ACTA ALIMENTARIA POLONICA
Vol. XIII (XXXVII), No. 2 1987

HALINA GAMBUŚ
TERESA FORTUNA
ANNA NOWONTA
MIECZYSŁAW PAŁASIŃSKI

PHYSICAL PROPERTIES OF TRITICALE STARCH. PART III. DETERMINATION OF FLOW CURVES OF TRITICALE STARCH PASTES

Department of Carbohydrates Technology, Agricultural University, Kraków

Key words: triticale starch, flow curves, "n" and "K" constants of the Oswald-de Waele power equation

Flow curves of pastes from 53 Polish triticale breeding lines were investigated. Rheological parameters of those pastes, viz. constants "n" and "K" of the power equation, were determined. Seven starches can be distinguished among all the samples, their pastes possessing properties of the Newtonian liquid.

INTRODUCTION

Being a polysaccharide, starch has properties typical for compounds with colloidal dissipation [4], and since it undergoes hydratation it is a typical hydrophylic colloid.

The rheological properties of non-Newtonian liquids are best determined by plotting a curve representing the dependence of shearing stress on the rate of shear in the broadest possible range of these magnitudes. We call this curve the flow curve [4].

There have been attempts to describe this curve [2, 4]. The simplest rheological mathematical model for intermediate rate of shear is the so called power model proposed by Ostwald and de Waele [4]

$$\tau = K\left(\frac{du}{dx}\right)^n \quad \text{where } \frac{du}{dx} = D.$$

The "n" and "K" constants are rheological parameters determined experimentally for the given measurement system and they are characteristic for the given fluid. The "n" constant has no unit and is a measure of the departure of the properties of the given fluid the more "n" differs from unity the more pronounced become the properties of the non-Newtonian fluid. The "K" constant Pa•s^n is a measure of apparent viscosity "K" increases with the increase of fluid viscosity.

For concentrations in the range $1\% < c < 12\%$ the "n" constant does not depend on the paste concentration]9[. It was calculated in several works [7, 9, 11, 12] but only for potato starch pastes; the obtained figures ranged from 0.40 to 0.70.

Thus, to determine the rheological properties of triticale starch pastes it is not enough to investigate their pasting characteristics. This characteristics provides data only about apparent viscosity of the pastes for one strictly defined rate of shear. This viscosity does not describe the rheological properties of a non-Newtonian fluid since systems of diametrically different rheological properties may have the same apparent viscosity at the given rate of shear [4]. Accordinly, in this work we tried to characterize triticale starch pastes with regard to their rheological properties by determining the flow curves of these pastes. Our studies also provide data about the rheological parameters of the pastes of this starch which have never before been determined.

MATERIAL

The information about the starches used in the experiments is given in part I of this research [3].

METHODS

1. The flow curves of starch water pastes 7.4% dry substance were determined with a Rheotest 2 viscosimeter at 50°C. The determination of these curves consisted in measuring the shear stress in depedence on the rate of shear in the range of rate of shear obtainable in the applied viscosimeter: the lowest of these is $1b = 1.5\ s^{-1}$ and the highest is $12a = 1312\ s^{-1}$.

2. The rheological parameters, i.e. the "n" and "K" constants of the power model, were calculated from the flow curves of starch pastes with an Odra 1325 computer using the Ostwald-de Waele formula.

RESULTS AND DISCUSSION

Table conttains the value of the Ostwald-de Waele power model constants calculated from the flow curves. The differences in "n" values are evidence of various departures of the studied pastes from properties

Table. Constants of the Ostwald-de Waele power model for 7.4% dry substance water pastes of triticale and wheat starches determined from flow curves with a rotary viscosimeter Rheotest 2 at 50°C

Sample no.	"n" constant	"K" constant mPa · s	Sample no.	"n" constant	"K" constant mPa · s	Sample no.	"n" constant	"K" constant mPa · s
1	0.51	7966	20	0.61	3347	39	0.61	2917
2	0.53	4569	21	0.59	4105	40	0.59	2891
3	0.52	2640	22	1.00	83	41	0.62	2436
4	0.53	3578	23	0.63	1719	42	0.61	1604
5	0.55	3188	24	0.99	70	43	1.10	33
6	0.48	3582	25	0.56	4327	44	0.97	74
7	0.52	2698	26	0.66	1151	45	0.63	2341
8	0.54	4908	27	0.53	5168	46	0.62	3511
9	0.56	4116	28	0.64	2237	47	0.55	3065
10	0.56	3178	29	1.00	77	48	0.63	1176
11	0.68	1565	30	0.90	181	49	0.49	6577
12	0.53	3981	31	0.60	2931	50	0.52	4573
13	0.51	3963	32	0.54	3616	51	0.45	3854
14	0.61	1127	33	1.10	37	52	0.56	3802
15	0.62	2667	34	0.62	3181	53	0.51	4006
16	0.55	2771	35	0.49	6388	mean	0.62	3055
17	0.62	2888	36	0.44	7924	Grana I	0.65	
18	0.64	3125	37	0.50	5706	Grana II	0.63	1794
19	0.51	3002	38	0.57	2310			1751

of the Newtonian fluid. For most of the triticale starch pastes the values of "n" were confined to the range 0.44-0.68. However, the starch pastes of seven triticale breeding lines (22, 24, 29, 30, 33, 43 and 44) displayed values of this constant close to unity 0.90-1.10. Hence, these pastes exhibited properties of the Newtonian fluid in Fig. 2 their flow curves pass through the origin of the coordinate system. It appears that the starch pastes of these several breeding lines did not exhibit the capacity to form structural viscosity. At least two causes must tentatively be held responsible for this phenomenon:

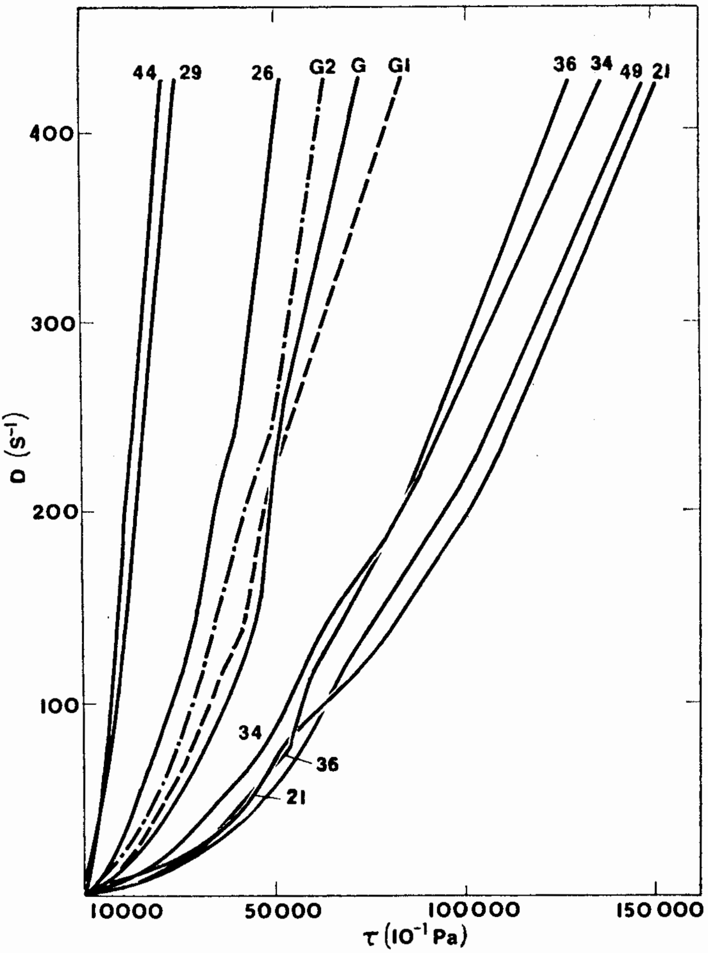

Fig. 1. Flow curves for selected starches: no. 29, $n = 1$, no. 44, $n = 0.97$, no. 26, $n = 0.66$, no. 34, $n = 0.62$, no. 21, $n = 0.59$, no. 49, $n = 0.49$, no. 6, $n = 0.48$, no. 36, $n = 0.44$, G_1, $n = 0.65$, G_2, $n = 0.63$; shear stress $\tau = \alpha \cdot z$, where α — reading from the viscosimeter scale, z — the instrument's constant; z for range I $= 5.81 \left[10^{-1}\frac{\mathrm{Pa}}{\mathrm{Skt}}\right]$ z for range II $= 58.9 \left[10^{-1}\frac{\mathrm{Pa}}{\mathrm{Skt}}\right]$, D = rate of shear (S^{-1})

1. Genetical conditions which weakened the chemical bonds and the van der Waals forces in the starches of the breeding lines in question, and

2. The destructive activity of amylolytic enzymes we know from the literature [1, 5] that triticale grain is marked by increased amylolytic activity causing the hydrolytic decomposition of starch molecules in starch grains.

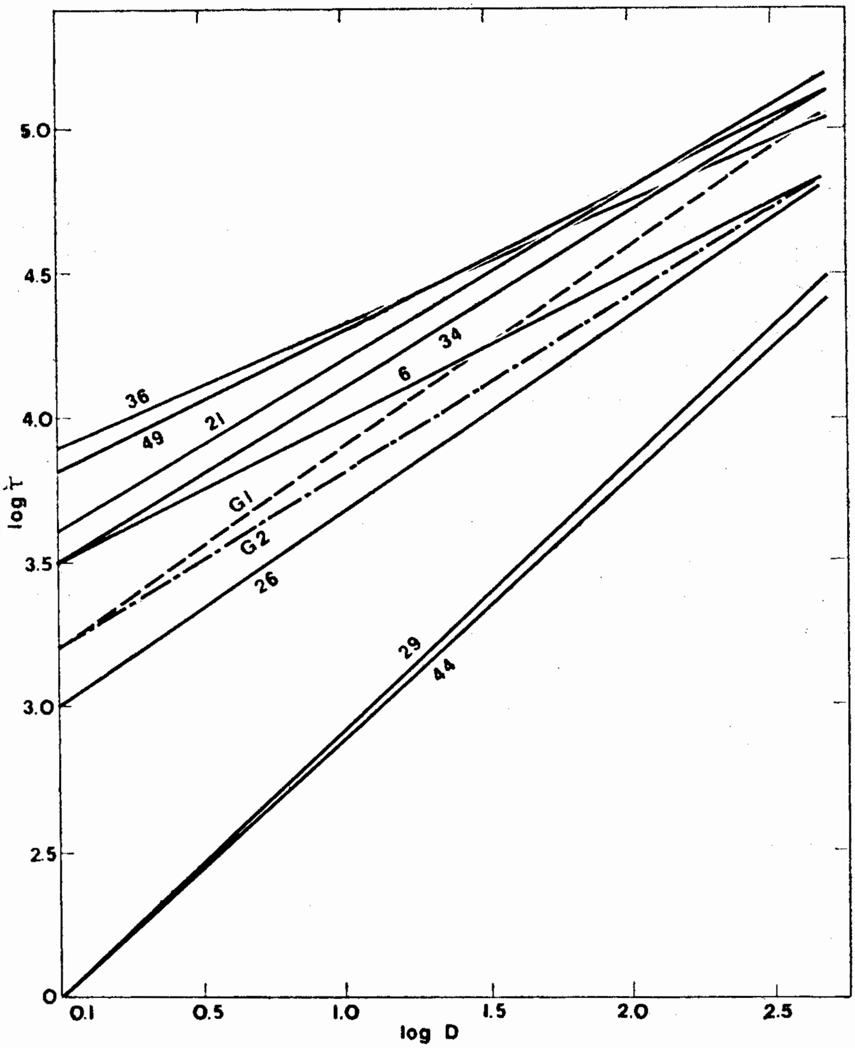

Fig. 2. Flow curves for selected starches in the logarithmic system (starches: no. 29, n = 1, no. 44, n = 0.97, no. 26, n = 0.66, no. 34, n = 0.62, no. 21, n = 0.59, no. 49, n = 0.49, no. 6, n = 0.48, no. 36, n = 0.44, G_1, n = 0.65, G_2, n = 0.63). Descriptions of the values of the ordinate and the abscissa as in Fig. 1.

It is also possible that the two factors act together. The final effect of this was the increased solubility of the starch molecules. Aside from that the grain fragments which remained were too small and, additionally, given the decreased bonding force, they were incapable of forming the structure of starch paste [8]. Hence, in agreement with the above hypothesis, the entire system may be referred to the definition of Newtonian fluid in which the viscuous dissipation of energy is the result of collisions of relatively small molecules [4].

The starch pastes of all other triticale lines and of the "Grana" wheat behaved as typical shear-thinning non-Newtonian liquid [4] Fig. 1 which is in agreement with the contemporary views on starch [7, 9, 11, 12].

The mean value of "n" for all the triticale starch samples was 0.62, while for the standard starch of „Grana" wheat the "n" values were 0.65 and 0.63.

The considerably differentiated "K" values indicate that the studied starches differe widely as to the viscosity of their respective pastes. The "K" value of triticale starch pastes remained in the range 33-7966 $mPa \cdot s^n$, the mean value being 3055 $mPa \cdot s^n$. The pastes with the "n" value close to unity had the lowest "K" constants, ranging from 33 to 181 $mPa \cdot s^n$; the other pastes were characterized by much higher "K" values. For wheat starch pastes the "K" constant was 1798 and 1751 $mPa \cdot s^n$.

Both Fig. 1 and 2 as well as the data in Table 1 indicate little dependence of constant "n" on "K". Only for very high "n" values close to unity we observe low values of the "K" constant. This inversely proportional dependence is not maintained fully, this being evident in the diagrams and from the low coefficient of correlation between "n" and "K", $r = -0.31$ at significance level $\alpha = 0.05$.

Many starches with the same or similar values of "n", i.e. with similar structural properties of pastes, differed considerably as to the "K" constant, i.e. as to viscosity. It thus seems that in any one measurement method the structural viscosity is affected by other factors in addition to structural properties, e.g. by the phenomena of molecule ordering and of the abrasion of the solvation coat of the starch molecules.

CONCLUSIONS

1. The flow curves of most triticale starch pastes were typical for shear-thinning non-Newtonian liquid.

2. Pastes of seven of the investigated triticale starches had properties of the Newtonian fluid "n" = 1.

3. The study of flow curves revealed only a small dependence between the "n" and "K" constants of the power model, which means that

the discrepancy of rheological properties of triticale starch pastes from those of the Newtonian fluid has only a small effect on the viscosity of these pastes.

LITERATURE

1. Bushuk W.: Hodowla roślin, aklimatyzacja i nasiennictwa 1980, **24**, 603.
2. Djakovic D., Dokic P.: Die Stärke 1972, **24**, 195.
3. Fortuna T., Gambuś H., Nowotna A., Pałasiński M.: Acta Alimentaria Polonica 1985, **11** (35), 53.
4. Kembłowski Z.: Heometria płynów nienewtonowskich WNT, Warszawa 1973, 27, 30, 31.
5. Klassen A. J., Hill R. D., Larter E. N.: Crop Science 1971, **11**, 265.
6. Koubek J.: Die Stärke, 1974, **26**, 81.
7. Lancaster E. B., Conway H. F., Schwab F.: Cereal Chem. 1966, **43**, 637.
8. Leach H. W.: Starch chemistry and technology, vol. 1. Whistler E. L., Paschal E. F.: Ac. Press New York and London, 1965, 289.
9. Nowotna A.: Fizyko chemiczna charakterystyka skrobi niektórych gatunków Solanum — The doctors thesis. AR, Kraków 1978.
10. Richter M., Augustat S., Schierbaum F.: Ausgewählte Methoden der Stärkechemie, VEB Fachbuchverlag, Leipzig 1969, 22.
11. Schutz R.: Die Stärke 1963, **15**, 394.
12. Schutz R.: Die Stärke 1966, **18**, 18.
13. Winkler S., Luckow J., Donie H.: Die Stärke 1971, **23**, 235.

Manuscript received: April, 1985
Authors address: 30-059 Kraków, Mickiewicza 24/28

H. Gambuś, T. Fortuna, A. Nowotna, M. Pałasiński

WŁAŚCIWOŚCI FIZYCZNE SKROBI PSZENŻYTA.
III. WYZNACZANIE KRZYWYCH PŁYNIĘCIA KLEIKÓW SKROBI PSZENŻYTA

Zakład Technologii Węglowodanów, AR, Kraków

Streszczenie

W celu określenia właściwości reologicznych kleików skrobiowych pszenżyta wyznaczono ich krzywe płynięcia. Przebadano w ten sposób skrobie z 53 polskich rodów pszenżyta. Z krzywych płynięcia wyliczono stałe „n" i „K" modelu potęgowego Ostwalda i de Waele (tabela). Dla większości skrobi pszenżyta stała „n" mieściła się w zakresie 0,44-0,68. Natomiast skrobie siedmiu rodów (nr 22, 24, 29, 30, 33, 43, 44) nie wykazywały zdolności tworzenia lepkości strukturalnej, lecz odznaczały się właściwościami płynu newtonowskiego (stała „n" od 0,90-1,10). Przypuszcza się, że spowodowane to było uwarunkowaniami genetycznymi lub podwyższoną aktywnością enzymów amylolitycznych w ziarnie [1, 5]. Kleiki, które miały stałą „n" zbliżoną do jedności charakteryzowały się najniższą stałą „K":

od 33-181 mPa•s^n, natomiast pozostałe znacznie wyższymi wartościami tej stałej (od 1127 do 7966 mPa•s^n). Z wyjątkiem wymienionych siedmiu rodów krzywe płynięcia pozostałych kleików były typowe dla płynów nienewtonowskich rozrzedzanych ścinaniem (rys. 1). Zaobserwowano niewielką zależność pomiędzy stałymi modelu potęgowego „n" i „K"; $r = -0{,}31$ przy poziomie istotności $\alpha = 0.05$.