A C T A A L I M E N T A R I A P O L O N I C A

Vol. XVII/XLI/ No. 3 1991

MIECZYSŁAW BORUCH
STANISŁAW BRZEZIŃSKI
TOMASZ KILJAŃSKI*

CHANGES OF RHEOLOGICAL PROPERTIES OF SEMI-SWEET CHOCOLATE COVERTURE DURING INDUSTRIAL CONCHING

Insitute of Chemical Food Technology, Technical University, Łódź
* Institute of Chemical Engineering, Technical University, Łódź

Key words: chocolate mass, conching process control, rheological properties

Changes of rheological properties of semi-sweet chocolate coverture were studied during 24-h dry conching in an industrial conche. Measurements were carried out with a Rheotest 2 rotational rheometer with coaxial cylinders at various shear rates and at temperatures ranging from 30 to 80°C. The obtained results show that simple and fast methods of studying rheological properties can be employed to control conching of chocolate masses.

Chocolate mass is a non-Newtonian fluid with viscoplastic properties [7] consisting of cocoa pulp, cocoa fat (components originating from cocoa grain), sugar, lecithin and possible additions such as milk, coffee, nuts, vanilline, ethylvanilline and other flavours. Its quality depends mainly on the composition of components and the kind and effectiveness of thermal-mechanical processing. Much effort has been devoted over the past years to improve chocolate masses and also to intensify the conching process and reduce its duration with the aim of ensuring continuous, effective and speedy production. Numerous studies also concentrated on the nature of changes taking place during conching and affecting the quality of chocolate masses [2, 6, 8]. It is believed that the most important of these changes are:

— comminution of the solid phase particles,
— water content reduction,
— rounding and unification of solid phase particles,
— emulsification of the mass and coating of the solid phase particles with fat,
— reduction of viscosity resulting from the above changes,
— reduction of the content of volatile substances, especially of acids detrimental to taste and aroma,
— reduction of tannins content through oxidation,
— increasing content of colouring substances.

These changes alter the rheological properties of chocolate masses as conching progresses. Since the measurement, of these properties is relatively simple, it may

be used to study this process.

In the present research we investigated changes of rheological properties of chocolate masses during conching in the context of humidity and comminution changes with a view to improving the monitoring of this process.

EXPERIMENTAL

Changes of rheological properties during production of semi-sweet (up to 55% sugar) chocolate coverture obtained with the dry conching method were studied. 24-h conching was carried out in a CRT 3000 industrial conche manufactured by Nagema (DDR), with samples collected 5, 10, 15, 20, 22 and 24 h after the start of the process. We thus studied samples from two charges and also the final sample from the third charge after 24 h. Aside from measuring rheological properties, we also determined in each sample its water content by drying with sand at 105°C and its comminution degree (micrometrically).

Rheological properties were measured with a Rheotest 2 rotational rheometer with coaxial cylinders. Given the wall effects occurring in the case of chocolate masses, we used the wide-gap (2.5 mm) "H" measuring set. These effects are due to a fat layer accumulating on the cylinder walls. Being less viscuous than chocolate mass, the fat acts as a lubricant causing the mass to slip on the walls. This phenomenon distorts measurement results, with the distortion being higher for narrower gaps between the cylinders. In order to check the consequences of this effect, we repeated some measurements with the "S1" measuring set featuring a very narrow gap (0.5 mm).

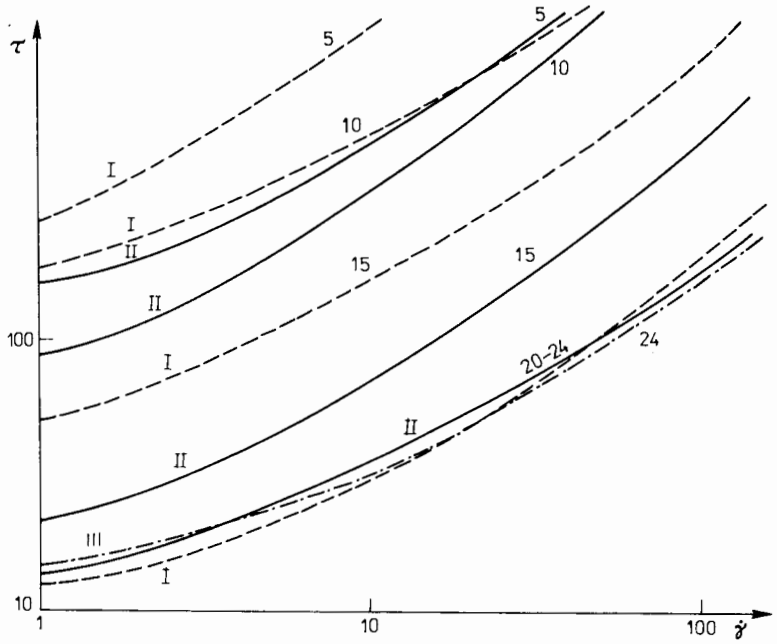
Table Humidity and comminution degree of semi-sweet chocolate coverture from two charges at different times of conching

	Conching time (h)					
	5	10	15	20	22	24
Charge 1 humidity (%)	0.59	0,57	0.38	0.31	0.28	0.27
comminution (μm)	83.5	61.3	55.4	40.8	39.4	38.9
Charge 2 humidity (%)	0.61	0.57	0.41	0.30	0.29	0.28
comminution (μm)	84.2	63.5	57.2	41.1	40.5	39.6

All measurements were carried out at 30, 40, 50, 60, 70 and 80°C for increasing shear rates, following which the samples were subjected to shearing at maximum rate of 146 s^{-1} and the measurements repeated for decreasing shear rates. The differences between the determined shear stresses at increasing and decreasing shearing rates were a measure of thixotropy (viscosity changes over time due to shearing).

ESULTS

Table lists figures for water content and comminution degree for various tages of conching determined in samples from two charges. Results of heological properties measurements are represented as flow curves in the shear tress-Newtonian shear rate system. The Newtonian shear rate listed in the heometer manual for various rotation speeds of the cylinder is equal to the ctual shear rate at the wall of the inner the cylinder if the studied fluid is lewtonian, and its values for non-Newtonian fluids must be suitably corrected. lowever, since the results of this research are to serve only conching monitoring, e did not attempt this fairly labor-consuming computation which would lead to mall shifts of the plotted flow curves without altering their relative positions. We orrected the shear rates only in this measurements which were used for omparisons of results from two measuring systems with different cylinder iameters ratios meant to assess the wall effects.



ig. 1. Flow curves of chocolate coverture sampled after 5, 10, 15, 20, 22 and 24 h of conching. Measurements were performed at 40°C; I — charge 1 coverture, II — charge 2 coverture, III — charge 3 coverture

The experiments provided a vast quantity of data and only some of them are resented here. Fig. 1 presents flow curves for samples from both charges and for he final sample from the third charge, all studied at 40°C. There is a clear drop in hear stress (and hence in viscosity) in the considered range of shear rate until the

20th hour of conching. After that time the properties of the chocolate mass become practically constant, also in the other temperatures. It is interesting to note that despite the clear differences in the initial stage of conching, the properties of masses as reflected in the flow curves are almost identical after 20 h. The shape of most flow curves was similar to that in Fig 1: their slope is very small in the range of lowest shear rates which means that the covertures are strongly shear-thinning (considerable decrease of viscosity with an increase of shear rate).

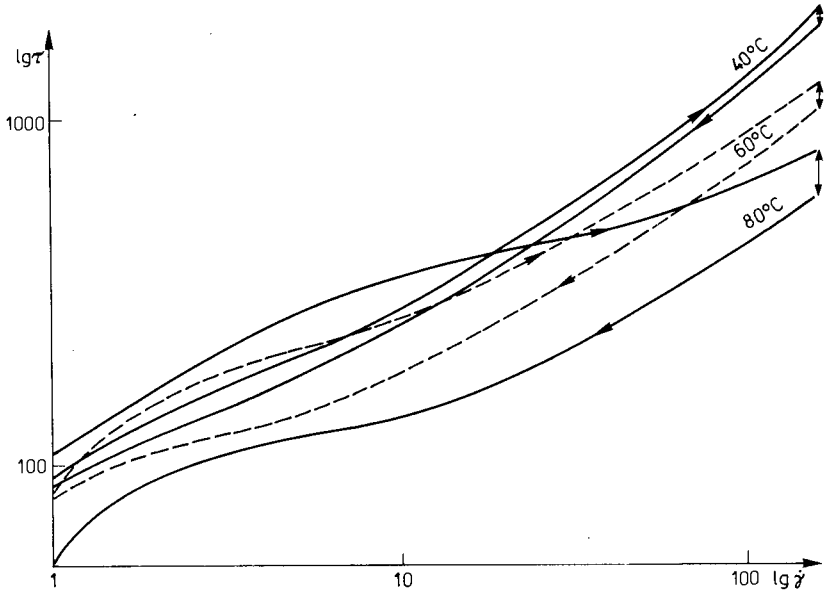


Fig. 2. Flow curves of charge 1 coverture after 5 h of conching. Measurements performed at 40, 60 and 80°C.

At higher shear rates, the non-Newtonian character of the masses is increasingly less pronounced, to become almost Newtonian at the maximum shear rate of 146 s^{-1}, especially in the lower temperatures: the slope of flow curves is close to 45°. Irregularities in the flow curves are observed at conching times below 15 h and temperatures over 60°C, leading to anomalies such as increasing viscosity at increasing temperatures in the range of intermediate shear rates. Fig. 2 shows such irregular flow curves after 5 h of conching. Arrows on the curves indicate the direction of shear rate changes. Hysteresis loops appear, with shear stresses (and hence also viscosities) determined for decreasing shear rates being lower than those determined for increasing rates. This phenomenon is known as thixotropy, and indicates structural changes in conched masses due to shearing. Samples collected after 20 and more hours of conching are completely rheostable: the flow curves for increasing and decreasing shearing rates coincide (Fig. 3).

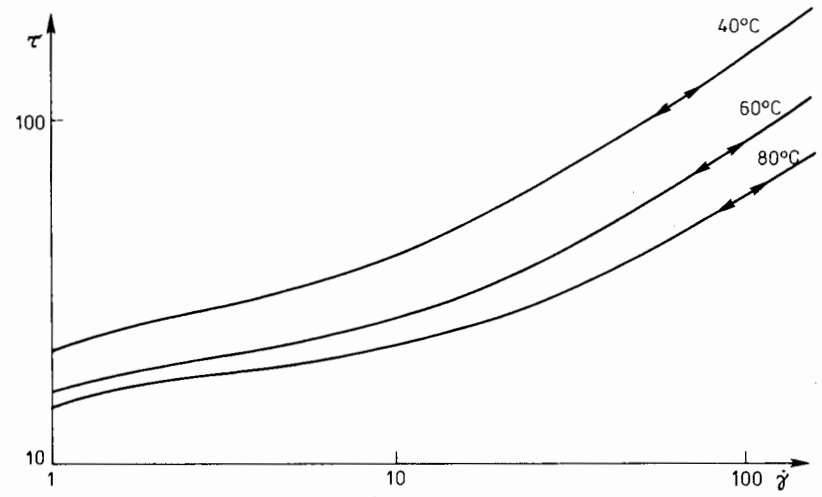


Fig. 3. Flow curves of charge 1 coverture after 20 h of conching. Measurements performed at 40, 60 and 80°C

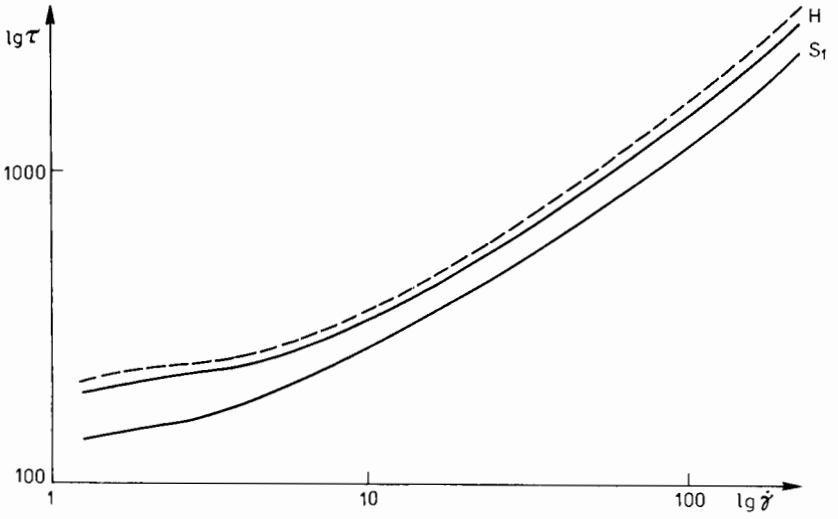


Fig. 4. Flow curves of charge 1 coverture after 20 h of conching. Measurements performed at 40°C with two measurement sets ("H" and "S1"). Broken line — corrected flow curve

In order to assess the impact of wall effects of measurement results, some of the measurements were repeated using the "S1" measuring set with a 0.5 mm gap, five times narrower than in set "H". Exemplary results for chocolate mass conched for 20 h at 40°C are shown in Fig. 4 where the actual (corrected) shearing rates are represented on the X-axis. The substantial differences between flow curves plotted on the basis of results from the two measurement sets are a clear indication of the interference of wall effects, especially at low shearing rates. A corrected flow curve free from the error due to slip on measurement cylinder walls, was plotted using the obtained results. The method of correction is described in [3]. As can be seen, the corrected curve is very similar to the one plotted according to results obtained with measurement set "H": the differences in shear stress do not exceed 7%. This means that for a 2.5 mm gap the wall effects are of negligible significance. Results of similar studies of wall effects in other temperatures and for other conching times lead to the same conclusion. Since the described measurements are to be used for monitoring the conching process, what matters is the variability of chocolate masses properties with temperature, time, composition, etc. rather than absolute values of viscosity or shear stresses at given shearing rates. For these purposes the results obtained with measurement set "H" (2.5 mm gap) are sufficient and there is no need to carry out the tedious corrections compensating for the wall phenomena.

CONCLUSIONS

The flow curves of the studied chocolate coverture became stable after 20 h of conching in the entire temperature range that was considered. After 20 h the chocolate mass lost its thixotropic properties and ceased to display anomalously high viscosity in temperatures over 60°C. This stabilization of rheological properties after 20 h suggests that the changes of composition and structure of the chocolate mass were practically completed by that time. This is also indicated by analyses of humidity and comminution which change only slightly after 20 h. The best temperatures for monitoring conching by means of viscosity measurements in fixed conditions are those below 50°C at which flow is completely stable. If stabilization of the masses' properties is to be determined by thixotropy measurement, temperatures of at least 70°C are required at which this phenomenon is clearly apparent. If a rotational rheometer is used, the width of the working gap may not be less than 2 mm to offset the distorting effect of wall phenomena. Despite the clear differences of initial rheological properties of covertures from various charges, their flow curves after 20 h are almost identical. It must be made clear, however, that the reported results pertain only to the concrete studied mass and the particular conching conditions and apparatus. Nevertheless they do indicate possibilities of using simple and speedy methods of rheological studies in monitoring the process of conching chocolate masses.

LITERATURE

1. Bielig H. J., Fischer-Ayloff-Cook K. P.: Z. Lebensmitt. Untersuch., 1984, **179** (5), 364.
2. Boruch M., Sikora M.: Zeszyty Naukowe Politechniki Łódzkiej. Technologia i Chemia Spożywcza 1986, 40.
3. Kiljański T.: Rheologica Acta (in press).
4. Lewicki P., Skierkowski K.: Przem. Spoż., 1979 (6), 209.
5. Maczidzin Iu. A., Berman G. K., Maksimow A. S.: Piszczew. Technol., 1985, **167** (4), 9.
6. Maksimow A. S., Antonow A. A.: Chlebopiekarnaja i Konditierskaja Promyszlennost 1986 (5), 38.
7. Rao M. A.: Food Technology 1982 (2), 116.
8. Zubczenko A. W., Czerpakow W. P., Bunina N. M.: Chlebopiekarnaja i Konditierskaja Promyszlennost 1986 (9), 25.

Manuscript received: November 1988
Authors address: 90-924 Łódź, Stefanowskiego 4/10

*M. Boruch, S. Brzeziński, T. Kiljański**

BADANIE ZMIAN WŁAŚCIWOŚCI REOLOGICZNYCH KUWERTURY PÓŁSŁODKIEJ W WARUNKACH KONSZOWANIA PRZEMYSŁOWEGO

Instytut Chemicznej Technologii Żywności, Politechnika, Łódź
* Instytut Inżynierii Chemicznej, Politechnika, Łódź

Streszczenie

Przeprowadzono badania zmian właściwości reologicznych w czasie produkcji kuwertury półsłodkiej otrzymanej metodą suchego konszowania. Proces konszowania prowadzony był w konszy przemysłowej przez 24 h. Pomiary właściwości reologicznych przeprowadzono za pomocą reometru rotacyjnego o współosiowych cylindrach Rheotest 2. Pomiary wykonano przy rosnących i malejących szybkościach w temperaturze od 30 do 80°C. Uzyskane wyniki wskazują na możliwość zastosowania prostych i szybkich badań właściwości reologicznych do kontroli przebiegu procesu konszowania mas czekoladowych.