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.

**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 X 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 $30 \pm 0.5^\circ C$ 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

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deformation energy, \( W \), (maximum height of the curve \( \times 1.1 \)) 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.

Equal significant differences were found for deformation energy; \( W \) values determined by the standard test ranged from 21.0 to 71.1 \( J \times 10^{-4} \) but increased to 40.4–101.4 \( J \times 10^{-4} \) 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 might be attributable to varied flour strength.

As for the relationships between \( W \) and grain quality attributes of individual cultivars (cultivars OAC-87-0-1, H-1-1-3, Frankenmuth, Houser, and O-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-1-1-5, 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.

TABLE I

<table>
<thead>
<tr>
<th>Quality Attributes of Soft White Winter Wheat Cultivars Grown in Ontario in 1984 and 1983 (( n = 49 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attributes</td>
</tr>
<tr>
<td>Test weight (kg/hl)</td>
</tr>
<tr>
<td>1,000-kernel weight (g)</td>
</tr>
<tr>
<td>Grain protein (%)</td>
</tr>
<tr>
<td>Grain hardness</td>
</tr>
</tbody>
</table>

1Time (sec) to grind a 20-g sample in a Wiley mill (de la Roche and Fowler 1975).

TABLE II

<table>
<thead>
<tr>
<th>Quality Attributes of Flours* Milled from Soft White Winter Wheat Cultivars Grown in Ontario in 1984 and 1983 (( n = 49 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute</td>
</tr>
<tr>
<td>Protein (%)</td>
</tr>
<tr>
<td>MacMichael viscosity (°M)</td>
</tr>
<tr>
<td>Alkaline water retention capacity (%)</td>
</tr>
<tr>
<td>Starch damage (%)</td>
</tr>
<tr>
<td>Farinograph absorption (%)</td>
</tr>
<tr>
<td>Cookie diameter (cm)</td>
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</tbody>
</table>

*Straight-run flours milled on Buhler laboratory mill MLU 202 with a bran finish.

4Determined in the presence of 2% NaCl on flour weight basis.

TABLE III

<table>
<thead>
<tr>
<th>Alveogram Data for Straight-Run Flours Milled from Soft White Winter Wheat Cultivars Grown in Ontario in 1984 and 1983 (( n = 49 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index</td>
</tr>
<tr>
<td>Overpressure, ( P ) (mm)</td>
</tr>
<tr>
<td>Extensibility, ( L ) (mm)</td>
</tr>
<tr>
<td>P/L</td>
</tr>
<tr>
<td>Swelling index, ( G ) (ml)</td>
</tr>
<tr>
<td>Deformation energy, ( W ) (( 10^{-4} \times J ))</td>
</tr>
<tr>
<td>Water in dough (% of flour solids)</td>
</tr>
</tbody>
</table>

*CW = Constant water content, CC = constant dough consistency.
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.
(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

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**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: ∇. ***, Significantly different at P < 0.001.

**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 Lcw and Gcw, 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

![Graph](image)

**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.
higher water content as well as a different mode of mixing, the constant water content doughs gave consistently lower values of deformation energy with 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.

**ACKNOWLEDGMENTS**

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**LITERATURE CITED**


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