HGCA

PROJECT REPORT No. 3

MEASURES OF THE BREADMAKING QUALITY OF WHEAT

OCTOBER 1988

FREE

MEASURES OF THE BREADMAKING QUALITY OF WHEAT

Project No. 0035/1/87

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Final report on a project of duration 1 year, starting date 1st May 1987

Abstract

In the UK the most commonly used rapid test for breadmaking quality in wheat is the SDS sedimentation test. Other EC countries normally use the Zeleny sedimentation or Chopin Alveograph tests, and these have entered into Intervention (Zeleny only) and export specifications. The aim of this work was to compare the performance of the three tests and investigate the relationships between them. The intercorrelations between the three tests were all found to be high, although the relationships were not sufficiently precise to permit the calculation of one test result from another. All three tests were of value for identifying wheats of breadmaking quality, and all three were useful for predicting the loaf volumes obtained in test bakes, the SDS test giving the best correlations with loaf volumes. Blending experiments confirmed that SDS and Zeleny results were approximately additive (i.e. could be calculated by linear interpolation) in wheat blends, but unpredictable results were obtained with the Alveograph W value. There was little change in the results of either sedimentation test when wheats were stored at ambient temperature for several months, but Alveograph W values tended to increase.

OBJECTIVES

To examine the correlations between the SDS, Zeleny and Chopin Alveograph tests for the breadmaking quality of wheat, to determine the effects of ageing and blending of wheat samples on the results of these tests, and to obtain information on the performance of UK varieties in the tests.

1. INTRODUCTION

The EC Commission has introduced the Zeleny sedimentation test as a quality criterion for accepting wheat into Intervention in both the common and premium categories. The Commission has also announced that in order to qualify for export restitution, wheat destined for export should meet certain quality standards involving Zeleny and Alveograph tests. Since the Zeleny and Alveograph tests are not normally used on a routine basis to assess wheat and flour quality in the UK, little was known about their correlation with each other or with the commonly used UK test, the SDS sedimentation test. The main aim of this work was to investigate these relationships and to examine how different home-grown wheat varieties performed relative to one another in each test.

In the Zeleny test a white flour is milled from the wheat sample and shaken in a tube with lactic acid and isopropyl alcohol. The resulting suspension is allowed to settle into a column, and its volume is measured after a fixed time. This volume is strongly dependent on the physical properties of the hydrated protein and is a useful measure of the strength of the protein. The similar SDS test uses a ground wholemeal sample and a mixture of SDS (sodium dodecyl sulphate) and lactic acid for hydration. In the Alveograph test a dough is made using a fixed amount of water and a bubble is blown from a disc of dough. The W value is a measure of the energy required to inflate the bubble to bursting point.

Results of the other protein quality test used for Intervention and export, namely the machinability test, have been shown to be affected by the age of the wheat sample, and therefore it was important to investigate whether Zeleny and Alveograph values, which are also an indication of protein quality, varied in a similar manner.

The original intention was to include the machinability test in the study, but the lack of suitable samples prevented this.

2. MATERIALS AND METHODS

It had been hoped to use wheat from several National Institute of Agricultural Botany (NIAB) Recommended List trials in 1987, where protein contents and loaf volumes would already be available. In the event, due to the disastrous harvest, only two centres, Rosemaund and Sutton Bonington, provided suitable samples, the remainder being unsuitable due to weathering and very low Falling Number values. Samples of the 20 varieties in the Recommended List trials at each of these sites were used in the correlation studies. Many of these samples had lower Falling Numbers than was desirable, but they were the best available. Some of the samples from the HGCA's Wheat Quality Survey were sound, although small in quantity, and these were used for some of the blending and ageing work. Due to the limitations on the size and number of suitable samples it was not possible to carry out the project as originally proposed. In particular there was no source of sound samples of sufficient quantity to carry out machinability tests. In order to obtain additional information on varieties, SDS volumes were measured on samples from the 1987 Wheat Quality Survey using wholemeals already prepared for protein and Falling Number determinations.

The Zeleny sedimentation volumes were obtained using the ICC Standard Method No. 116. SDS sedimentation volumes were measured at 22^{o}C, but otherwise according to the published method (Axford, McDermott and Redman, 1978). Flour protein and moisture were measured by NIR. Bread was baked by the standard Chorleywood Bread Process (CBP) and long fermentation process (LFP) methods used by the Wheat and Flour Testing Laboratory at the Flour Milling and Baking Research Association. The Chopin Alveograph was used in accordance with the manufacturer's instructions as given in the Alveograph Handbook (Faridi and Rasper, 1987).

3. RESULTS

3.1 Correlations between the SDS, Zeleny and Alveograph tests

The three tests were compared on 40 wheat samples, comprising 20 varieties from two sites. The results are plotted in Figures 1-3 which show the relationships between the tests and the pairwise correlation coefficients. All three correlations were highly significant ($p<.001$), but the plots reveal considerable scatter. The fitted equations relating Zeleny (Z) and Alveograph (W) results to the SDS test (S) were

$$Z = -19.83 + 1.026 \times S \qquad \sigma = 6.0$$

$$W = -30.3 + 2.18 \times S \qquad \sigma = 17.0$$

where σ is the standard deviation about the fitted line and indicates the likely magnitude of the errors should the equations be used to predict one test from another.

3.2 Ability of the three tests to discriminate between wheat varieties

The mean test results for each of the 20 varieties (means of results from two sites) are listed in Table 1 in descending order of SDS values. The top seven varieties in the table were all classified as I or II (HGCA, 1987), i.e. as breadmaking varieties. The remainder were either class III, non-breadmaking varieties, or were not classified in 1987. Two of the tests, SDS and Zeleny, succeeded in ranking all the class I and II varieties above the rest, albeit only narrowly. The very low W value for Mission, a class II variety, combined with the high values recorded for the two hard class III wheats Fortress and Slejpner prevented the Alveograph from achieving the same result.

3.3 Prediction of breadmaking performance

The same 40 wheat samples were milled into flour and baked by the CBP and LFP methods. The results of correlating loaf volumes with the three tests are given in Table 2. For comparison the correlations between loaf volumes and protein content are also given in Table 2.

3.4 Effects of blending wheats

3.4.1 Zeleny sedimentation test Avalon, a breadmaking variety, was blended in turn with three feed wheat varieties, Galahad, Longbow and Squadron, in the following proportions: 0, 25, 37.5, 50, 62.5 and 100% of Avalon. Flours were prepared by milling the blended wheat on two Sedimat mills, one more than 20 years old and one purchased recently from Brabender. There was a small but consistent difference between the old and new mills, the old mill producing results which were higher by an average of 1 unit. The results shown in Table 3 were obtained with the new mill. For the varieties examined, there was very good agreement between observed Zeleny sedimentation values and those calculated by linear interpolation between the measurements on the two parent wheats.

3.4.2 SDS sedimentation test The effects of blending on the SDS test were examined using the same varieties blended in the same proportions as for the Zeleny test. The results are shown in Table 4. For two of the varieties, Galahad and Squadron, there was fairly good agreement between the observed and calculated SDS sedimentation volumes although the calculated SDS volumes were slightly lower than those observed. Results were more erratic for the variety Longbow. The results for 100% Longbow and for the 25:75 blend were confirmed by four replicate determinations.

The blending of Avalon and Longbow was repeated using different samples of both varieties. In addition Mercia and Brock were included in further blending experiments. The results of this work are shown in Table 5. The sample of Longbow, checked by electrophoresis, again gave an SDS volume (57) higher than would be expected for this variety. However, on blending with Avalon the calculated and observed results were in much better agreement than those obtained in the first experiment. The Avalon:Brock and Mercia:Longbow blends behaved predictably, but the Mercia:Brock blends gave higher SDS volumes than would be expected.

3.4.3 Chopin Alveograph The effects of blending on the Chopin Alveograph W value were examined using two breadmaking varieties, Avalon and Mercia, each blended with a series of feed wheats. The results are shown in Table 6. The effect of blending one wheat with another appeared to depend upon the varieties involved. An extreme example is shown in the case of Avalon and Slejpner where the addition of 62.5% Slejpner had little effect on the Alveograph W value.

3.5 Effects of ageing

3.5.1 Zeleny sedimentation test Samples of the varieties Avalon (2 samples), Galahad (2), Brock (1) and Longbow (1) were stored at ambient temperatures at a moisture content of 14.5 - 15%. At times 0, 2, 5 and 11 weeks after harvest, sub-samples were tested for Zeleny sedimentation volume. The values for the two stored samples of Avalon decreased steadily from 64 to 59 and 53 to 47 respectively. Of the feed varieties, which had much lower Zeleny values, only one sample of Galahad showed a decrease, from 30 to 27. The other Galahad sample, along with those of Longbow and Brock, remained constant throughout the storage period. Sample size prevented continuation of the experiment beyond this point. Over the longer term, samples of 20 varieties from each of two NIAB trial sites were examined in mid-November and again at the end of March following a period of storage at ambient temperature. The means for the Rosemaund and Sutton Bonington sites were 28.9 and 36.4 respectively in November, and 29.7 and 36.9 respectively in March. Three quarters of the samples showed a small increase, typically of 1 unit. In no case did the change in the sedimentation value for any variety exceed 2.5 during this period.

3.5.2 SDS sedimentation test In a similar short term study samples of Avalon (2), Galahad (2) and Brock (1) were tested 0, 6 and 15 weeks after harvest. The SDS results decreased with time for all samples, by an average of 6 units. Over the longer storage period samples of 20 varieties from Rosemaund were tested in November and March. The mean SDS values were 50.6 in November and 49.1 in March. Most varieties showed a slight tendency to decrease during this storage period.

3.5.3 Chopin Alveograph The samples used for the ageing experiments immediately post-harvest with Zeleny and SDS sedimentation tests were insufficient to Buhler mill into the white flour required for the Alveograph. However, it was possible to test samples of flour milled from wheats from the Rosemaund and Sutton Bonington sites in November and March. The mean Alveograph W values for Rosemaund and Sutton Bonington were 80.1 and 85.7 respectively in November and 90.0 and 94.4 in March. In the 40 individual comparisons, only 11 samples showed small decreases in W value during the period of storage whilst the remaining 29 increased, some by 30 units or more.

3.6 SDS volumes on the Wheat Quality Survey samples

SDS volumes were measured on all the samples of wheat collected by the HGCA's Regional Cereals Officers for the Wheat Quality Survey. Varietal means and ranges are given in Table 7 for all varieties where more than 12 samples were received. Protein contents (at 14% moisture) and SDS values for the two most popular varieties, Avalon and Galahad, were correlated. In each case there was a significant positive correlation between these two parameters: for Avalon $r = 0.55$ ($p<.001$) and for Galahad $r = 0.22$ ($p<.05$). The regional mean SDS volumes and protein contents for the varieties Avalon and Galahad are shown in Table 8. For the variety Avalon there was no obvious relationship between mean regional SDS volumes and protein contents. For the variety Galahad the mean regional SDS volumes were ranked in the same order as the mean regional protein contents.

3.7 Production of flour for Alveograph testing from small samples of wheat

An experiment was set up to compare the results of Alveograph tests on flours milled by a laboratory Buhler mill and by a Brabender Quadrumat Junior mill. The latter mill is much simpler to use and needs a smaller wheat sample. Wheat samples were selected to cover a range of baking quality from No.1 Canadian Western Red Springs (CWRS) to the poorest UK feed wheat variety. The results are shown in Table 9. Flour produced by the Quadrumat mill gave a higher Alveograph W value for seven of the eight varietal types examined. The average increase for the six varieties other than Brock was 6%. The result for Brock increased by 41%. Milling method had no effect on the ranking of varieties by the Alveograph test.

4. DISCUSSION

The results reported above were all obtained on wheats from the 1987 harvest. Serious problems with weather damage and low Falling Number restricted the numbers of suitable wheat samples available for this work, thus curtailing the original programme, and the relatively poor quality of the samples that were used may well have influenced the results obtained. It will be important to confirm some of the results, particularly the correlation exercises, with wheat samples from the 1988 harvest.

The correlations between the three tests, SDS, Zeleny, and Alveograph W, were strong enough to suggest that all three are measuring very similar properties of the sample, but not strong enough to permit the reliable calculation of one test result from another. The derived relationship between SDS and Zeleny volumes agrees well with that given by Lindley (1986), but given the magnitude of the errors involved the rough rule of thumb

$$\text{Zeleny} = \text{SDS} - 20$$

is probably the best summary of both exercises. A similar approximate rule that might be useful in some circumstances is

$$W = 2 \times \text{SDS} - 20.$$

The scatter in Figures 1 - 3 emphasises just how approximate these rules are.

Although the three tests did not rank UK wheat varieties in the same order, all three were fairly successful in separating wheats of breadmaking quality. The low W value obtained by the variety Mission may have been partly a result of the low Falling Number of both the samples tested. The SDS was the most successful in predicting both CBP and LFP loaf volumes, but none of the three performed particularly impressively. Again the high levels of alpha-amylase activity in many of the samples may have been at least partially to blame for this failure. All three tests did however do better than a simple measure of protein content in both predictions.

The results from the blending experiments indicated that in predicting Zeleny and SDS sedimentation volumes for blends of wheat it is usually safe to assume that additivity will hold, although some of the results with the SDS test suggested that this is not always true. The much more unpredictable results obtained in blends with the Alveograph suggest that it would be unwise to make the same assumption in general for this test. This finding has important implications for the blending of wheat to meet export specifications.

Both SDS and Zeleny volumes decreased in the period immediately after harvest. The reason for this is unknown, and it conflicts with the fact that baking quality is known to improve over the same period. It was not possible to investigate the Alveograph test in the same period. Over a longer period of storage, from March to November, the SDS and Zeleny results on stored samples changed very little but the Alveograph W values increased by an average of about 10 units.

The tests carried out on the 1987 Wheat Survey Quality samples gave average SDS volumes for the popular varieties which agreed closely with those measured on the samples from the Recommended List trials. However the much wider range of samples available from the Survey also demonstrated the variability of SDS values for a particular variety grown at different locations. In particular the ranges for the breadmaking varieties (Avalon and Brimstone) overlapped those of the non-breadmaking varieties.

To test a wheat sample on the Alveograph it is necessary first to produce a white flour from the wheat. This is usually done by milling on a laboratory Buhler mill. However this requires at least 2kg of sample and is very time consuming. The results obtained with samples milled on the Quadrumat mill, although consistently a little higher than those on Buhler milled flours, were reliable enough to allow the use of this mill as an alternative. This procedure will be used in measuring Alveograph W values on some samples from the 1988 Wheat Quality Survey.

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TABLE 1: Mean test results on 20 varieties of UK wheats

Variety	Sedimentation volume (ml) SDS	Sedimentation volume (ml) Zeleny	Alveograph W ($J \times 10^{-4}$)
Avalon	71	54	112
Brimstone	66	40	93
Moulin	65	59	131
Parade	64	52	140
Mercia	63	50	132
Rendezvous	59	37	93
Mission	55	35	76
Norman	54	32	73
Fortress	51	29	90
Longbow	50	26	65
Fenman	49	32	69
Riband	49	26	61
Rocket	47	24	63
Aquila	46	28	77
Slejpner	45	27	87
Galahad	44	22	77
Mandate	42	24	50
Apollo	38	23	60
Brock	37	20	56
Hornet	35	22	40
LSD* (5%)	9	7	20

* Least significant difference, based on two-way analysis of variance, varieties x sites

TABLE 2: Correlations between loaf volumes and four measures of breadmaking quality

Quality Measure	Correlation with loaf volume CBP	Correlation with loaf volume LFP
SDS	0.59***	0.85***
Zeleny	0.42**	0.72***
Alveograph, W	0.47**	0.70***
Protein, %	0.03	0.45**

n = 40, **significant at p<.01, *** p<.001

TABLE 3: Effect of blending on Zeleny sedimentation volumes

Composition of blend %			Zeleny sedimentation volume (ml) Observed	Calculated*
AVALON	:	GALAHAD		
100	:	0	44	-
62.5	:	37.5	34	35
50	:	50	31	32
37.5	:	62.5	28	28
25	:	75	25	25
0	:	100	19	-
AVALON	:	LONGBOW		
100	:	0	44	-
62.5	:	37.5	36	35
50	:	50	33	32
37.5	:	62.5	31	29
25	:	75	28	26
0	:	100	20	-
AVALON	:	SQUADRON		
100	:	0	44	-
62.5	:	37.5	35	36
50	:	50	33	33
37.5	:	62.5	31	30
25	:	75	28	28
0	:	100	22	-

* by linear interpolation

TABLE 4: Effect of blending on SDS sedimentation volumes

Composition of blend %			SDS sedimentation volume (ml) Observed	Calculated*
AVALON	:	GALAHAD		
100	:	0	73	-
62.5	:	37.5	64	63
50	:	50	62	59
37.5	:	62.5	59	56
25	:	75	56	53
0	:	100	46	-
AVALON	:	LONGBOW		
100	:	0	73	-
62.5	:	37.5	68	69
50	:	50	66	68
37.5	:	62.5	61	67
25	:	75	54	66
0	:	100	63	-
AVALON	:	SQUADRON		
100	:	0	73	-
62.5	:	37.5	63	60
50	:	50	56	56
37.5	:	62.5	53	52
25	:	75	50	48
0	:	100	39	-

* by linear interpolation

TABLE 5: Effect of blending on SDS sedimentation volumes

Composition of blend %			SDS sedimentation volume (ml) Observed	Calculated*
AVALON	:	LONGBOW		
100	:	0	69	-
83.3	:	16.7	65	67
66.7	:	33.3	63	65
50	:	50	60	63
33.3	:	66.7	60	61
16.7	:	83.3	58	59
0	:	100	57	-
AVALON	:	BROCK		
100	:	0	60	-
83.3	:	16.7	63	62
66.7	:	33.3	57	55
50	:	50	50	48
33.3	:	66.7	44	41
16.7	:	83.3	34	34
0	:	100	27	-
MERCIA	:	LONGBOW		
100	:	0	67	-
83.3	:	16.7	65	64
66.7	:	33.3	63	62
50	:	50	61	62
33.3	:	66.7	60	60
16.7	:	83.3	59	59
0	:	100		-
MERCIA	:	BROCK		
100	:	0	65	-
83.3	:	16.7	61	59
66.7	:	33.3	57	52
50	:	50	51	46
33.3	:	66.7	45	40
16.7	:	83.3	37	33
0	:	100	27	-

* by linear interpolation

Note: samples of Avalon and Longbow not the same as those in Table 4

TABLE 6: Effect of blending on the Chopin Alveograph W value

Composition of blend %			Alveograph W value ($J \times 10^{-4}$) Observed	Calculated*
AVALON	:	GALAHAD		
100	:	0	145	-
62.5	:	37.5	102	122
50	:	50	100	115
37.5	:	62.5	89	107
25	:	75	87	99
0	:	100	84	-
AVALON	:	LONGBOW		
100	:	0	145	-
62.5	:	37.5	114	118
50	:	50	100	109
37.5	:	62.5	100	100
25	:	75	86	91
0	:	100	72	-
AVALON	:	SQUADRON		
100	:	0	145	-
62.5	:	37.5	105	117
50	:	50	95	108
37.5	:	62.5	81	99
25	:	75	78	89
0	:	100	71	-
AVALON	:	SLEJPNER		
100	:	0	122	-
62.5	:	37.5	123	109
50	:	50	128	105
37.5	:	62.5	122	100
25	:	75	118	96
0	:	100	87	-
MERCIA	:	GALAHAD		
100	:	0	172	-
62.5	:	37.5	115	136
50	:	50	117	124
37.5	:	62.5	99	112
25	:	75	95	100
0	:	100	76	-

Table 6 continued

Composition of blend %			Alveograph W value ($J \times 10^{-4}$) Observed	Calculated*
MERCIA	:	LONGBOW		
100	:	0	173	-
62.5	:	37.5	122	133
50	:	50	102	120
37.5	:	62.5	93	107
25	:	75	91	88
0	:	100	67	-
MERCIA	:	SLEJPNER		
100	:	0	173	-
62.5	:	37.5	123	137
50	:	50	122	126
37.5	:	62.5	117	114
25	:	75	103	103
0	:	100	79	-

* by linear interpolation

TABLE 7: SDS volumes (ml) for 1987 harvest wheats

Variety	No. of samples	SDS volume (ml) Mean	Range
Avalon	92	72	51 - 90
Brimstone	15	65	45 - 87
Brock	28	38	30 - 58
Galahad	79	49	30 - 67
Slejpner	14	48	37 - 57

TABLE 8: Regional mean SDS volumes (ml) and protein contents (%) for Avalon and Galahad from the 1987 harvest

	Avalon		Galahad	
	SDS volume (ml)	Protein %	SDS volume (ml)	Protein %
South Western	70.7	11.2	44.4	10.0
South Eastern	71.7	11.9	52.4	10.9
Western & Midlands	74.1	11.3	48.5	10.4
Eastern	72.8	11.7	50.6	10.6
Northern	73.3	11.7	49.6	10.4

TABLE 9: Chopin Alveograph W values for flours milled by Buhler and Quadrumat Junior mills

Wheat type	W value ($J \times 10^{-4}$)	
	Buhler mill	Quadrumat Junior mill
No. 1 CWRS	255	264
Yecora (Spanish)	270	295
Soft mixture (German)	208	212
Avalon	128	144
Rendezvous	144	163
Brock	70	99
Slejpner	66	68
Hornet	51	50

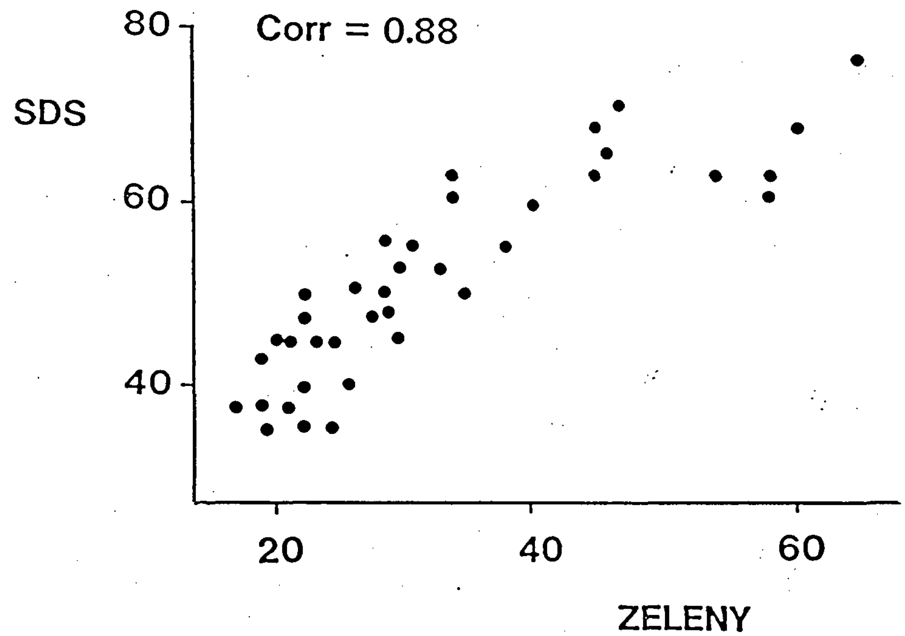

Fig. 1 SDS sedimentation volume (ml) versus Zeleny sedimentation volume (ml) for 40 samples of wheat

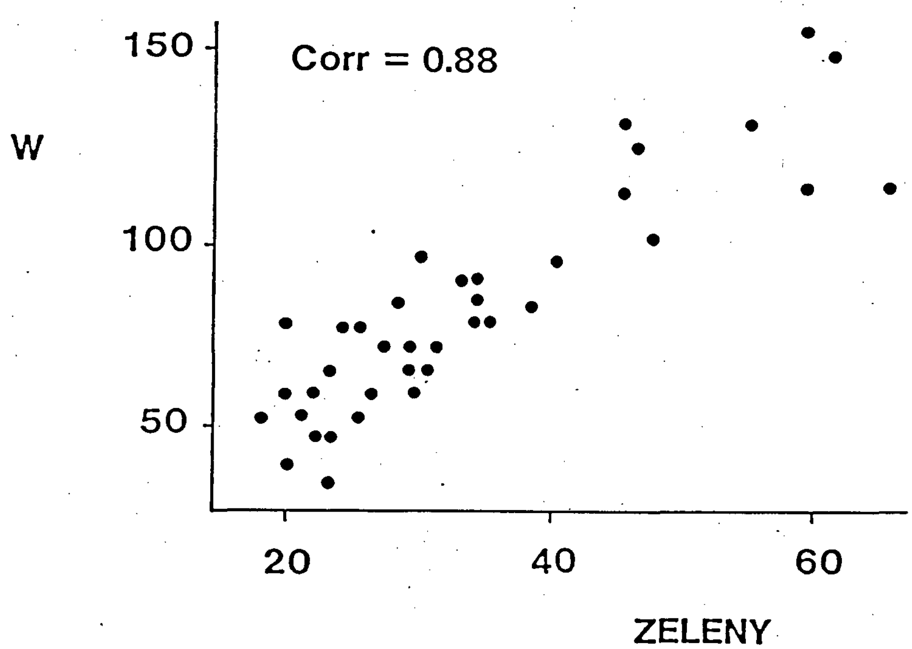

Fig. 2 Alveograph W value (J x 10^{-4}) versus Zeleny sedimentation volume (ml) for 40 samples of wheat

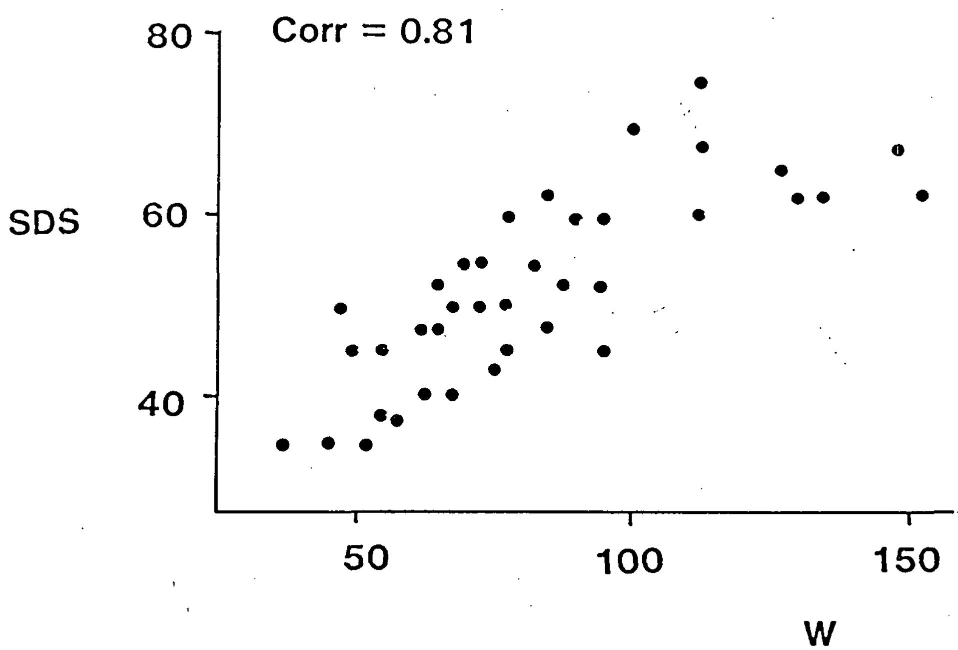

Fig. 3 SDS sedimentation volume (ml) versus Alveograph W value (J x 10^{-4}) for 40 samples of wheat