FY Sedimentation Test for Evaluation of Flour Quality of Canadian Wheats[1]

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ABSTRACT

The FY sedimentation test is commonly used by manufacturers of steamed and fried noodles as one of their flour quality specifications. The FY sedimentation values of Canadian wheat flours were determined, and some of the factors influencing the test results were examined. FY readings within the first hour for different wheat classes were as predicted on the basis of their relative protein content and strength. In subsequent 2- and 3-hr sedimentation gel volumes, variations in trends existed between the different classes. Canadian Western Red Spring and Red Winter wheat classes increased in sedimentation gel volumes, while the Canadian Prairie Spring and Western Soft White wheat classes decreased. Examination of flours increasing in protein content and dough strength suggested that the latter was associated with the resultant changes in sedimentation volumes with time. Flour extraction rate was also found to have an influence on FY sedimentation values, as the 30% extraction flours' initial readings were all significantly different from those at or above 50 or 60% flour extraction. Effects due to sprout damage were minimal. A minimum two-week aging period after milling was necessary to ensure reproducible discrimination of the sediment interface.

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The FY sedimentation test was developed by the Committee of Japanese Bread Science (Akatsu 1954) as an indication of the characteristics of flour for various end-products. It is similar to a Zeleny sedimentation test (Zeleny 1947), but it is performed on flour rather than on wheat. Furthermore, the volume of sediment is read not only at 5 min, but at 30 and 60 min, after which the suspension is shaken again and the process repeated, followed by a third shaking and reading of sedimentation volumes. These readings produce an FY diagram that is indicative of the suitability of the flour for bread, noodles, or confectionery products. It is also useful for blending of flours to achieve optimum specifications for these products. As with the Zeleny sedimentation test, the main influence on the FY sedimentation test appears to be the protein content of the flour and its inherent dough stability (Moss 1984, Martin and Stewart 1991). In recent years, some mills in Southeast Asia may have included FY sedimentation values in their flour quality specifications at the request of instant noodle makers. In many cases, only 5 min readings are necessary, and a minimum FY value of 50–55 is required generally for noodles.

The present study was conducted to determine the FY sedimentation values of flours representative of the main classes of wheat grown in Canada. In addition, the degree to which factors such as protein content, mill extraction rate, and sprout damage influenced test results was examined.

MATERIALS AND METHODS

Flour Samples

Flours (28) were from 1991 and 1992 crop year cargo or new crop composite samples and represented the Canadian Western Red Spring (CWRS), Canadian Western Red Winter (CWRW), Canadian Prairie Spring white (CPS white) and red (CPS red), Canada Western Soft White Spring (CWSWS), and Canada Western Extra Strong (CWES) wheat classes. All were milled on an Allis-Chalmers laboratory mill using the GRL sifter flow as described by Black et al (1980).

The milling procedure for the production of composite flours with different degrees of refinement and their properties are described in Kruger et al (1994). Wheats representative of the CWRS, CWRW, CPS white, CPS red, and CWSWS classes were milled on the laboratory Allis-Chalmers mill and individual mill streams composited on the basis of increasing ash to produce flours with an extraction range of ~30–75%.

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FY Sedimentation Test

The procedure of Akatsu (1954) was followed, except that the water bath temperature was maintained at 35° C rather than 50° C. A 5-g sample of flour was placed in a 100-ml graduated cylinder, and 50 ml of 0.2% lactic acid at 35° C was added. The cylinder was capped and shaken by hand for 10 sec. An additional 50 ml of lactic acid solution was added. The cylinder was inverted five times and placed in a 35° C water bath. Readings of the sediment volume were taken at 5, 30, and 60 min. After the 60-min reading, the cylinder was quickly inverted five times to resuspend the material, and the three new timed measurements recorded. This process was repeated a third time to yield nine data points. A typical FY diagram and the nomenclature used to indicate various points are indicated for CWRS wheat flour in Figure 1. Analyses were performed in triplicate (average coefficient of variation = 3.3%). Sedimentation volumes could be read more easily by adding 0.01% bromophenol blue to the lactic acid solution and using fluorescent backlighting. Preliminary investigations using the test procedure determined that freshly milled samples were difficult to read and required at least two weeks aging before satisfactory discrimination of the gel interface could be obtained.

Ash Content

Ash content was determined using AACC method 08-01 (AACC 1983) on a 4-g sample in a silica dish incinerated overnight at 600° C.

Protein Content

Protein content was determined by the modified Kjeldahl method (Williams 1973), and the results are expressed on a 14% moisture basis.

Falling Number

Falling number was determined on a 7-g sample of ground wheat using AACC method 56-81B. Wheat (300 g) was ground in a Falling Number laboratory mill 3100, and the results are reported on a 14.0% moisture basis.

Physical Dough Properties

Rheological properties were determined according to AACC method 54-21 (AACC 1983) using a farinograph equipped with a 50-g bowl. CWES wheat flours do not develop at a mixing speed of 65 rpm; consequently, a speed of 90 rpm was used, as described by Preston and Kilborn (1984).

Statistical Analyses

All statistical analyses were performed using SAS (version 6.08) software (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

FY Sedimentation Values of Canadian Wheat Classes

Typical FY diagrams for flours of Canadian wheat classes grown in Western Canada are shown in Figure 1. Canadian Red Spring wheat is the predominant wheat class grown in Western Canada, and the FY diagram for its flour has been superimposed on that of the other classes for better comparison. It is obvious that there are substantial differences in the various diagrams and that much more information is potentially available with this test than with the Zeleny sedimentation test, in which only one reading is taken. In general terms, the height of the initial reading relates to both the protein and the overall strength of the flour, much as the Zeleny sedimentation test does (see reports issued by the Canadian Grain Commission for specific information on quality differences between Canadian wheat classes). For example, the greater protein content and stronger dough characteristic in the CWRS, CWRW, and CWES wheat classes result in initial FY sedimentation values (T5-1) over 70 ml. The medium protein and dough strength CPS class give values around 60 ml, whereas the low protein and weaker CWSWS wheat flour results in FY sedimentation values lower than 40 ml. Measurements after the second and third shaking periods (T5-2 and T5-3) vary from class to class and either increase or decrease. These changes again appear to reflect the relative characteristics of the wheat flour in terms of protein strength. Thus, CWES wheat flour is extremely strong and is used for blending purposes. Its sedimentation volumes increased dramatically with each shaking period. CWRS wheat flour, which has good dough strength, also increased in sedimentation volume with time, but to a lesser extent than CWES. CWRW wheat is slightly less strong than CWRS wheat flours and had sedimentation volumes that increased minimally. Contrasted to this were the two CPS wheat flour types of medium dough strength that decreased in sedimentation volume with each shaking period. Finally, the very weak CWSWS wheat flour decreased in sedimentation volume with each shaking period, but because of its low initial sedimentation volume, the overall decrease in sedimentation volume was limited.

In most cases, although not all, the rate of decrease in sedimentation volume with time after each progressive shaking (T30 and T60 readings) paralleled each other for a particular wheat class (Fig. 1). This suggests that representative information can be obtained from the 5-min values after each shaking period (T5-1, T5-2, and T5-3). As a consequence, although the entire nine points were recorded for all flours in the present study, our discussion will focus primarily on the 5-min values.

Effect of Increasing Protein Content and Strength on FY Sedimentation Values

The effects of increases in flour protein content on the FY sedimentation values (5-min readings) were examined for the CPS red, CPS white, and CWES classes. Wheat samples from across Western Canada during the 1991 (CPS white and red) and 1992 (CWES) harvest seasons were composited on the basis of protein content and milled to produce straight-grade flours. The resultant FY sedimentation volumes at T5-1, T5-2, and T5-3 are shown in Figure 2. Both protein and farinograph dough stabilities are included, and it shows that, particularly in the case of CPS red and CWES wheat flours, increased protein is accompanied by increased dough strength.

For all three classes, there is a progressive increase in FY sedimentation values with increasing protein content. In the case of the CWES wheat flours, the higher protein flours are approaching the maximum FY sedimentation volume possible. It is likely that a increased liquid-to-solid ratio would increase the differentiation between protein levels.

The most interesting finding is the relationship between farinograph dough stability on the time-dependent stability of the gel volumes, as illustrated by the CPS wheat flours. For the CPS white wheat flours, there is very little difference in dough stabilities

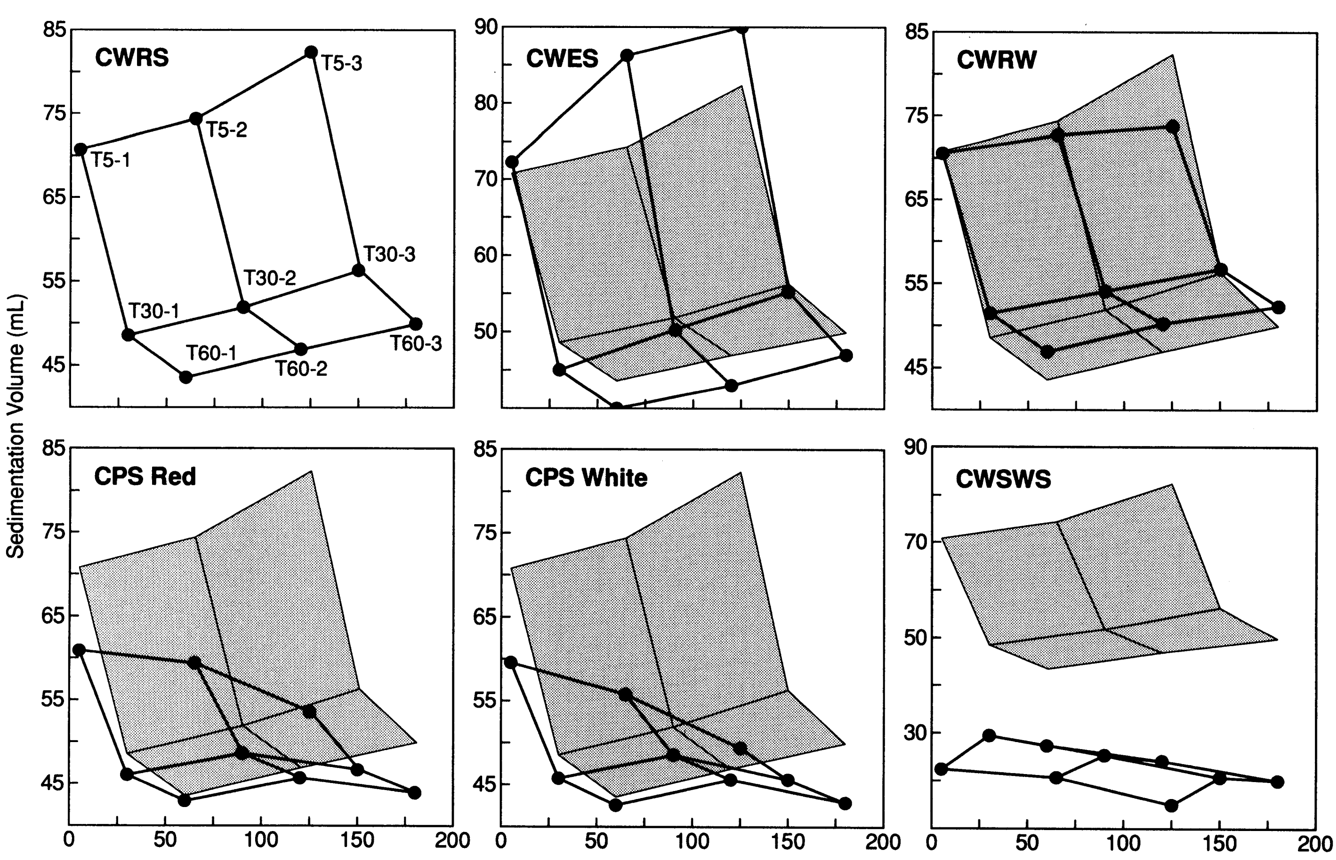

Fig. 1. FY diagrams of flours of Canadian wheat classes: CWRS (11.8), CWES (10.6), CWRW (10.2), CPS red (10.2), CPS white (10.0) and CWSWS (9.7). The respective flour proteins (%) are indicated in parentheses.

at the different protein levels, and the FY sedimentation values at successive 5-min shaking periods are consistent in that decreases in gel volumes occur in most cases. For the CPS red wheats flours, those with dough stabilities through 7.5 min decrease in gel volume with progressive shakings. The flour with a protein content of 11.7% and dough stability of 10.0 min, on the other hand, has a fairly constant gel volume with time, and the flour with a protein content of 12.5 and dough stability of 12.5 min has an increased sedimentation volume with later 5-min values compared to the initial reading. These results would implicate dough strength as a factor associated with time-dependent gel stability.

Effect of Flour Refinement on FY Values

End-products such as oriental noodles are normally prepared not from straight-grade flours but by combining mill streams with lower ash contents (i.e., up to final ash content of ~0.4%). It is well known that this has a pronounced effect on the visual and textural properties (i.e., maximum cutting stress) of a product such as raw Cantonese noodles (Kruger et al 1994) depending on wheat class. It was of interest to see whether differences in flour refinement were also reflected in differences in FY sedimentation values. The resulting FY sedimentation values at the 5-min reading for each of the three shaking periods for different Canadian wheat classes are shown in Figure 3.

For the CWRS class, the difference in sedimentation volumes of flours with different extraction rates was minimal, decreasing slightly from 60–75% extraction. Although the 30% flour was significantly distinct ($\alpha = 0.05$) from the remaining flours, no pattern associated with refinement was detected with the higher extraction flours. This is in spite of the fact that protein content increased overall by 1.7% and wet gluten increased by 4.3% (results not shown). One explanation for this is that the sedimentation volumes are approaching the maximum sedimentation volume possible (100 ml). Another explanation would be the negative influence of increasing bran contamination destabilizing potential increases in the gel volume due to higher protein content. Consistent with the CWRS class, the sedimentation volumes increased with each succeeding shaking period for all of the flours.

Of all the wheat classes, the CWRW flours showed the greatest change due to flour refinement. The lowest ash flour had an unusually high, statistically distinct ($\alpha = 0.05$, LSD = 1.94) FY sedimentation volume for its protein level. At the first shaking period, it is comparable to the CWRS wheat flours, although with over 2% less protein. This flour was also significantly different ($\alpha = 0.05$) at both T5-2 and T5-3 readings. Note that this flour also had an exceedingly high farinograph stability of 28 min compared to the other higher extraction CWRW flours, which ranged from 10.5–12.0 min (results not shown). As the flour extraction increased, there was a gradual decrease in FY sedimentation values, even though flour protein increased slightly. Clearly, with this class of wheat flour, FY sedimentation values obtained at one extraction rate cannot be extrapolated to another. With the exception of the 30% flour extraction, the sedimentation volumes of the individual flours did not change to any great extent at the successive shaking time periods.

Flours from both the red and white CPS class of wheat flours had FY sedimentation values that did not change in any predictable fashion with increasing flour extraction, although the 30% extraction flours were significantly different ($\alpha = 0.05$) than those of 60% or higher yield. The finding that FY sedimentation values did not progressively decrease with higher extraction flours suggests that they are fairly insensitive to increased bran contamination, at least up to the extraction rate of a straight-grade flour. Within the CPS wheat class, all flours showed a diminishing of sedimentation gel volume with successive shaking periods.

CWSWS wheat flours were very low in sedimentation volumes and close to the minimum of the FY sedimentation scale. Although values in the range of 15–25 ml were observed, a fully sedimented cylinder had a volume of 12 ml. As such, changes observed among flours of different extraction rates were very small. If anything, increasing the extraction rate had the effect of slightly increasing FY sedimentation values concomitant with slightly increasing protein content. As observed for the other wheat classes, the initial 5-min reading for the 30% extraction flour was distinct ($\alpha = 0.05$) from the corresponding higher extraction flours.

Effect of Sprout Damage on FY Sedimentation Values

Carlot samples of CWRS wheat were composited on the basis of similar protein content, but increasing sprout damage values ranging from a falling number (FN) of 485 down to 85 sec. Patent and straight-grade flours were produced to investigate the influence of flour refinement on sprout damage during the FY test. FY sedimentation values for the three 5-min readings for the different flours are shown in Figure 4. Observe that all samples are within ~1% protein of each other, with the exception of one

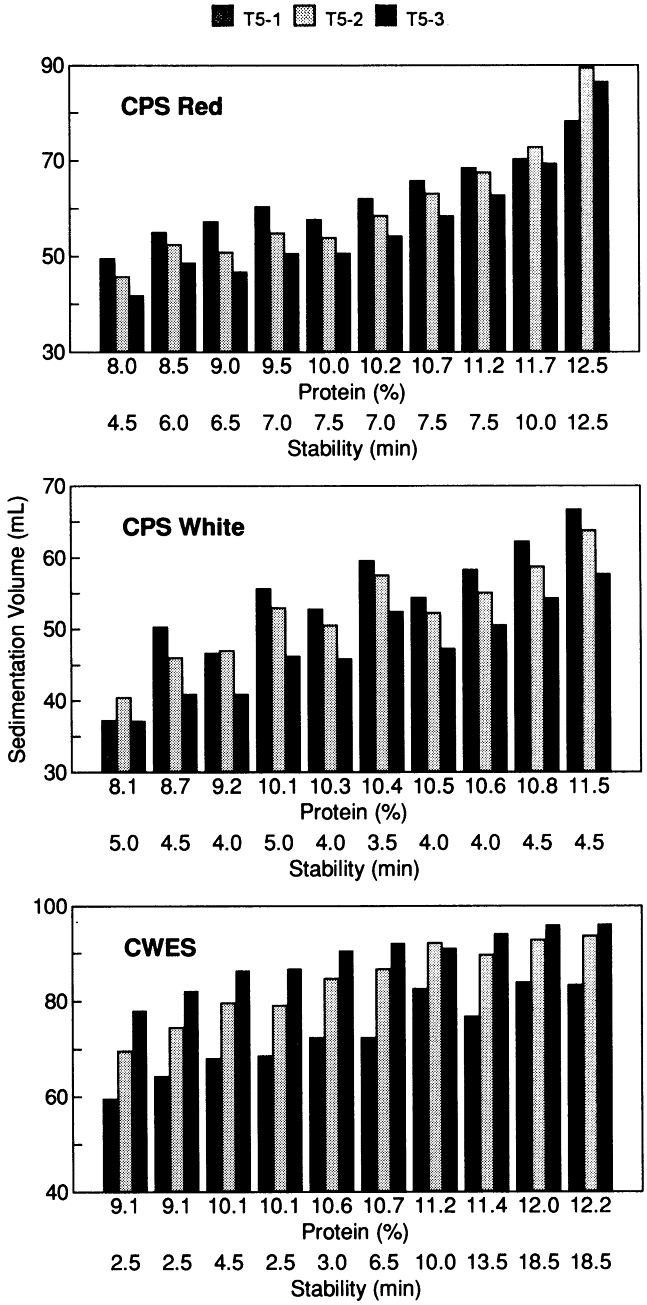

Fig. 2. Effect of protein content (14% mb) on the T5-1, T5-2, and T5-3 sedimentation volumes for CPS red, CPS white, and CWES wheat flours. Farinograph stabilities are included and were performed at 65 rpm for the CPS red and white wheat flours and at 90 rpm for the CWES wheat flour. The least significant difference values (ml) for T5-1, T5-2, and T5-3 are: CPS red 1.90, 2.88, 2.71; CPS white 1.06, 1.28, 1.11; CWES 1.67, 2.30, 2.15.

lower protein sample (FN 120 sec).

For each flour, the FY sedimentation values for the patent flours were greater than for the straight-grade flour. Two main findings are apparent. First, it appears that there are no deleterious effects on the FY sedimentation values of flours containing fairly high levels of sprout damage. In fact, there is a statistically distinct ($\alpha = 0.05$) small increase in FY sedimentation values as the level of sprout damage increases. Secondly, the time-dependent gel sedimentation volumes (i.e., T5-2 and T5-3 readings) increase even with the most severely sprouted sample. It is well known that the germination process is accompanied by increasing amounts of proteolytic enzymes (Kruger and Reed 1988). The present results indicate that no in situ damage has occurred to the storage proteins and, furthermore, no degradation of such proteins has occurred before the final 125-min reading (T5-3).

One possible explanation for increased FY values with increasing sprout damage is that the endosperm becomes more mellow in that kernel hardness goes down and, in turn, solubilization of storage proteins is enhanced. To test this hypothesis, a sound sample of CWRS wheat with a FN of 440 sec was steeped for 16 hr and then rapidly air-dried. The FN decreased to 380 sec, indicating that the wheat had not germinated to any significant amount. Upon milling, the starch damage of the flour, however, had dropped from 27 to 18 Farrand units, indicating that it had become considerably softer. A comparison of the FY sedimentation test values of the two flours with varying hardness indicated that there was no significant difference ($\alpha = 0.05$) between them.

To further examine the possible effects of endogenous enzymes on the FY sedimentation test, a crude enzyme extract was substituted for the lactic acid solution normally used in the test. This extract was prepared from a highly sprouted wheat sample by stirring 0.2% lactic acid and ground sample (20:1) for 1 hr, followed by centrifugation at 15,000 rpm for 5 min. This extract was added to a sound (FN 485 sec) flour, and the test performed in a normal manner. The extract decreased FY sedimentation values, but the effect was as great as that of using a crude extract,

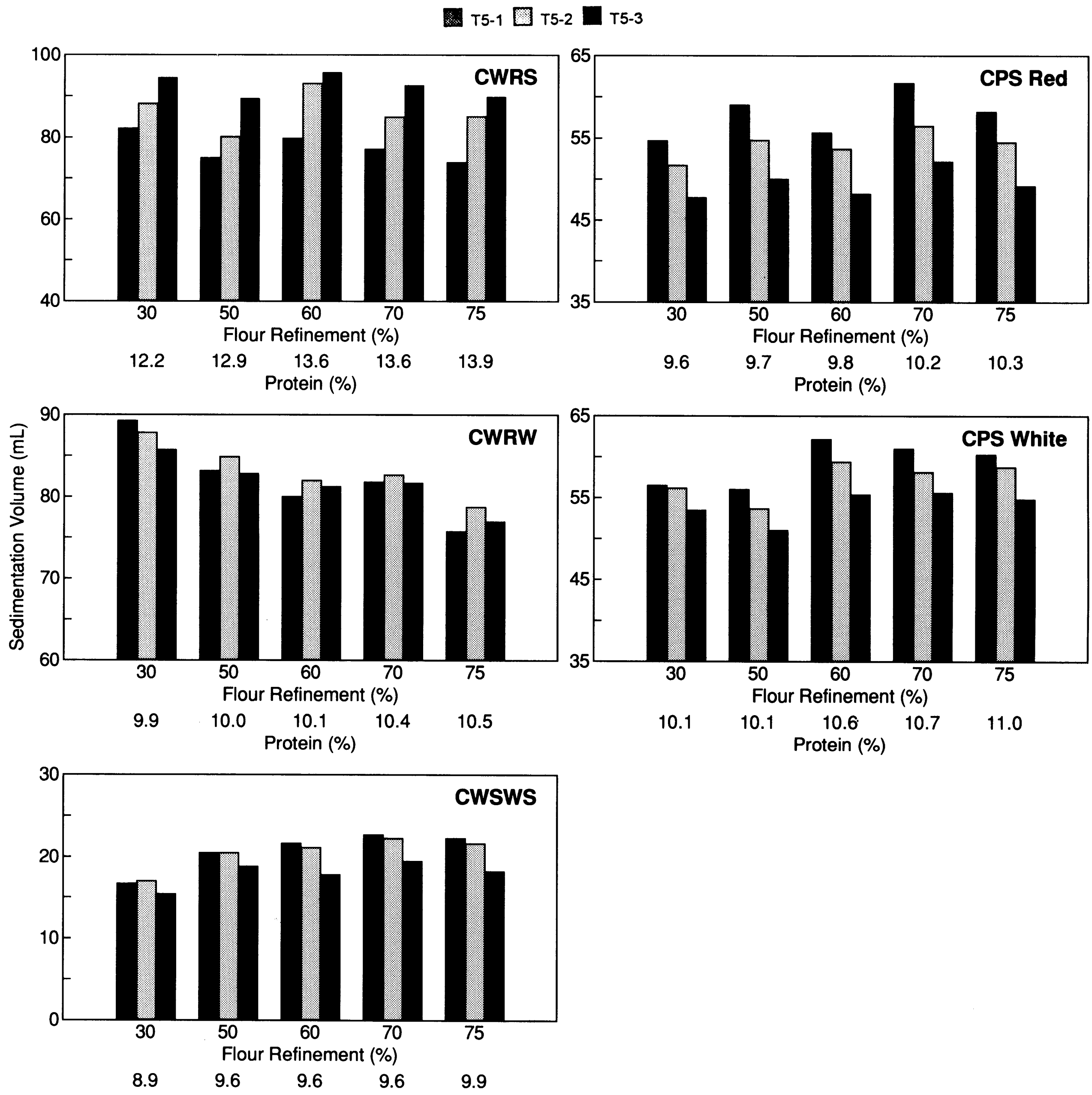

Fig. 3. Effect of various levels of flour refinement (approximate %) on the T5-1, T5-2, and T5-3 sedimentation volumes for different Canadian wheat classes. The least significant difference values (ml) for T5-1, T5-2, and T5-3 are: CWRW 1.94, 2.20 2.62; CWRS 1.22, 5.96, 2.12; CPS red 2.27, 1.25, 1.36; CPS white 1.89, 3.95, 3.10; SWS 1.71, 1.06, 0.77.

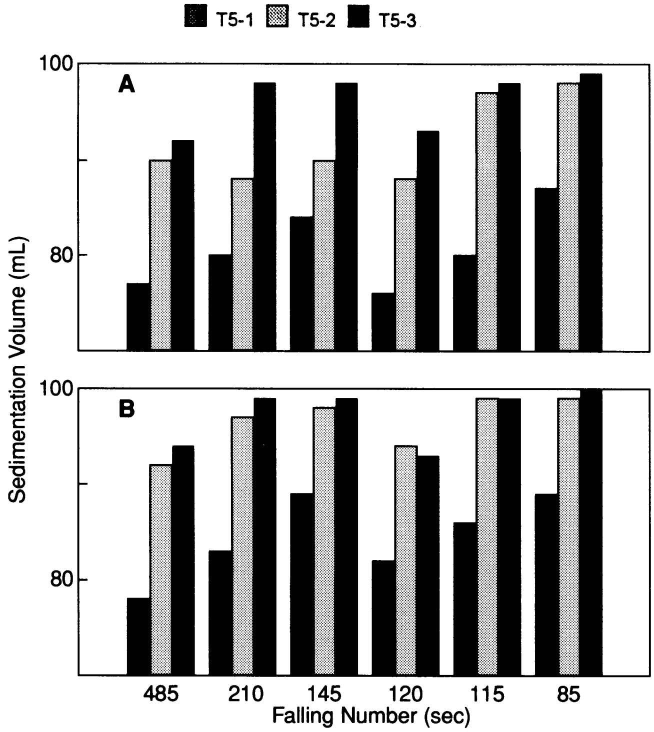

Fig. 4. Effect of increased sprout damage (decreasing falling number values) on the T5-1, T5-2, and T5-3 sedimentation volumes from CWRS patent (**A**) and straight-grade (**B**) flours. The least significant difference values (ml) for T5-1, T5-2, and T5-3 are: patent 1.48, 1.87, 1.72; straight-grade 1.68, 0.84, 1.46.

heat-treated to inactivate enzymes. This indicated that other components (i.e., reducing agents) in the extract were responsible for the effect.

CONCLUSIONS

The FY sedimentation test differs from the Zeleny sedimentation test, not only in that flour rather than wheat is used, but that readings are taken at different times. The resulting profiles are more informative because unique profiles result that are more indicative of the flour's potential for different types of end-products. It is particularly interesting that the gel sedimentation volumes can either increase or decrease with time. This appears to be related to the relative dough stability of the flour, but the exact mechanism of why it occurs needs to be elucidated. These time-dependent differences can be obtained by the first three 5-min readings, obviating the time involved in measuring all nine points for an FY diagram. However, the complete FY diagram may be needed when blending flours to particular specifications.

The FY sedimentation test results are influenced by the flour mill extraction rate and, likely, the type of mill, suggesting that comparisons of FY results from different flours must be done at similar extractions and very likely under the same milling conditions. The finding that flours with falling numbers as low as 85 sec do not adversely affect sedimentation volumes and, in fact can increase them, means that this test can still be used with wheat containing this type of environmental damage.

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