RHEOLOGIC CHARACTERISTICS OF BINDING JUNCTIONS IN CURED FORMED HAMS IN RELATION TO BRINE IONIC STRENGTH AND TUMBLING DISTANCE

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Background
The sliceability of formed ham depends on the meat product binding in course of the heat treatment. This relation is conditioned by the quantity and the kind of proteins extracted from meat in the process of plasticising. Good binding is achieved if the proteins (myosin and actomyosin) make a sol, what is possible only in the presence of salts increasing the ionic strength (Theno et al., 1978). The exudate formed in tumbling process is a half fluid protein mass. It consists of dissolved, extracted proteins and fragments of meat tissue and myofibrils (Theno et al., 1978; Katsaras, 1993). The exudate causes meat product binding in course of the heat treatment. The slice strength for well bound product is not less than 0,7- N/cm^2 (Motycka and Bechtel, 1983; Olkiewicz, Senik, Tyszkiewicz, 1994).

Objectives
The aim of the work was to study the influence of the brine ionic strength and the distance of tumbling, on the strength of meat product binding, and on the rheological characteristics of binding junctions made of thermally denaturated protein exudate.

Methods
Pork ham muscles were mechanically tenderised (meat activator, "Günter Wensing") and tumbled ("Hoffman" tumbler, model HS ϕ 640, 19 rpm, temp. 6 - 8°C; tumbling cycle: 20min rotation /10min rest). There was added the brine of 5,9%, 7,9% or 11,3% of salt concentration equivalent to the ionic strength respectively: 1,01, 1,33 and 1,93. The exudate and the meat were sampled separately after a distance of 765, 1530, 2295, 4950 and 6885m, and then canned and pasteurised (core temperature: 68°C). After cooling, the meat binding strength was estimated in the samples of the meat, by characterising the cooking loss and by measuring the slice strength (Tyszkiewicz, Olkiewicz, 1991). In the samples binding junctions (protein exudate termally treated) there were determined protein content (Kjeldahl's method), and the rheological properties: plasticity, elasticity, fluidity, according to CASRA method (Tyszkiewicz, Olkiewicz, Daun, 1994). Six experimental series were done, and the results were tested statistically with: Multifactor ANOVA Analysis, Multiple-Variable Analysis and Principal Component Analysis (PCA) - using Statgraphics Plus for Windows.

Results and discussion
The results of ANOVA Multifactor Analysis for the factors are illustrated in Table 1 (factor-ionic strength) and Table 2 (factor-tumbling distance). When the brine ionic strength (Table 1) was changed from 1,01 to 1,93, the slice strength rises from 1,1N/cm^2 to 1,88N/cm^2 with the cooking loss decrease from 22,58% to 9,57%. The protein content of binding junctions rised from 8,29% to 12,75%, and the plasticity rised about 6 times: from 27,1x10^3 N/cm^2 to 160,7x10^3 N/cm^2. In the same time both elasticity (about 6 times) and fluidity (about 5 times) decreased, especially when the brine ionic strength rised from 1,01 to 1,33. As the distance of tumbling was increased from 765m to 6885m (Table 2), the slice strength rised too, from 0,78N/cm^2 to 1,25N/cm^2, and the cooking loss lowered from 17,20% to 13,35%. Protein contents in binding junctions increased from 9,58% to 11,62%, the plasticity rised 2 times. Elasticity and fluidity lowered 1,3 times and 1,9 times respectively.The above results concluded that the changes of protein exudate characteristics, caused by brine ionic strength, were much more important than the changes caused by tumbling process. The brine ionic strength influence was very significant, and the tumbling influence less distinct and different for the variables: for the proteins content - was very significant, for the sliceability - significant, and for cooking loss, plasticity and elasticity - not significant.
According to Multiple-Variable Analysis, all the variables, excluding the distance of tumbling, were very significantly correlate (Table 3). The PCA shown that two first components explained about 86,6 %, and the three first components explained about 91,6 % of the total variation (Table 4). For the first PC, all variables were important, except the distance of tumbling; for the second PC - the most important were: the distance of tumbling, the brine ionic strength and elasticity; and for the third PC - the value of cooking loss and elasticity.Figure demonstrates a biplot for the variables in multivariate space.

Conclusion
The main factor creating the meat binding ability in course of tumbling, was the brine ionic strength. The tumbling intensity was not of great weight. When the brine ionic strength increased, the proteins content in binding junction and the slice strength rised; the cooking loss decreased; plasticity rises, and elasticity and fluidity lowerd.

Literature
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Table 1. Effect of ionic strength

ionic strength	Binding ability characteristic: slice strength [N/cm^2]	cooking loss [%]	Binding junction characteristic: proteins content [%]	plasticity [x10^3 N/m^2]	elasticity [x 10^{-5} m^2/N]	fluidity [x 10^{-6} m^2/Ns]
1.01	0.10^a	22.58^a	8.29^a	27.1^a	26.7^a	10.8^a
1.33	1.04^b	13.88^b	10.94^b	89.9^b	6.5^b	4.9^b
1.93	1.88^c	9.57^b	12.75^c	160.7^c	4.6^b	2.2^c

Values with different superscript within the same column are significantly different (P < 0.05)

Table 2. Effect of tumbling distance

tumbling distance [m]	Binding ability characteristic: slice strength [N/cm^2]	cooking loss [%]	Binding junction characteristic: proteins content [%]	plasticity [x10^3 N/m^2]	elasticity [x 10^{-5} m^2/N]	fluidity [x 10^{-6} m^2/Ns]
765	0.78^a	17.20^a	9.58^a	55.5^a	13.3^a	8.0^a
1530	0.83^{ab}	16.39^a	10.29^b	77.8^{ab}	13.0^a	6.1^{ab}
2295	0.98^{abc}	15.47^a	10.58^b	90.7^{ab}	12.9^a	6.2^{ab}
4590	1.18^{bc}	14.33^a	11.23^c	119.0^b	13.3^a	5.4^{ab}
6885	1.25^c	13.35^a	11.62^c	119.8^b	10.6^a	4.2^b

Values with different superscript within the same column are significantly different (P < 0.05)

Table 3. Correlation between variables

	ionic strength	tumbling dist.	slice strength	cooking loss	protein cont.	plasticity	elasticity
tumbling distance	-						
slice strength	0.8873***	0.2224$^{n.s.}$					
cooking loss	-0.7140***	-0.1908$^{n.s.}$	-0.7820***				
protein contents	0.8826***	0.6424$^{n.s.}$	0.8951***	-0.6955***			
plasticity	0.7502***	0.3148$^{n.s.}$	0.9204***	-0.6850***	0.7956***		
elasticity	-0.6222***	-0.0619$^{n.s.}$	-0.6805***	0.2875$^{n.s.}$	-0.7459***	-0.6207**	
fluidity	-0.7859***	-0.2629$^{n.s.}$	-0.8209***	0.7995***	-0.8635***	-0.7062***	0.6826***

Levels of significance: *** = P < 0,001, ** = P < 0.01, * = P < 0,05, n.s. = P > 0,05

Table 4. Results from the Principal Component Analysis

PC	Eigen value (l_i)	Portion of $s^2_{tot.}$ (%)	Cumulative s^2
1	5.566	69.575	69.575
2	1.04201	13.025	82.600
3	0.71653	8.957	91.557
4	0.347076	4.338	95.895
5	0.213882	2.673	98.568
6	0.595357	0.744	99.312
7	.0365196	0.456	99.769
8	.0185062	0.231	100.000
Σ PC 1 - PC8	8.00000	100.000	-

Biplot for the variables in multivariate space

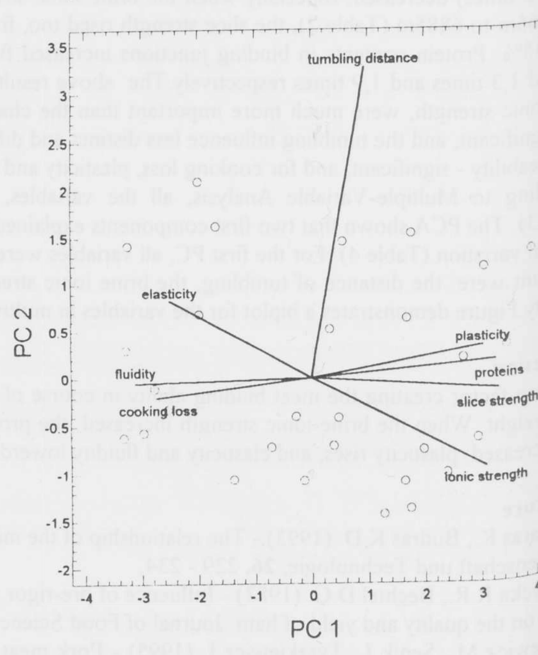

Table 5. Coefficient in the Eigen Vectors (loadings) for Three First Components (PC)

Variables	PC 1	(%)	PC 2	(%)	PC 3	(%)
ionic strength	0.38	13.9^a	-0.27	16.0^a	0.12	6.3
tumbling distance	0.12	4.4	0.93	55.0^a	-0.18	9.4
slice strength	0.41	15.0^a	-0.04	2.4	0.05	2.6
cooking loss	-0.34	12.4^a	-0.06	3.6	-0.06	33.9^a
proteins content	0.41	15.0^a	0.05	3.0	-0.14	7.3
plasticity (P)	0.38	13.9^a	0.09	5.3	-0.02	1.0
elasticity (E)	-0.31	11.3^a	0.24	14.2^a	0.71	37.0^a
fluidity (F)	-0.39	14.2^a	-00.1	0.6	-0.05	2.6
Σ / loadings/	2.74 = 100%		1.69 = 100%		1.92 = 100%	

[a] variables with a loading > 10% of the sum of the absolute loadings (Σ/loadings/)