Alveography in Quality Assessment of Soft White Winter Wheat Cultivars

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ABSTRACT

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The suitability of alveography for quality assessment of soft white winter wheats was examined. The current standard alveograph technique based on biaxial extension of doughs with a constant flour solids to water ratio was compared with a procedure employing doughs of a variable water content but constant maximum development consistency. The tests were performed on straight-run flours milled from the wheat cultivar samples. Despite differences in the values of the individual alveogram indexes determined by the two testing procedures, no significant effect of index response to the variations in the grain quality was recorded, with the exception of P/L ratio. The strongest correlation between the results of the two procedures was found with the deformation energy (W) values ($r = 0.858$, $P<0.001$). Quality ranking of the tested wheats based on these values was practically identical for both testing techniques. Replacing the standard technique with the constant dough consistency procedure had no significant effect on the strength of correlations between the alveogram indexes and other quality attributes of the tested flours. Most indexes correlated significantly with flour protein and MacMichael viscosity but failed to show any close relationship to cookie diameter, which was used as an indicator of the actual baking quality of the tested wheats.

Methods used to assess the quality of soft wheats and soft wheat flours have been the subject of many critical considerations among cereal chemists and processors. In search of a reliable instrumental method suitable for routine quality testing, many North American cereal laboratories have recently made increasing use of alveography, a rheological technique based on subjecting a dough piece to biaxial extension until rupture (Chopin 1927). Some aspects of this technique that were widely disputed by dough rheologists several decades ago have once again been brought to our attention. Concern has been expressed about performing a stretchability test on doughs of constant water content without allowing for differences in the hydration capacity of the tested flours. A constant mixing time, a relatively short dough resting period, and a narrow range of method applicability have also been frequent targets for criticism. Many efforts were made to establish the practical relevance of the effects of these disputed aspects on the validity of the test results in predicting actual baking quality of tested flours (Tchetveroukhine 1947, 1948; Marcelle 1955; Maes and Pirotte 1957; Nuret et al 1970; Khattak et al 1974; Weipert 1981; Rasper et al 1985; Chen and D'Appolonia 1985). From these efforts, it became evident that judgments of relevance could only be made relative to the type of flour tested and its rheological contribution to the system in which it would be involved. To date, most published studies are concerned with stronger flours intended for fermented doughs. Because of well-recognized differences in the physico-chemical nature and functional requirements of different flour systems, conclusions from such studies may not be fully applicable to soft wheat flours and their behavior in systems such as cake batters and cookie doughs.

The objective of the present study was to evaluate the suitability of alveography for quality assessment of soft white winter wheat cultivars. Alveogram data for straight-run flours milled from these wheats were compared with results of tests constituting the current testing methodology. These comparisons were made for both alveogram data obtained on doughs prepared by the standard procedure, i.e., using a constant flour solids to water ratio (ISO 1983), and on doughs that were mixed to a predetermined constant maximum development consistency. To reach this constant consistency, the water added to each flour was adjusted according to its farinograph absorption. Although the terms "constant water content" and "constant dough consistency" procedure are used throughout the paper, the doughs prepared under the conditions of these two procedures differed in more than just water content and consistency. Other factors, such as the mode and temperature of mixing, also contributed to differences in the rheological nature of the doughs (Bailey and Levesconte 1924, Khattak et al 1974).

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MATERIALS AND METHODS

Soft Wheat Flours

Flours were prepared by milling 2,000-g samples of 14 soft white winter wheat cultivars grown in three areas in Ontario in 1984 and seven cultivars grown in 1983. All flours were milled on a Buhler laboratory mill MLU 202 supplemented with a bran finisher. The average milling yield of straight-run flours that were used for testing was 72.2% (SD = 1.61).

Quality Testing of Grain and Flour

Test weight and weight of 1,000 kernels were determined according to the Official Grain Grading Guide (Canadian Grain Commission 1984). Kernel hardness was determined in terms of grinding time (sec) using a Wiley mill to grind duplicate 20-g samples as described by de la Roche and Fowler (1975). Protein in both grain and flour was determined using a Kjeltec Auto 1030 analyzer. All values were expressed as percent protein ($N \times 5.7$) on a 14.0% moisture basis. The apparent viscosity of the acidulated flour-water suspensions, generally referred to as the MacMichael viscosity, and the percentage of damaged starch in the tested flours were determined according to AACC methods (AACC 1983). AACC methods were also followed in the determination of farinograph absorption (method 54-21) and in the cookie baking quality test (method 10-50D), which gives the results as cookie diameter in centimeters. Alkaline water retention capacity (AWRC) was determined using the method described by Yamazaki (1953).

Alveograph Testing

For alveograph tests performed under the condition of constant dough water content, the standard ISO procedure (ISO 1983) recently adopted by the AACC (method 54-30) was followed. The instrument used was a Chopin Alveograph MA 82 with a built-in diaphragm pump to supply air for inflating the tested dough piece. For testing doughs of constant consistency, the instrument was used in combination with a Brabender Farinograph equipped with a 300-g mixing bowl. Sodium chloride was added to flour in solid form (2% on flour basis) before adding water. The addition of water to flour during the mixing stage was adjusted so that the dough reached a consistency of 500 BU upon maximum development at a mixing temperature of $30 \pm 0.5°$ C and fast-speed setting on the farinograph mixer. Mixing was done according to the dough preparation procedure of the AACC extensigraph method 54-10 (AACC 1983). Upon reaching the maximum development consistency, the doughs (400 g) were transferred into the alveograph mixer, mixed for an additional 30 sec, and extruded through the extrusion slot of the mixer. After extrusion, they were handled as prescribed by the standard method.

The alveograms were evaluated in terms of overpressure, P; average length of the curve, L; P/L ratio; swelling index, G; and deformation energy, W. P (maximum height of the curve × 1.1) was defined by the ISO standard alveographic method as an indicator of dough resistance to deformation (ISO 1983). Some researchers consider the P value to be a measure of the flour-water absorbing capacity (Scott Blair and Potel 1937); dough stiffness, shortness, and tightness (Aitken et al 1944a,b); and even dough stability (Amos 1949). The average length of the alveogram L is commonly taken as an indicator of dough extensibility. The swelling index, G, which represents the square root of the volume of air required for inflating the dough until rupture, is considered dependent on the product of properties usually described as springiness and shortness (Scott Blair and Potel 1937). The most commonly reported index is the deformation energy, W, which can be obtained by multiplying the area under the curve by a factor of 6.54. It represents the energy necessary to inflate the dough until it ruptures and is usually taken as a measure of flour strength.

RESULTS AND DISCUSSION

Ranges and mean values for individual quality attributes of the tested wheat cultivars and their straight-run flours are given in Tables I and II, respectively. Table III summarizes the alveogram indexes determined for the straight-run flours under the conditions of constant water content and constant dough consistency procedures. When measured on doughs prepared in the standard manner under constant water content conditions, the P values were all found to be lower than those that characterized doughs mixed to the constant maximum development consistency of 500 BU. Lower P values of the constant water content doughs were accompanied by higher L values of extensibility and, consequently, higher G values of swelling index, which like L is directly derived from the length of the alveographic curve. The P/L ratios gave a pronounced response to the dough preparation procedure, increasing by approximately 100% in the constant consistency doughs. Equally significant differences were found for deformation energy; W values determined by the standard test ranged from 21.0 to 71.1 J × 10^{-4} but increased to 40.4–101.4 J × 10^{-4} when the tests were performed on doughs of constant consistency. These differences in individual alveogram index values might be attributable to varied flour hydration and different levels of free water in the doughs because different amounts of water were added in the two dough preparation procedures. The total water content in doughs prepared in the standard manner was calculated as 43.0% v/w. To mix the constant consistency doughs to a maximum development consistency of 500 BU, the total water content had to be reduced by 0.5 to 1.3%. However, these reductions did not seem high enough to be fully responsible for the observed differences in the alveogram indexes. Design differences of the mixers involved, affecting mixing speed and temperature, suggest that the lower P and higher L values recorded with the constant water content doughs were at least partly attributable to the conditions of mixing. Doughs prepared by the standard procedure are mixed for 7 min at 24–25° C in the alveograph mixer before their extrusion and sheeting, whereas constant consistency doughs were never mixed for longer than 2½ min (30° C) in the farinograph mixer.

TABLE I
Quality Attributes of Soft White Winter Wheat Cultivars Grown in Ontario in 1984 and 1983 (n = 49)

Attributes	Mean	Range	SD
Test weight (kg/hl)	76.6	71.9–80.6	1.96
1,000-Kernel weight (g)	34.9	30.9–40.3	1.79
Grain protein (%)	9.8	8.7–11.0	0.45
Grain hardness[a]	50.8	42–57	3.88

[a]Time (sec) to grind a 20-g sample in a Wiley mill (de la Roche and Fowler 1975).

TABLE II
Quality Attributes of Flours[a] Milled from Soft White Winter Wheat Cultivars Grown in Ontario in 1984 and 1983 (n = 49)

Attribute	Mean	Range	SD
Protein (%)	8.2	7.2–9.1	0.48
MacMichael viscosity (° M)	45.8	26.0–76.2	11.50
Alkaline water retention capacity (%)	64.9	63.2–71.7	9.24
Starch damage (%)	1.9	1.5–2.8	0.30
Farinograph absorption (%)[b]	48.6	47.5–49.6	0.53
Cookie diameter (cm)	8.9	8.6–9.2	0.12

[a]Straight-run flours milled on Buhler laboratory mill MLU 202 with a bran finisher.
[b]Determined in the presence of 2% NaCl on flour weight basis.

TABLE III
Alveogram Data for Straight-Run Flours Milled from Soft White Winter Wheat Cultivars Grown in Ontario in 1984 and 1983 (n = 49)

Index	Testing Procedure[a]	Range	Mean	SD
Overpressure, P (mm)	CW	16.1–27.3	20.0	2.79
	CC	29.3–37.4	39.5	4.95
Extensibility, L (mm)	CW	86–201	132.3	34.3
	CC	65–163	105.7	22.8
P/L	CW	0.11–0.30	0.16	0.04
	CC	0.18–0.57	0.34	0.09
Swelling index, G (ml)	CW	17.0–28.8	24.0	3.17
	CC	18.0–28.5	22.7	2.63
Deformation energy, W (10^{-4} × J)	CW	21.0–71.7	43.9	13.06
	CC	40.4–101.4	70.1	14.26
Water in dough (% of flour dry solids)	CW	···	43.0	···
	CC	41.7–42.5	42.1	0.21

[a]CW = Constant water content, CC = constant dough consistency.

Despite differences arising from the different conditions in the two dough preparation procedures, individual alveogram indexes for doughs prepared by these procedures followed almost the same trend (Figs. 1 and 2). The two types of tests were significantly ($P < 0.001$) correlated for P ($r = 0.643$). A somewhat greater spread in the L and G data (r = 0.418 and 0.439, respectively; both significant at $P < 0.01$) was presumably caused by reduced reproducibility of the curve length measurements at larger extensions such as those recorded with some of the tested flours. The spread became pronounced in the upper half of the measured range at L > 120. The only alveogram index that failed to show any closeness between the data obtained by the two techniques evaluated was the P/L ratio. On the other hand, a very strong correlation emerged from the relationship of the W values (r = 0.858, $P < 0.001$). When these values were used as a criterion for ranking the tested wheats, the ranking patterns based on the results obtained by both procedures were found to be almost identical (Table IV). The only minor discrepancies were seen in the midsection of these patterns, where differences in the W values of individual cultivars (cultivars 0-97-4-01, H-1-11-3, Frankenmuth, Houser, and 0-97-32-1) were so small that they bordered on the limits of the method reproducibility and made the distinction between the individual samples rather difficult. Results of both procedures put cultivars OAC-82-31, H-1-11-5, 099-6-1, Fredrick, and Augusta into the upper sections of ranking lists characterized by high W values, whereas cultivars OAC-82-14, TW-82-221, TW-232-33, and Gordon received the lowest ranking regardless of whether the tests were performed on the constant water content or constant consistency doughs.

As the next step, relationships between the alveogram indexes and the individual quality attributes of the tested wheats and their straight-run flours were examined. Once again, emphasis was put on identifying the effects of the two evaluated alveograph techniques on the nature of these relationships. A graphical presentation of those involving deformation energy is given in Figure 3. In Figure 4, similar relationships involving the quality attributes of straight-run flours milled from the tested grains are presented. As for the relationships between W and grain quality attributes, the former correlated strongly with both grain test weight and grain protein; neither the strength of these correlations nor the slope of the linear regression lines changed in any significant way when doughs of constant consistency were used in place of those prepared following the standard alveographic procedure. No significant correlation, however, was found between the W values and grain hardness as determined by the grinding procedure of de la Roche and Fowler (1975).

Similarly, relationships between the W values and the individual quality attributes of straight-run flours milled from the tested wheats did not appear to be significantly affected by the conditions of the dough preparation procedure. With both types of dough, highly significant correlations were established between the W values and the MacMichael viscosity (r = 0.823 and 0.713 for constant water content and constant consistency doughs, respectively; both significant at $P < 0.001$) as well as flour protein

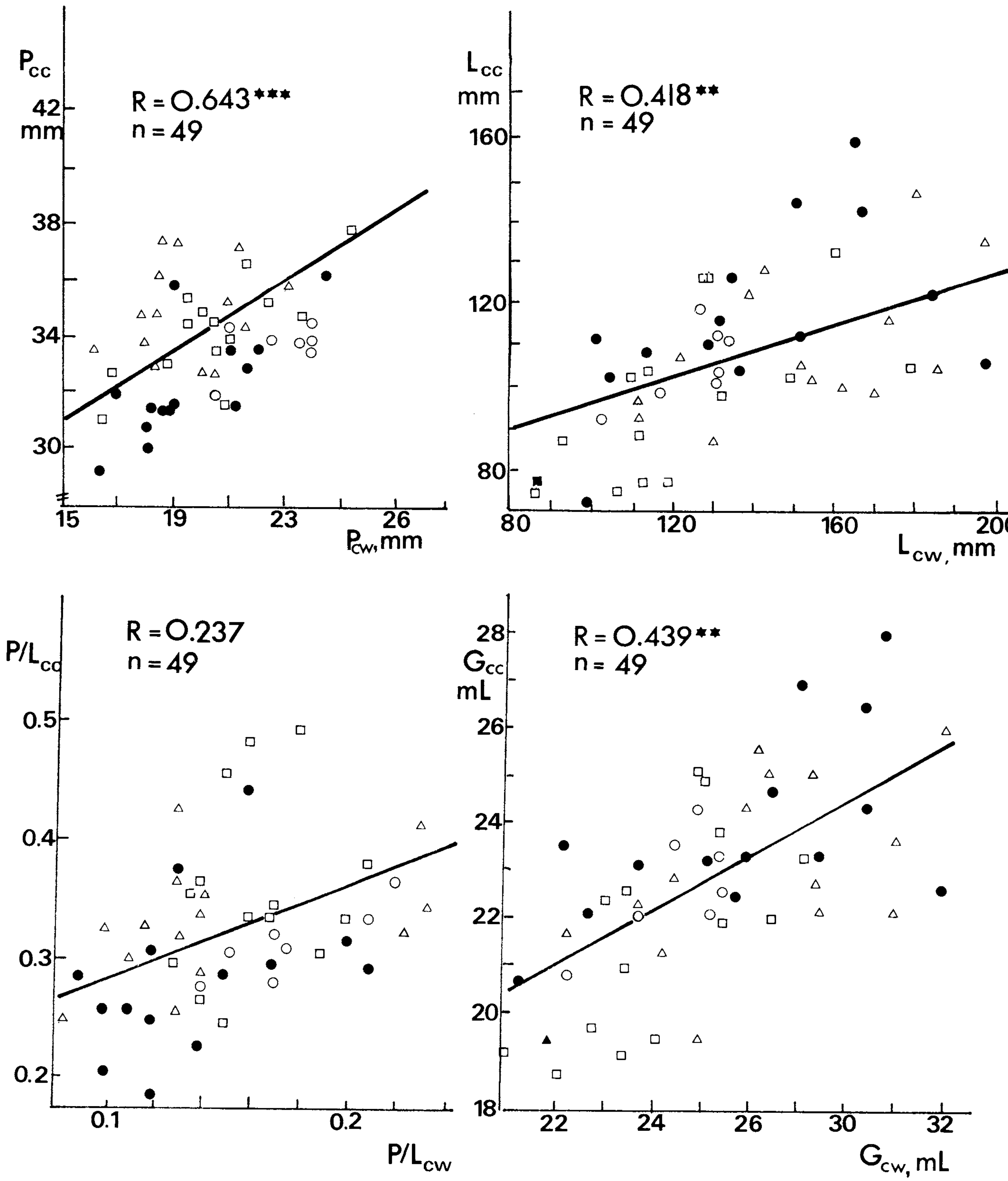

Fig. 1. Relationship between P, L, P/L, and G values determined for straight-run soft white winter wheat cultivar flours under the conditions of two dough preparation procedures ($n = 49$). Subscripts **CW** and **CC** denote the constant water content and constant dough consistency procedures, respectively. 1984 Cultivars: □ = area 1, • = area 2, Δ = 3; 1983 cultivars: o. ***, Significantly different at $P < 0.001$; **, $P < 0.01$.

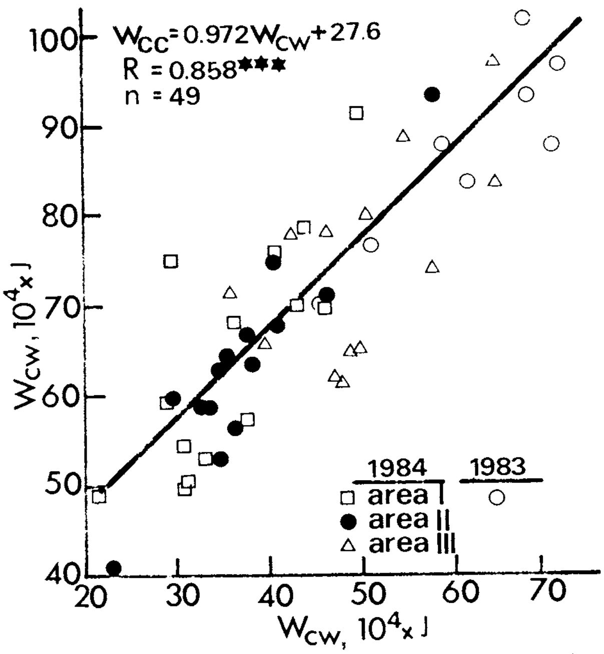

Fig. 2. Relationship between deformation energy W values determined for straight-run soft white winter wheat cultivar flours under the conditions of two dough preparation procedures (n = 49). Subscripts **cw** and **cc** denote the constant water content and constant dough consistency procedures, respectively. 1984 Cultivars: □ = area 1, • = area 2, △ = area 3; 1983 cultivars: o. ***, Significantly different at $P < 0.001$.

(r = 0.673 and 0.603 for constant water content and constant consistency doughs, respectively, both significant at $P < 0.001$). Although the level of significance of these correlations was the same for data obtained by both techniques, the correlation coefficients calculated for the constant water content doughs were consistently higher than those for the constant consistency ones. Among the other quality indicators, farinograph absorption was the only one to give an indication of a closer relationship with the W values (r = 0.445 and 0.471 for constant water content and constant consistency doughs, respectively; both significant at $P < 0.01$). No such indication was displayed by either AWRC or cookie diameter readings. A relatively low sensitivity of the cookie test (Abboud et al 1985) and a limited range in the baking quality of flours tested in this study may explain the failure in establishing any closer link between the most commonly used alveogram index and the results of an ultimate test of the baking potential of the tested wheats. The range of measured cookie diameter values (8.6–9.2 cm) was evidently not wide enough to reveal any consistent trend in the relationship between the two evaluated variables.

Correlations between the evaluated flour quality attributes and all alveogram indexes are summarized in Table V. Both protein content and MacMichael viscosity, which were shown to correlate closely with W values, were also found to correlate strongly with most of the other indexes. Overpressure P determined on the constant consistency doughs was the only index that failed to yield any closer relationship with flour protein, and MacMichael viscosity appeared to be in no meaningful relationship with the P/L ratio, regardless of the dough preparation procedure used. Farinograph absorption, which displayed a tendency to correlate

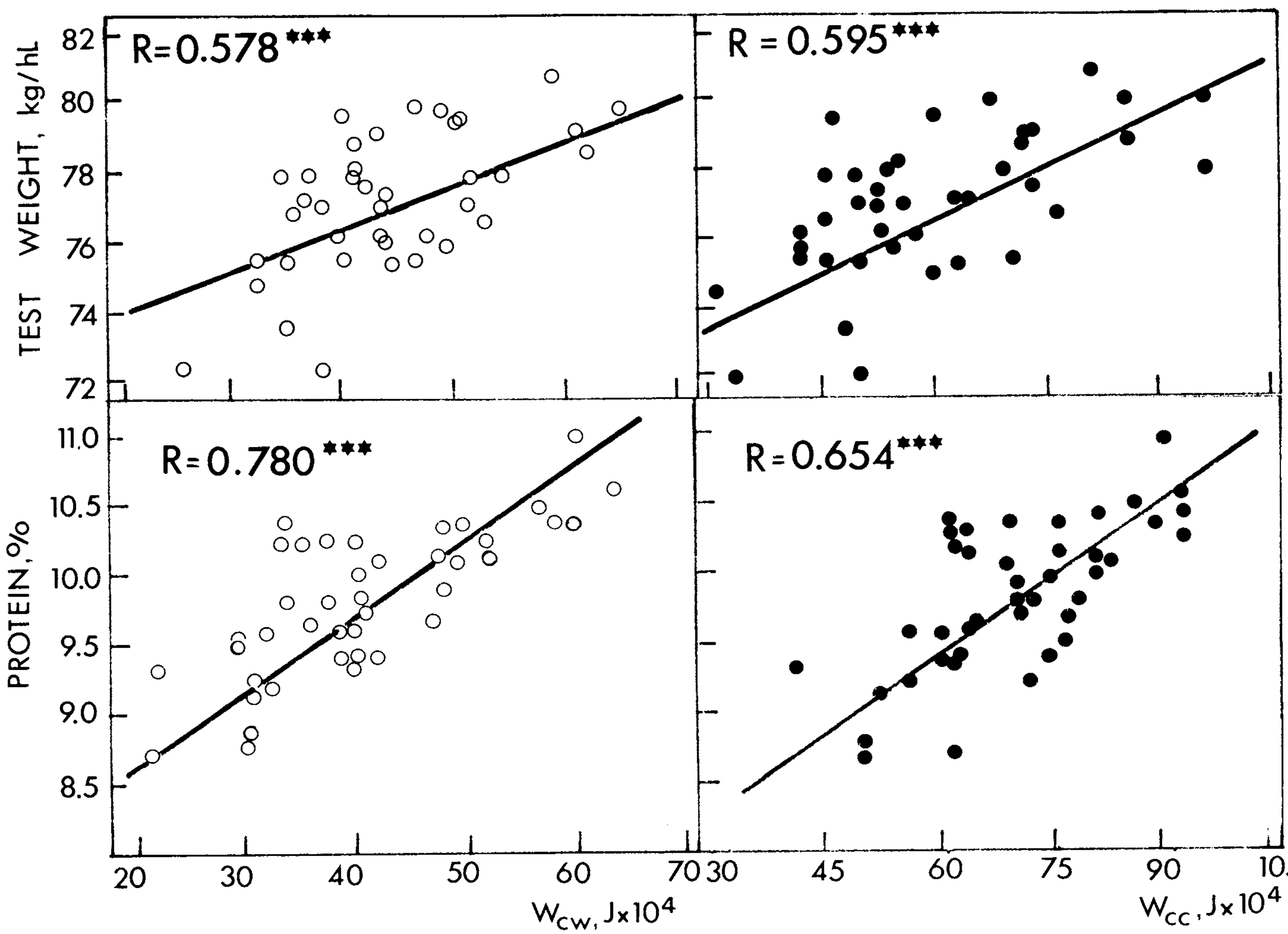

Fig. 3. Relationship between deformation energy W of straight-run soft white winter wheat cultivar flours and test weight and protein of the tested wheat grains (n = 42). Subscripts **cw** and **cc** denote the constant water content and constant dough consistency procedures, respectively. ***, Significantly different at $P < 0.01$.

with the W values, indicated a similar tendency towards the L, G, and P/L data, but only if these were determined on doughs of constant consistency. The same tendency emerged from relating these alveogram indexes to the AWRC data. These indexes are all derived from the length of the alveogram. Thus, it appears that when the doughs are mixed to a constant consistency under the conditions of a variable water content, the length of the curve will become more visibly influenced by adjustments in the dough water content proportional to the water absorption capacity of the tested flour. As for the cookie diameter, the only indication of a somewhat closer relationship with the alveogram data was observed in the case of extensibility and, consequently, the swelling index when these two parameters were determined on constant water content doughs. However, neither of these correlations appeared strong enough to be considered a reliable predictor of the cookie baking quality of the tested wheats ($r = -0.362$ and -0.370 for L_{CW} and G_{CW}, respectively; both significant at $P < 0.05$).

CONCLUSIONS

The alveograph proved to be a useful tool in testing and quality ranking of soft white winter wheats. Replacing doughs prepared in the standard manner, i.e., by maintaining their flour-to-water ratio at a constant level, with doughs having a variable water content but a constant predetermined maximum development consistency, did not have any significant effect on the final ranking of the tested wheats. Neither did the constant dough consistency test present any advantage that would compensate for a greater complexity due to a combined use of the Chopin alveograph with a recording mixer such as Brabender farinograph. Because of a relatively low hydration capacity of the tested flours, the quantity of the total water prescribed for the constant water content doughs (43%) exceeded the quantity required for the doughs to reach the maximum development consistency of 500 BU used in the preparation of the constant consistency doughs. As a result of a

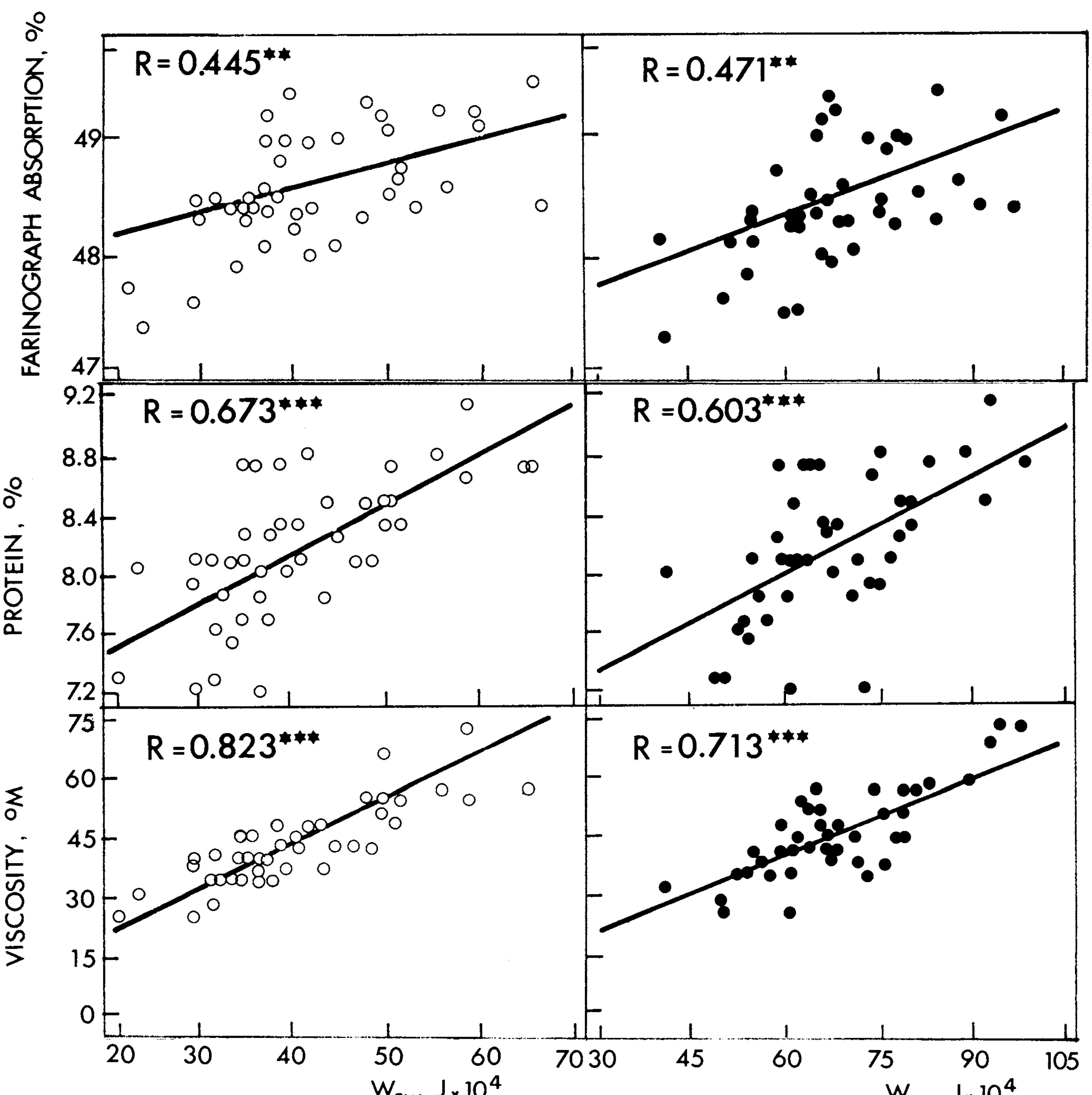

Fig. 4. Relationship between deformation energy W and quality attributes of straight-run soft white winter wheat cultivar flours ($n = 42$). Subscripts **cw** and **cc** denote the constant water content and constant dough consistency procedures, respectively. ***, Significantly different at $P < 0.001$; **, $P < 0.01$.

TABLE IV
Ranking of Tested Soft White Winter Wheat Cultivars[a] on the Basis of Their Deformation Energy Values (W) Determined by Two Alveograph Procedures[a]

	Constant Water Content		Constant Dough Consistency	
Cultivar	Deformation Energy[b] ($J \times 10^{-4}$)	Ranking	Deformation Energy[b] ($J \times 10^{-4}$)	Ranking
OAC-82-31	57.3	1	93.4	1
H-1-11-5	48.8	2	76.0	3
0-99-6-1	47.1	3	77.6	2
Fredrick	45.4	4	70.9	5
Augusta	44.6	5	72.5	4
0-97-40-1	40.1	6	63.9	7
H-1-11-3	39.9	7	60.3	8
Frankenmuth	38.9	8	57.6	11
Houser	38.2	9	60.2	9
0-97-32-1	37.7	10	65.3	6
OAC-82-14	36.6	11	57.8	10
TW-82-221	34.9	12	55.7	13
TW-82-232-33	32.4	13	59.5	12
Gordon	24.3	14	49.9	14

[a]Grown in 1984.
[b]Ranking based on mean W values for three growing areas.

TABLE V
Correlation Coefficients for Alveogram Data and Other Quality Attributes of Straight-Run Flours Milled from Soft White Winter Wheats Grown in Ontario in 1984 and 1983 ($n = 49$)

Alveogram Index[a]	Protein	MacMichael Viscosity	Farinograph Absorption	AWRC[b]	Cookie Diameter
P_{CW}	0.404**[c]	0.701***	n.s.	0.324*	n.s.
P_{CC}	n.s.	0.588***	n.s.	n.s.	n.s.
L_{CW}	0.530***	0.539***	n.s.	n.s.	−0.362*
L_{CC}	0.542***	0.372*	0.373*	0.471**	n.s.
P/L_{CW}	−0.331*	n.s.	n.s.	n.s.	n.s.
P/L_{CC}	−0.458**	n.s.	−0.403*	−0.396**	n.s.
G_{CW}	0.562***	0.509**	n.s.	n.s.	−0.370*
G_{CC}	0.524***	0.410***	0.310*	0.457**	n.s.
W_{CW}	0.673***	0.823***	0.445**	n.s.	n.s.
W_{CC}	0.603***	0.713***	0.471**	n.s.	n.s.

[a]Subscripts CW and CC denote the constant water content and constant dough consistency procedures.
[b]AWRC, alkaline water retention capacity.
[c]*, Significantly different at $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$; and n.s., not significant.

higher water content as well as a different mode of mixing, the constant water content doughs gave consistently lower values of overpressure and higher values of extensibility. Some of these values were obtained at the lower limit of the method. Nevertheless, the method responded with a satisfactory sensitivity to the variations in most of the evaluated quality attributes of the tested wheats. Most of the relationships established between these attributes and the individual alveogram indexes remained almost unaffected by the conditions of the two testing techniques. A strong correlation between the deformation energy with the protein content and MacMichael viscosity of the tested flours is worth noting. On the other hand, no significant correlation was established between the alveogram data and results of the cookie test, which responded to the variation in the quality of the tested wheats by a very narrow range of cookie diameter values. Thus, it appears that the failure in relating any of the alveogram indexes to the results of the cookie-baking test should be considered more a reflection of a limited sensitivity of the latter rather than an insufficient ability of the alveograph test to respond to the quality differences in the tested wheats.

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