viscous and elastic elements, so called Maxwell's body, Kelvin-Voight's body and Burgers' body. The sloping lines on diagrams manifest the existing viscous

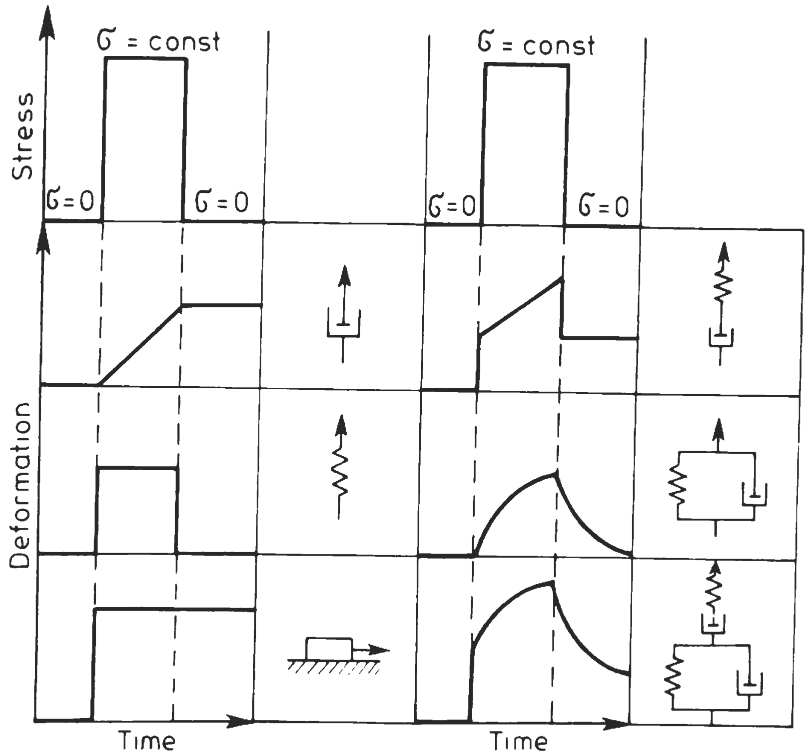

Fig. 2. Typical stress-strain relations for viscous, elastic, plastic and different complex bodies

elements — which may be called "delaying factors" — and the vertical lines manifest the existing elastic elements. The vertical lines on deformation diagrams can also indicate the instant destruction, which is the characteristic feature of plastic body. According to the last statement, the most valid evidence for existing the body elasticity is the reconstruction of body shape after stress disapearing.

Asymptotic curves are typical for visco-elastic fluid of Kelvin-Voight. In Fig. 3 the rheogram of sausage is presented. The unit fragments of the rheogram show the composite structure of the product. Its model consists of plastic elements as well as of viscous ones, in series and parallel connections, as it is specific for model of Burgers' body. When the stress is relatively high, structure of sausage is damaged. Therefore the yield point of tested sausage is the same. So we can consider sausage to be a plastic body and assuming some simplifications, describe its characteristic with Bingham's equation.

The method described can be applied for constructing the rheological models of different bodies [1].

It can be assumed that the rheological model of sausage is valid for all cooked meat products, except the raw smoked sausages and pastes, which are characterized by lack of elastic elements.

Construction of rheological models and calculation of particular constant values can be done throughout the full range of stress but sometimes it is not useful. More useful is selection of any synthetic parameter which could be able to characterize the mechanical properties of tested body in general. Proposed unconventional parameters can be appointed on the base of rheograms outlines analysis. These outlines of rheograms are likely magnetic hysteresis loops. The larger extension of curves limiting the rheogram outlines, the higher elasticity of a tested body. When both the curves are covered one with the other, it can be assumed the tested body to be inelastic, remembering that it is said about a gum-type body characterized by high Young's modulus.

The steep slope of curves observed on the rheogram of paste and raw sausage is due to the lack of elastic elements of structure and it means that the body is susceptible to irreversible deformation.

For the interpretation purpose the most convenient parameter is the yield point σ. It can be determined by defining the stress range which is accompanied by the deflection of rheogram. The shape of this bend characterizes the sample additionally. Sharp bends are typical for plastic bodies — such as sausage — and soft and indistinct bends are typical for pseudoplastic bodies — such as ripe cheese.

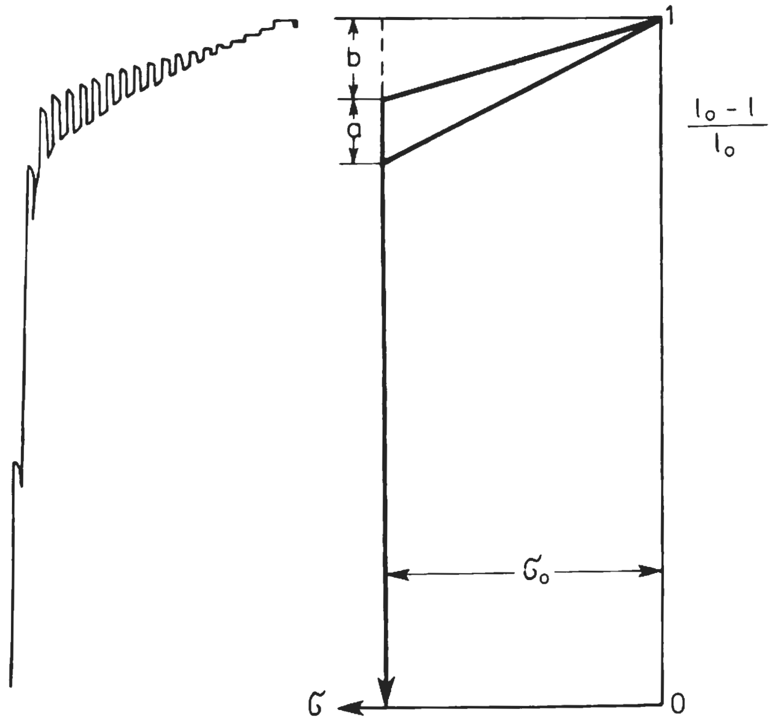

Fig. 3. Sausage rheogram and the principle of its shape interpretation

As it concents cooked meat products, one can make an interpretation resulting from the fact that the rheogram is of triangle shape, what can be seen on Fig. 3. Three characteristic numbers: plasticity P, elasticity E, fluidity F are defined by the following equations:

$$P = \sigma_0 \qquad (N/m^2)$$

$$E = \frac{a}{\sigma_0} \qquad (m^2/N)$$

$$F = \frac{b}{\sigma_0 t} \qquad (m^2/N \cdot s)$$

where a, b, σ_0 — values taken from the rheogram presented on Fig. 3, t — duration time of measure cycle.

The full comparability of the results in the discussed method can be obtained with the punch of the same dimensions and when identical programs of stepwise stress changes are used. The duration time of measure cycle is also a very important factor, especially in the case of bodies containing viscous elements.

Therefore an empirical selection of the most suitable conditions of testing is necessary.

RHEOLOGICAL CHARACTERISTICS OF SAUSAGES OF DIFFERENT DEGREES OF DESINTEGRATION, HYDRATION AND NON-MEAT PROTEIN PREPARATIONS LEVELS

14 types of cooked sausages were the object of investigation. Sausages were produced under experimental conditions. Meat raw materials were partly, up to 30%, substituted by hydrated protein preparations. Sodium caseinate was hydrated in ratio to water as 1:4 and textured vegetable protein (TVP) as 1:2,5.

The technological characteristic, level of meat substitution by sodium caseinate or TVP completed with the name of sausage is presented in Table 1.

The chemical compoisition of sausages was analyzed by determination of protein, water and fat contents assording to Polish Standards. The factors characterizing the proportion of water to protein and fat to protein were calculated.

Table 1. Technological characteristic of tested sauseges

Assortment Name	Symbol	Degree of desintegra- tion Hydration	Substitution level
Parówkowa Mortadela	P M	fine comminuted highly hydrated	sodium caseinate 20%
Zwyczajna Nadwiślańska Mazowiecka Biała Łódzka	Z N MA B L	medium comminuted non-hydrated	sodium caseinate 20% TVP 7% TVP 10.5% TVP 10.5% TVP 10.5%
Serwolatka Jałowcowa Toruńska	S J T	medium comminuted slightly dehydrated	TVP 10.5% TVP 10.5% TVP 10.5%
Krakowska parzona	KP	coarse comminuted medium non-hydrated	TVP 10.5%
Myśliwska półsucha	MP	medium comminuted semidried	pure meat
Myśliwska sucha	MS	medium comminuted dried	
Krakowska sucha	KS	coarse comminuted dried	

The rheological characteristics of sausages were measured on the basis of rheograms interpretation. Rheograms were prepared under constant following conditions: punch diameter 5 mm, duration time of one measuring cycle — 15 s of loading and 15 s of unloading, single weight of the sample — 50 g. Each kind of sausage was represented by 3 samples taken each from 3 bars, making together 9 samples.

The parameters characterizing the elasticity E, fluidity F and plasticity P were calculated and confronted with to chemical composition. Summarized results are presented in Table 2.

It was stated that rheological characteristics of cooked sausages were specified mainly by their protein content. The relationship between rheological parameters and protein contents of the sausages may be observed in Fig. 4 and 5. Plasticity increased with the increasing protein content and the relation was nearly linear one (Fig. 4). Inversely, the increasing protein content was accompanied by the decrease of fluidity (Fig. 5) and this relation was more evidently a curvilinear one (diagram on semilogarithmic scale).

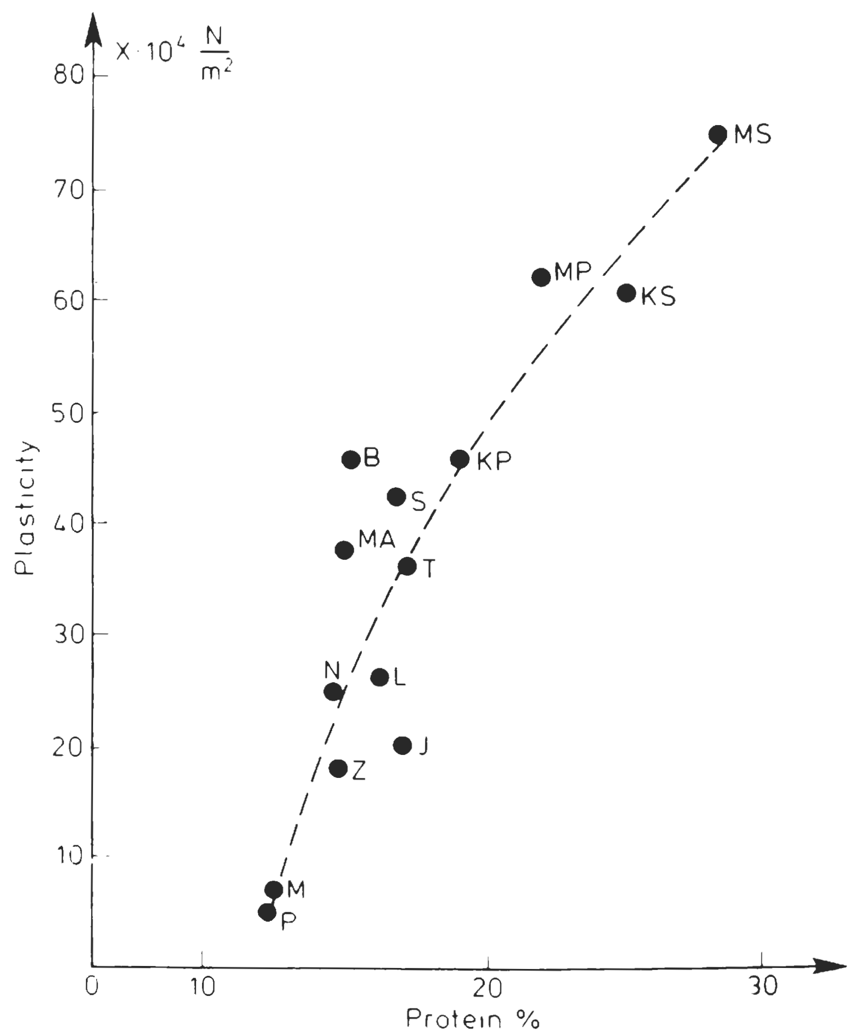

Fig. 4. Relation of sausages plasticity to their protein contents

As it can be seen, for a certain protein content in the sample fluidity increased to infinity. Under the conditions of experiment this critical content was near to 12%. The relationship between elasticity and protein content was a characteristic one (Fig. 6). At low protein level the elasticity was very below measureability

Table 2. Rheological parameters and chemical compositions of tested sausages

Assortment symbol	Plasticity $x \cdot 10^2 \frac{N}{m^2}$		Elasticity $x \cdot 10^{-9} \frac{m^2}{N}$		Fluidity $x \cdot 10^{-9} \frac{m^2}{N \cdot s}$		Protein	Water	Fat	Water/Protein	Fat/Protein
	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$	S	$\bar{x}$ %	$\bar{x}$ %	$\bar{x}$ %		
P	500	50	—	1)	463	123	12.2	57.1	29.6	4.68	2.43
M	666	145	—	1)	195	91	12.6	67.4	18.0	5.35	1.42
Z	1760	725	144	101	141	74	14.9	60.0	24.6	4.02	1.65
N	2455	705	142	88	61	27	14.9	49.6	31.0	3.33	2.08
MA	3750	150	169	22	41	6	15.2	57.0	24.3	3.75	1.60
B	4563	1890	214	66	67	26	15.5	63.4	18.4	4.09	1.19
L	2610	1140	288	82	83	51	16.3	63.9	16.6	3.92	1.02
S	4250	1010	206	34	49	22	17.0	58.7	20.0	3.45	1.18
J	2000	490	244	20	70	12	17.2	51.8	26.3	3.01	1.53
T	3625	500	174	40	42	8	17.6	53.2	25.3	3.02	1.44
KP	4565	2145	212	52	53	20	19.2	66.0	11.1	3.44	0.58
MP	6225	1810	172	44	34	17	22.3	50.2	22.3	2.25	1.00
MS	6060	2295	182	52	27	12	28.2	42.0	25.1	1.49	0.89
KS	7460	2540	132	40	30	13	25.3	50.8	21.0	2.09	0.83

1) unmeasurable

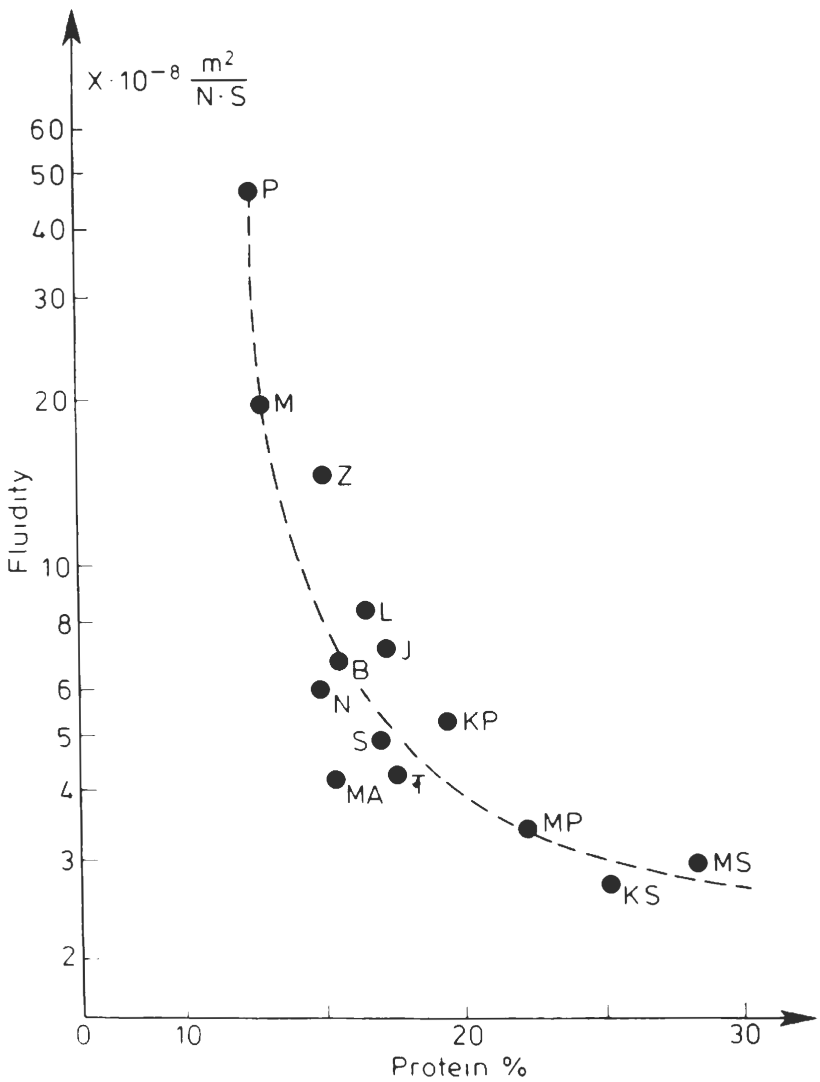

Fig. 5. Relation of sausages fluidity to their protein contents

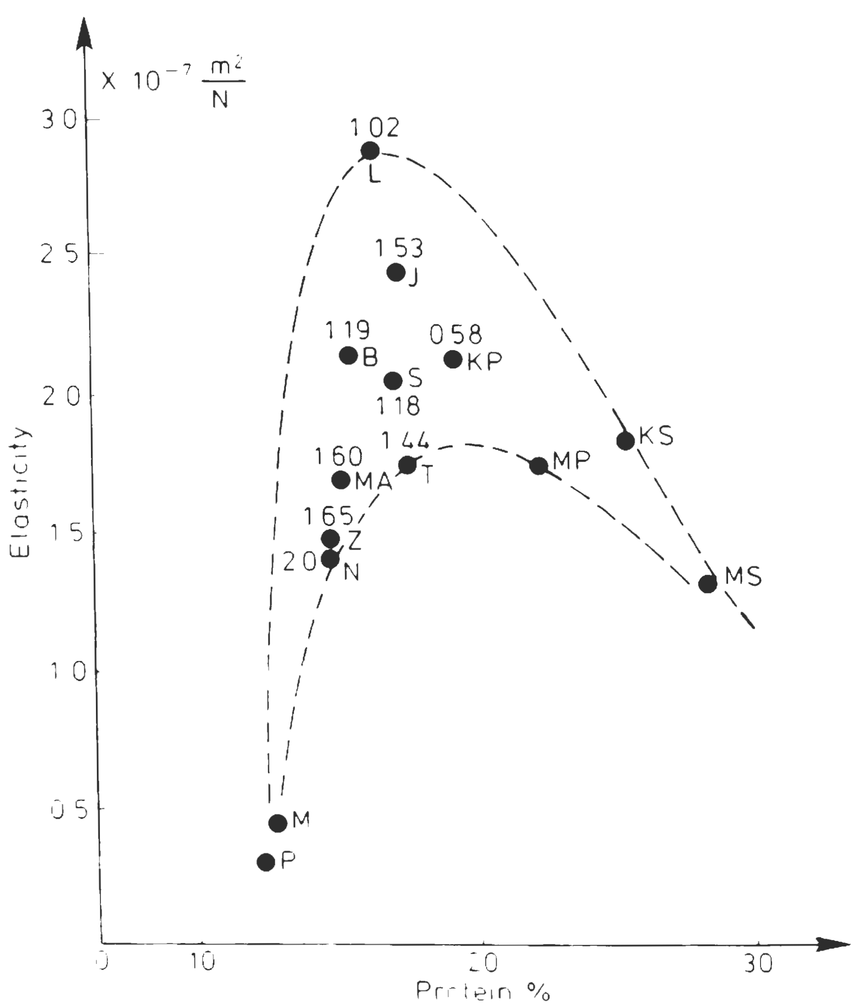

Fig. 6. Relation of sausages elasticity to their protein contents. Numbers at points demonstrate the FAT/PROTEIN ratio. Data for homogenized sausages (M, P) obtained with pivot of 7 mm diameter

limit, when the punch of 5 mm diameter was used. Then the elasticity increased paralelly to the increasing protein contents, achieved a maximum and succesively decreased with further increasing protein contents in dry sausages.

Unexpectively, low effect of fat content and degree of raw materials desintegration on rheological parameters were observed. The one exception was the elasticity: near the maximum value the parameter distribution depended on the fat to protein ratio. Sausages higher in fat were less elastic.

In this point it should be noticed that elasticity of sausages was unmeasurable when punch of 5 mm diameter was used. The data presented on the diagram were obtained with the punch of 7 mm diameter.

THE EFFECT OF SUBSTITUTION LEVEL ON THE RHEOLOGICAL CHARACTERISTICS OF SAUSAGES

5 types of sausages, medium comminuted, nonhydrated or slightly dehydrated, containing 10,5; 14, 17,5, 20,5% of hydrated TVP were examined. The level of 10,5% of substitution was used as a reference one. In the other experiment 6 types of sausages representing fine, medium and coarse comminuted products were tested. In those sausages meat was substituted by sodium caseinate at the level of 10 up to 30%. The levels were differentiated according to the type of sausage — higher (up to 30%) in homogenized (fine comminuted) sausages and lower in other ones.

The rheological parameters were measured according to the method described. Results are presented in Table 3 and 4. The standard deviation values

Table 3. Rheological parameters of sausages at different levels of meat substitution with TVP

Rheological parameters	Assortment symbol		Level of substitution			
			10.5%	14.0%	17.5%	21.0%
Plasticity $x \cdot 10^2 \frac{N}{m^2}$	T	$\bar{x}$	3625	3250	3188	2835
	J	$\bar{x}$	2000	1959	2750	3290
	S	$\bar{x}$	4250	2915	4500	4165
	MA	$\bar{x}$	3750	3835	3585	5665
	B	$\bar{x}$	4563	2500	3540	3165
Elasticity $x \cdot 10^{-9} \frac{m^2}{N}$	T	$\bar{x}$	174	213	216	218
	J	$\bar{x}$	240	250	191	219
	S	$\bar{x}$	206	291	256	218
	MA	$\bar{x}$	169	240	161	178
	B	$\bar{x}$	214	278	242	290
Fluidity $x \cdot 10^{-9} \frac{m^2}{N \cdot s}$	T	$\bar{x}$	42	60	50	54
	J	$\bar{x}$	70	79	93	69
	S	$\bar{x}$	49	64	35	47
	MA	$\bar{x}$	41	47	50	47
	B	$\bar{x}$	67	90	89	92

Table 4. Rheological parameters of sausages at different levels of meat substitution with sodium caseinate

Rheological parameters	Assortment symbol		Level of substitution				
			10%	15%	20%	25%	30%
Plasticity $x \cdot 10^2 \frac{N}{m^2}$	P	$\bar{x}$		750	500	< 500	< 500
	M	$\bar{x}$		834	667	675	500
	KP	$\bar{x}$		3665	2750		
	MA	$\bar{x}$	3500	4055	2875		
	Z	$\bar{x}$	1815	1790	1830		
	N	$\bar{x}$	2805	2165			
Elasticity $x \cdot 10^{-9} \frac{m^2}{N}$	P		unmeasurable				
	M		unmeasurable				
	KP	$\bar{x}$	244	232	226		
	MA	$\bar{x}$	248	256	184		
	Z	$\bar{x}$	178	258	354		
	N	$\bar{x}$		82			
Fluidity $x \cdot 10^{-9} \frac{m^2}{N \cdot s}$	P	$\bar{x}$		240	463	561	583
	M	$\bar{x}$		169	195	208	316
	KP	$\bar{x}$		86	116		
	MA	$\bar{x}$	46	53	102		
	Z	$\bar{x}$	119	141	167		
	N	$\bar{x}$	86	117			

are not presented because their statistical meaning is lost due to the unsymetric distribution of averaged values.

The effect of meat substitution by TVP on rheological parameters was not observed. It was due to the fact, that at the level of substitution applied in the experiment, meat pieces were well simulated by swollen TVP particles dispersed in sausage emulsion.

Quite different results were obtained when meat was substituted by sodium caseinate. That protein preparation was an unstructural component of dispersing phase of sausage emulsion. Different levels of sodium caseinate affected the fluidity of structure very evidently (Fig. 7). In semilogarithmic scale diagram a distinct increase of fluidity with increasing level of substitution can be seen. Plasticity demonstrated the tendency to lower the yield point at higher sodium caseinate contents (Fig. 8) but that observation was not very distinct.

In fine comminuted sausages of frankturter type, at higher level of meat substitution, the differentiation limits were exceeded.

The experiments were repeated under more sensitive conditions of analysis with use od punch of 7 mm diameter (Table 5). The results showed unquestionable increase of fluidity and decrease of plasticity and elasticity of sausages with increasing caseinate level.

Quite opposite effect was observed [2] when natural blood plasma was added

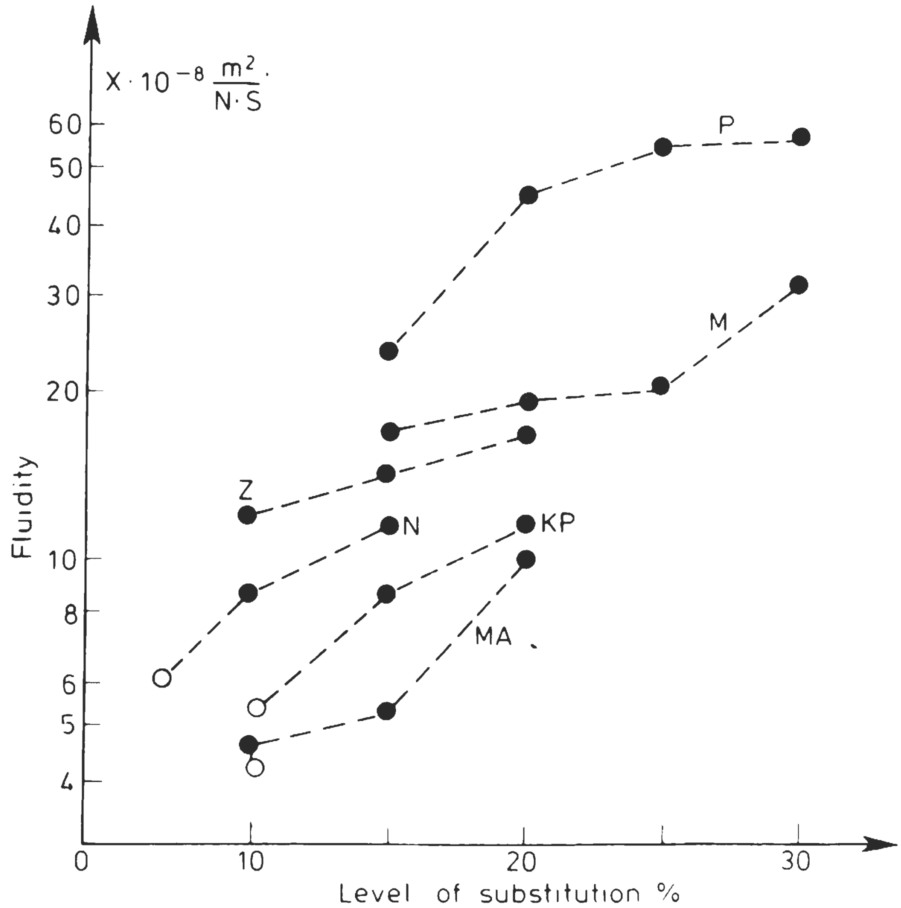

Fig. 7. Effect of meat proteins substitution by sodium caseinate on sausages fluidity; o — data for reference samples with TVP

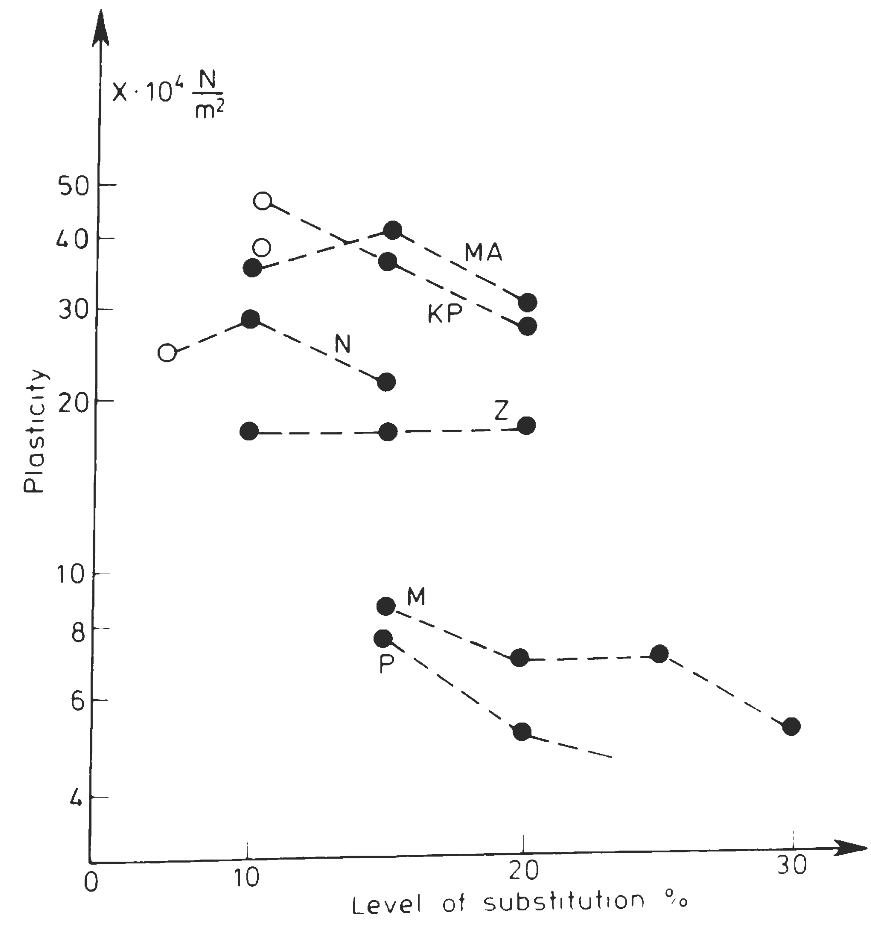

Fig. 8. Effect of meat protein substitution by sodium caseinate on sausages plasticity; o — data for reference samples with TVP

Table 5. Rheological parameters*) of fine comminuted sausages containing different quantities of sodium caseinate

Rheological parameters	Assortment symbol		Level of substitution			
			15%	20%	25%	30%
Plasticity $\times 10^2 \frac{N}{m^2}$	P	$\bar{x}$	765	510	383	280
	M	$\bar{x}$	1318	936	510	400
Elasticity $\times 10^{-9} \frac{m^2}{N}$	P	$\bar{x}$	49	30	unmeasurable	
	M	$\bar{x}$	55	44	24	unmeasurable
Fluidity $\times 10^{-9} \frac{m^2}{N \cdot s}$	P	$\bar{x}$	314	350	427	659
	M	$\bar{x}$	198	208	292	437

*) Punch diameter 7 mm

to sausages of frankturter type. 5% of meat was substituted by plasma at the proportion of plasma to meat as 3:1. The increase of yield point and elasticity with concurrent decrease of fluidity was observed. Those structure changes resulted from high gel-forming ability of blood plasma.

CONCLUSIONS

1. The stepwise programmed stress method of evaluation of rheologic characteristics of solid foods was used for examination of cooked sausages. Those were differentiated in degree of raw material desintegration, level of hydration and amount of non-meat proteins added. The values of plasticity, fluidity and elasticity characterizing the sausage structure were determined. It was stated that the parameters values depended mainly on protein contents. The type of relation was different for various rheologic parameters. The yield point was slightly curvilinearly rising and fluidity was quickly decreasing with increasing protein content. Elasticity demonstrated the maximum for certain protein content, with decrease below and above that range. Some effect of fat content on maximum value of structure elasticity was observed.

2. The effect of different levels of meat substitution by TVP and sodium caseinate on structure characteristics was examined. No effect of TVP was observed when levels differed by about 10%. The increasing amounts of sodium caseinate affected all three rheologic parameters, but first of all the increase of structure fluidity was noted. Changes of fluidity were observed at increasing sodium caseinate levels by every 5%.

LITERATURE

1. Tyszkiewicz S.: Roczniki IPMs. 1970 7, (1), 83.
2. Tyszkiewicz S., Tyszkiewicz I.: Wykorzystanie białek krwi w przetwórstwie mięsnym. Unpublished data. Warszawa 1975.

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WPŁYW KONCENTRACJI I POCHODZENIA BIAŁKA NA WŁAŚCIWOŚCI REOLOGICZNE KIEŁBAS PARZONYCH

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Streszczenie

Stosowane powszechnie metody konsystometrycznego badania mechanicznych właściwości stałych produktów żywnościowych nie pozwalają na przeprowadzenie pełnej analizy reologicznej badanego obiektu. Przypuszczalnie z tego powodu jak dotąd nie zbadano i nie opublikowano bardziej szczegółowych danych na temat strukturotwórczych właściwości szeregu dodatków i czynników modyfikujących konsystencję przetworów mięsnych. Szeroko propagowane w swoim czasie stosowanie zamienników białka w przetwórstwie mięsnym stanowiło inspirację do zajęcia się problemem strukturotwórczej roli białka w wędlinach z uwzględnieniem roli białek zamiennikowych. Zastosowano własną metodę charakteryzującą się specyficznym programem stopniowego wzrostu wywoływanych naprężeń. Metoda ta pozwala, na podstawie analizy reogramów rejestrujących deformację badanej próbki, na skonstruowanie modelu reologicznego i wyznaczenie stałych w równaniach stanu w funkcji rosnących naprężeń. Zastosowana w uproszczonej wersji metoda pozwala na wyznaczenie umownych parametrów charakteryzujących strukturę: plastyczności P (granica plastyczności), elastyczności E i płynności F. Badaniami objęto 14 rodzajów kiełbas parzonych (kiełbasy surowe mają zupełnie odmienną charakterystykę struktury mechanicznej) reprezentujących dużą gamę zmienności stopnia uwodnienia, rozdrobnienia surowców i udziału białek niemięsnych: kazeinianu sodu i teksturowanego białka roślinnego.

Stwierdzono, że wartości określanych parametrów zależą przede wszystkim od zawartości białka, przy czym różny jest charakter tych związków. Wraz ze wzrostem zawartości białka w kiełbasach rośnie łagodnie krzywoliniowo wartość granicy plastyczności i szybko maleje płynność, dążąc dla pewnej wyznaczonej zawartości białka do nieskończoności. Elastyczność wykazuje wartość maksymalną dla pewnego zakresu zawartości białka, poniżej i powyżej tego zakresu elastyczność maleje. Pewien, raczej nieznaczny, wpływ na maksymalną elastyczność struktury wydaje się mieć zawartość tłuszczu w farszu. Dla wielu kiełbas zbadano wpływ zróżnicowanego zastąpienia części mięsa białkami niemięsnymi: TVP i kazeinianem sodu. Nie stwierdzono wpływu zamienialności mięsa TVP przy przyroście rzędu 10% na określane parametry reologiczne. Stwierdzono natomiast, że rosnący udział kazeinianu sodu wpływa na wszystkie trzy mierzone parametry, a przede wszystkim wpływa na wzrost płynności struktury. Tłumaczyć to należy specyfiką kazeinianu sodu, który nawet w dużym stężeniu nie tworzy struktury pozostając wysoko lepką cieczą.