HGCA

PROJECT REPORT No. 36

THE CHARACTERISTICS AND PROCESSING REQUIREMENTS OF 'EXTRA STRONG' WHEATS

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by

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Final report of a 3 month project which commenced in April 1991. The work was carried out by the Flour Milling and Baking Research Association, Chorleywood, Hertfordshire, WD3 5SH and was supported by a grant of £39,200 from the Home-Grown Cereals Authority (Project No. 0003/1/91).

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ABSTRACT

Two samples of Torfrida (T1 and T2) were compared with Canadian Western Red Springs (CWRS) in analysis, gel-protein and baking performance using several breadmaking processes for white and wholemeal bread. Blends were made with a weak flour to compare the carrying capacity of Torfrida with CWRS. Using standard milling conditions Torfrida flours had higher starch damage than CWRS flour. CWRS had higher protein content and gave larger loaf volumes and higher crumb structure scores than Torfrida and was better able to maintain loaf properties in blends with weak flour. Comparison with CWRS was complicated by differences between the samples of Torfrida. T1 was most similar to CWRS in pattern of baking performance and gel-protein breakdown. T2 required longer mixing for gel-protein breakdown and higher work input than T1 and exhibited some of the characteristics of Fresco, another "extra strong" wheat variety.

OBJECTIVES

To establish whether there are encompassing criteria and characteristics for "extra strong" wheats as a type.

To compare a sample of Canadian Western Red Spring wheat (CWRS) with two samples of Torfrida in baking performance using several breadmaking methods for white and wholemeal bread.

To compare the ability of the strong wheats to carry 'weak' wheat in breadmaking.

To define a molecular basis for processing behaviour by comparing the biochemical analysis of flours, doughs and glutens.

INTRODUCTION

New varieties of extra strong wheat, of which Fresco is the present example, give flours that would require changes in current breadmaking practice to bring out their optimum breadmaking qualities. Specifically, they require higher levels of work input during dough mixing for the Chorleywood Bread Process. Higher levels of work input would lead to excessive temperature rise and longer mixing times, resulting in dough machining problems and lower production throughput compared with current breadmaking wheats. However, extra strong wheats have the potential to fulfil the historical role of North American wheats in being capable of carrying in the grists wheats of inferior quality that would otherwise be unsuitable for breadmaking. Such wheats could lead to complete self-sufficiency in home-grown wheat for breadmaking and have considerable export potential.

Studies into the characteristics and processing requirements of Fresco are the subject of another project, (partly funded with the HGCA levy). Since that work started the variety Torfrida has emerged which is thought also to be of the extra strong type.

This project was designed to identify the performance characteristics of Torfrida compared with those of imported North American wheat. In particular, the project aimed to study its breadmaking ability, mixing and processing requirements and the biochemical mechanisms underlying its breadmaking performance.

MATERIALS AND METHODS

Wheat samples

CWRS wheat, 1989 harvest, was obtained from a UK commercial flour mill.

Torfrida was obtained from a wheat breeder and seed merchant. Two samples, (T1 and T2), 1990 harvest, were used, both pre-basic seed stock.

Weak wheat, used as a 'grist' component for blending with CWRS or Torfrida, was a mixture of Haven (80%) and Beaver (20%), 1990 harvest, from ADAS secondary trial sites. The Haven/Beaver mixture is referred to in this report as 'weak'.

Milling and flour analysis

Wheats were Buhler-milled to produce white and wholemeal flours as described in Appendix 1.

Flours were analysed for moisture, protein, Grade Colour Figure (white flours only), Falling Number, damaged starch, and alpha-amylase. Water absorptions were measured using the Simon Extrusion Meter and a method appropriate to the breadmaking process used (Dodds, 1972). Torfrida and CWRS dough characteristics were compared using the Farinograph.

The flours from each 'strong' wheat, (CWRS, T1 and T2), was used alone and each flour was also blended 2/3 and 1/3 with the 'weak' flour. Thus each strong wheat was used at 100% strong, 2/3 strong with 1/3 weak and 1/3 strong with 2/3 weak, enabling the carrying ability of the strong wheats to be examined and compared.
Falling Number, Gel-protein and water absorption were determined for flour blends.

Breadmaking processes

The Chorleywood Bread Process (CBP), traditional bulk fermentation processes (BFP) and a Spiral mixing method (SMM) were used with each flour and each blend for the production of white and wholemeal bread. The recipes and processing methods are given in Appendix 2.

The standard conditions for breadmaking were varied to explore mixing and processing requirements. Using the CBP, work input during mixing was varied over the range 9 to 17 Wh/kg in increments of 2 Wh/kg. Using BFP, one and three hours of bulk fermentation time were employed, with appropriate adjustment of yeast level. Using SMM, two mixing times were used, 2 min slow followed by 4 or 6 min fast speed. With SMM half of each dough was processed immediately after mixing and the remainder after a rest period of 20 min which is common commercial practice for this process.

Loaf assessment

Loaf volume was measured by seed displacement (Cornford, 1969) and crumb structure scored by expert examination, with high marks awarded for a close and uniform structure of small cells. Crumb structure was photographed in colour for comparisons over the time period of the tests.

Gel-protein measurement

Gel-protein breakdown was measured during mixing using a Simon Majorpin mixing machine. During bread production doughs were sampled from each process immediately before dough scaling. Small pieces of dough were frozen by immersion in liquid nitrogen, then freeze dried and gel-protein determined.

Rheological measurements on gel-protein

The elastic modulus of gel-protein was measured using a Bohlin VOR rheometer. Methods used for gel-protein and rheological measurements are given in Appendix 3.

RESULTS

Flour properties

The analysis and water absorptions of the white strong flours and blends used in the different breadmaking processes are given in Table 1. Those for wholemeal flours are given in Table 2.

The protein contents of CWRS and weak flour blends with CWRS were higher than those of Torfrida. T2 had higher protein content and more starch damage than T1, which could explain the higher water absorption of T2.

Farinograph charts for CWRS, T1 and T2 are given in Fig. 1 together with the figures taken from the charts for development time, stability and degree of softening. In terms of stability and development time the two Torfrida samples were similar to each other but differed markedly from CWRS. However, in degree of softening CWRS showed the least (30BU) and T1 the most (95BU) and T2 intermediate (65BU).

Weak white flour analysis is given in Table 3.

Dough consistency during dough processing

White doughs handled and machined without difficulty. Wholemeal doughs made using the CBP were difficult to handle, particularly from Torfrida blends with weak flour. As a result of the 'stickiness' of these doughs several did not pass smoothly through the final moulding machine, which gave asymmetrical moulded shapes. The poor shaping during moulding could have affected loaf volume and crumb structure. Wholemeal doughs made by BFP and SMM handled and machined without difficulty.

White breadmaking performance

Loaf volume

Loaf volumes obtained using white strong flours and blends are given for each breadmaking process in Table 4.

In all three breadmaking processes loaf volumes from CWRS were significantly larger ($P<0.5$) than from T1 or T2.

In the CBP, increased work input significantly increased loaf volume from T2 but not from T1. T1 gave significantly larger volumes than T2 and both gave increased volume when blended with 1/3 weak flour.

In the BFP, differences in loaf volume between CWRS and Torfrida were much greater than in the CBP. CWRS gave the larger volume. Both 1 and 3 hours

fermentation times gave similar results, T1 gave larger volume than T2 except when T2 was blended with 2/3 weak, when volume was increased further.

In the SMM, CWRS gave larger loaf volumes than Torfrida and more volume than with the other breadmaking processes. T1 gave larger volumes than T2 except when T2 was blended with weak flour when volumes were similar to or greater than those for the comparable blends with T1. When the dough was allowed to rest for an extra 20 minutes after mixing there was generally no overall improvement in volume or change in the pattern of performance between the flours.

Overall, loaf volumes for the strong flours showed clearly that CWRS had substantially better performance than T1 or T2 and greater carrying ability when blended with the weak flour. However, the loaf volumes also showed that there were important differences in breadmaking performance of T1 compared with T2. T2 showed a response to increased work input in the CBP, with increase in loaf volume. In blends with weak flour, T2 gave larger loaf volumes at all work input levels, most marked at low input levels.

Crumb structure of white loaves

Crumb structure scores of white loaves are shown in Table 5. Loaves from CWRS had higher or equal crumb scores in every comparison with Torfrida. T1 had higher scores than T2 in all breadmaking processes. When blended with weak flour, T2 generally had scores equal to or higher than T1.

In the CBP, scores for 100% T1 decreased with increasing work input, whereas for T2 they increased, a further indication that T1 and T2 had different performance characteristics to each other.

Wholemeal breadmaking performance

Loaf volume

Loaf volumes obtained using wholemeal strong flours and blends are given for each breadmaking process in Table 6.

For all processes and blends, loaf volume was largest from CWRS.

In the CBP T2 gave significantly larger volumes than T1. There was no significant effect of work input for the strong flours. Loaf volume decreased significantly for increasing work input for the blends and this was most marked for the blend with the highest proportion of weak flour.

Crumb structure of wholemeal loaves

Crumb structure scores of wholemeal loaves are shown in Table 7. Scores showed clearly that CWRS alone and in blends with weak flour gave better crumb scores than Torfrida. Differences in scores between T1 and T2 were generally small, and scores tended to be higher for T2 in the CBP. Scores were very low when blends with Torfrida included 2/3 weak flour.

Gel-protein breakdown when mixing in Majorpin machine

The measurements of gel-protein breakdown during mixing of doughs using the strong white flours in the Majorpin machine, are given in Table 8. Fresco results, from unpublished work by Pritchard, are included for comparison. Fig 2 illustrates these results showing that gel-protein breakdown during mixing for T2 was significantly less than for CWRS or T1 ($p<0.01$). The rate and extent of breakdown for T2 was similar to that found previously with Fresco, a variety known to have "extra strong" gluten characteristics.

Gel-protein breakdown in doughs used for breadmaking

White flours and doughs

Compared with flour gel-protein, there were large decreases in gel-protein after mixing, as can be seen from Table 9. The extent of the decrease or 'breakdown' was affected by the intensity of mechanical action during mixing which differed between the mixing machines appropriate for each breadmaking process. After mixing using the CBP and SMM, gel-protein breakdown was substantially greater than after mixing for BFP. The extent of breakdown of gel protein was proportionally greater in the flour blends than for the strong flours themselves when using BFP.

During bulk dough fermentation, 1 and 3h for BFP and 20 min with SMM, there were some varietal differences, but in general gel-protein increased, in some cases to levels close to the levels found in the original flour. This is in

agreement with the work of Graveland et al (1979) who showed that gel-protein reaggregated after mixing.

Wholemeal flours and doughs

Gel-protein of the wholemeal flours and doughs are shown in Table 10. Gel-protein was lower than in the white flours and doughs and differences between doughs from different processes were much less clearly defined. In most cases gel-protein was fully broken down after mixing and reaggregation occurred to a much lesser extent than in white flour.

Rheology of gel-protein

Table 11 shows the elastic modulus of the gel-protein for the strong flours. CWRS and T1 gave similar readings. T2 was clearly different with lower rates of change in both modulus and viscosity.

DISCUSSION

Torfrida was only available as seed stock. Two samples were obtained, from the 1990 harvest grown on different sites, where they could have been subjected to different husbandry. The difference in husbandry was not expected to influence the variety character, milling or baking performance. However, this work has shown that the samples of Torfrida not only responded differently during milling and baking but were also different biochemically in relation to gel-protein breakdown. Examination by gel-electrophoresis confirmed that both samples were Torfrida.

Milling and flour properties

The standard milling procedure customarily used in tests of this sort resulted in differences in flour properties between CWRS, the two Torfrida samples and the weak wheat used for blending. Those differences could have been minimised had milling been optimised for each wheat. In future studies of this type milling procedure should be given greater consideration. The differences created by standard milling gave some exceptional flour properties which had an influence on baking performance. For instance, starch damage levels of both Torfrida samples were much higher than for CWRS or the weak wheat, and T2 had higher starch damage level than T1. Comparisons between the flours in baking performance

were made more complicated because of this, in that the higher water absorption required of flour with high starch damage is known adversely to affect loaf volume and crumb structure (Collins, 1970). The blending of high starch damage flour with one of lower starch damage, even when there is a small decrease in protein content, can improve baking performance. In the results, these effects can be seen, particularly in white breadmaking where the addition of weak flour to T2 improved its baking performance.

Flour protein content of CWRS was much higher than that of the Torfrida samples. Had the wheats milled to the same starch damage levels, the differences in protein contents alone would have been expected to tip baking performance in favour of CWRS. The beneficial effects of the higher protein content of CWRS, coupled with a reasonable starch damage for its type, on loaf volume and crumb structure scores were clear in the strong flour results.

The Farinograph data, together with supporting evidence from the Brabender extensograph (PBIC - unpublished results) show similarities between the two Torfrida samples.

The baking test results presented in this report, however, clearly differentiate between the two samples. It must be concluded that rheological instruments of the Farinograph and Extensograph type do not fully represent the performance of flour in a baking test, particularly where high work-input flours are being assessed.

Baking performance

CWRS gave higher loaf volumes and scores than either of the Torfrida samples. The addition of weak flour to CWRS had a more or less predictable effect and loaf volumes and scores decreased slightly. Torfrida samples showed different responses to mixing and blending compared with CWRS and, unexpectedly, to each other. Some of the differences in response could be explained by the flour properties, as discussed above, but others required further consideration. Compared with CWRS, differences in response to mixing and blending were most marked with T2. As work input in the CBP was increased loaf properties from T2 tended to improve, whereas from T1 they remained the same. The results are in contrast to those obtained by Plant Breeding International of Cambridge (PBIC-unpublished results), which showed that the loaf volume ot T1 increased in a similar way to T2 with increasing work input. The reason for this discrepancy

is not understood but may be caused by differences in baking methodology; in particular, we used fungal alpha-amylase and ascorbic acid improvers whereas PBIC retain a blend of ascorbic acid and potassium bromate without fungal alpha-amylase. In white flour blends, both T1 and T2 gave improved performance when blended with 1/3 weak flour, and for T2 also when blended with 2/3 weak flour. Not all of these improvements could be explained by a reduction in the level of starch damage resulting from blending.

Breadmaking results showed clearly that CWRS had a better baking performance than either of the Torfrida samples, and greater ability to carry weak flour. Allowing for the protein content differences, The performance of T1 was most closely matched to CWRS but T2 was clearly different.

Blending potential

The Torfrida samples tested were clearly different to each other and to CWRS. However, both Torfrida samples were successful in carrying weak flour in that at up to 2/3 weak flour inclusions the white bread produced was satisfactory.

Biochemical analysis

Studies of the glutenin fraction of wheat protein have shown that the fraction insoluble in Sodium dodecyl sulphate solution, known as gel-protein or glutenin 1 (Graveland et al, 1979) can be used as a measure of baking quality. The results of these tests revealed differences in gel-protein between T1 and T2 which supported their baking behaviour. Gel-protein breakdown during mixing in a Majorpin showed that CWRS and T1 were similar to each other but that T2 was different to T1 and similar to Fresco (see Fig 2). The plot of gel-protein level against mixing time showed that T2 required more mixing to break down its gel-protein than T1 or CWRS. The mixing time requirement to break down the gel-protein of T2 was similar to that required for Fresco.

These unexpected differences in the breakdown of gel-protein between T1 and T2 in relation to CWRS were also clear in the elastic modulus and viscosity reported in Table 11, and illustrated in Figs 3 and 4 respectively. The significance of these data is as yet unknown and forms a part of other studies in progress on the glutenin fraction of wheat protein. As a consequence of the differences between the two samples of Torfrida examined it was not possible to establish encompassing criteria and characteristics for "extra strong" wheats as a type nor

to form a definitive judgement about the ability of Torfrida to fulfill the traditional role of CWRS wheat in the UK bread grist.

CONCLUSIONS

1. Encompassing criteria and characteristics for "extra strong" wheats as a type were not established for the samples of Torfrida tested. However, Farinograph curves showed that mixing characteristics in that machine were different to CWRS and in the experience of PBIC these are typical of those of "extra strong" wheats.

2. The samples of Torfrida used had different baking performance and gel-protein breakdown properties. However, both Torfrida samples were able to carry weak flour in the making of white bread by the CBP. Loaf volumes of both samples were greater for Torfrida/weak flour blends at nearly all work inputs than for the undiluted Torfrida flour. In this respect they may be differentiated from normal varieties such as Mercia.

3. Compared with CWRS Torfrida samples generally gave lower loaf volumes and crumb scores from three different breadmaking processes. The carrying power of Torfrida was much lower than the CWRS flour, due in part to its lower protein content and different milling characteristics leading to higher damaged starch levels.

4. Biochemical analysis of gel-protein from flours and doughs confirmed that the Torfrida samples differed from each other. Torfrida 1 was similar to CWRS and Torfrida 2 exhibited some "extra strong" characteristics similar to those of Fresco.

RECOMMENDATIONS

This study on "extra strong" wheat identified differences between the two samples of Torfrida which were used. Both samples were obtained from PBIC and were grown as a seed crop, where uncontaminated seed harvested from non-lodged plants was the first priority and this explains why their protein contents were on the low side. The quality differences observed in our tests were of a kind which were not revealed by the procedures used by the breeder and the varietal and seed testing authorities. This emphasises the need for detailed information on the baking performance of new wheat varieties to be obtained prior to commercial

use. Further work needs to be undertaken with seed from crops that were managed with breadmaking in mind.

Canadian wheat (or dried gluten) is primarily used in wholemeal grists to fortify breadmaking quality wheats from the UK and Europe, (not the weak flour used in our tests). Further experiments should be undertaken to determine if Torfrida grain, (or other "extra strong" wheat), with adequate levels of protein can partially replace the current contribution made by Canadian wheat (or dried gluten) in our wholemeal bread, with concomitant economic advantage.

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TABLE 1

White strong flours and blends analysis

	100% strong			Blends 2/3 strong:1/3 weak			1/3 strong:2/3 weak		
	CWRS	T1	T2	CWRS	T1	T2	CWRS	T1	T2
FMBRA ref. No.	E942	E940	E941	NA	NA	NA	NA	NA	NA
Moisture % (130°C for 1.5h)	14.7	14.4	13.7	NA	NA	NA	NA	NA	NA
Protein % (N x 5.7, as is)	14.4	9.8	10.3	12.4	9.3	9.6	10.8	8.9	9.0
Grade Col. Fig . (Kent-Jones & Martin)	-0.6	1.3	1.4	NA	NA	NA	NA	NA	NA
Falling No. s (7g)	458	374	408	373	349	329	337	311	315
Damaged starch (Farrand Units)	26	40	49	26	35	41	25	30	33
Alpha-amylase (Farrand Units)	2	2	1	NA	NA	NA	NA	NA	NA
Water abs. % (Simon Ex. Met.)									
10 min	58.9	60.4	63.9	57.4	56.7	60.7	55.0	54.3	55.4
1 h	62.1	61.1	64.6	58.9	59.3	61.4	54.3	56.4	57.1
3 h (yeasted)	57.5	58.6	61.1	54.6	54.6	57.1	51.8	51.8	53.2
Gel-protein (g/5g flour)	11.2	8.4	9.3	8.1	6.7	7.6	6.6	5.2	5.3

NA = not available by analysis

Underlined figures were calculated from the strong and weak flour analysis

TABLE 2

Wholemeal strong flours and blends analysis

	100% strong			Blends 2/3 strong:1/3 weak			1/3 strong:2/3 weak		
	CWRS	T1	T2	CWRS	T1	T2	CWRS	T1	T2
FMBRA ref. No.	E807	E805	E806	NA	NA	NA	NA	NA	NA
Moisture % (130°C for 1.5h)	13.8	13.4	12.8	NA	NA	NA	NA	NA	NA
Protein % (N x 5.7, as is)	15.0	10.6	11.2	NA	NA	NA	NA	NA	NA
Falling No. s (7g)	413	381	378	355	322	337	309	297	294
Damaged starch (Farrand Units)	25	46	48	NA	NA	NA	NA	NA	NA
Alpha-amylase (Farrand Units)	2	1	0	NA	NA	NA	NA	NA	NA
Water abs. % (Simon Ex. Met.)									
10 min	65.4	66.8	70.0	62.1	64.6	67.9	62.1	61.1	64.6
1 h	65.0	64.6	69.6	61.7	63.2	65.7	60.4	61.4	62.1
3 h (yeasted)	63.6	64.3	68.2	62.9	60.8	66.4	61.1	60.4	60.7
Gel-protein (g/5g flour)	9.7	6.7	7.8	7.5	5.6	6.1	5.1	4.6	4.0

NA = not available by analysis

TABLE 3

Weak flour analysis

FMBRA ref. No.	E995
Moisture (130°C for 1.5h) %	14.6
Protein (N x 5.7, as is) %	8.4
Grade Colour Figure (Kent-Jones & Martin)	0.2
Falling No. (7g) s	294
Damaged starch (Farrand Units)	25
Alpha-amylase (Farrand Units)	2
Water absorption 10 min % (Simon Extrusion Meter)	51.1
Gel-protein (g/5g flour)	4.0

Wholemeal weak flour analysis was not carried out

TABLE 4

Loaf volume: white strong flours and blends compared in breadmaking (ml)

	100% strong			Blends					
				2/3 strong:1/3 weak			1/3 strong:2/3 weak		
	CWRS	T1	T2	CWRS	T1	T2	CWRS	T1	T2
CBP									
Wh/kg									
9	1755	1549	1462	1753	1577	1619	1665	1583	1611
11	1772	1570	1492	1761	1641	1621	1731	1581	1603
13	1816	1574	1487	1759	1582	1643	1700	1619	1574
15	1786	1549	1503	1782	1613	1611	1750	1598	1573
17	1770	1573	1568	1798	1574	1603	1693	1556	1622
BFP									
1 h	1706	1375	1269	1706	1491	1380	1705	1496	1496
3 h	1722	1346	1290	1710	1479	1432	1598	1425	1455
SMM									
0 min fermentation									
Mixing									
2/4	1849	1625	1473	1722	1600	1628	1703	1572	1612
2/6	1826	1629	1548	1769	1594	1623	1720	1568	1584
20 min fermentation									
Mixing									
2/4	1709	1580	1419	1800	1583	1599	1707	1580	1587
2/6	1754	1517	1441	1698	1532	1555	1662	1600	1607

TABLE 5

Crumb structure score: white strong flours and blends compared in breadmaking (max 10 points)

	100% strong			Blends					
				2/3 strong:1/3 weak			1/3 strong:2/3 weak		
	CWRS	T1	T2	CWRS	T1	T2	CWRS	T1	T2
CBP									
Wh/kg									
9	9	9	5	9	6	8	8	5	8
11	9	8	5	9	6	8	8	5	7
13	8	7	5	9	6	8	6	5	6
15	9	6	6	8	5	7	6	5	6
17	9	6	7	9	5	7	7	5	6
BFP									
1 h	8	5	3	8	5	5	8	7	7
3 h	9	5	3	9	5	5	7	5	5
SMM									
0 min fermentation									
Mixing									
2/4	9	8	5	8	6	6	8	5	6
2/6	8	7	6	7	7	7	7	5	6
20 min fermentation									
Mixing									
2/4	9	8	6	9	8	8	8	8	7
2/6	9	6	5	8	7	6	8	6	6

TABLE 6

Loaf volume: wholemeal strong flours and blends compared in breadmaking (ml)

	100% strong			Blends					
				2/3 strong:1/3 weak			1/3 strong:2/3 weak		
	CWRS	T1	T2	CWRS	T1	T2	CWRS	T1	T2
CBP									
Wh/kg									
9	1395	1225	1197	1360	1244	1231	1234	1149	1189
11	1398	1162	1264	1300	1212	1211	1240	1119	1133
13	1365	1188	1281	1290	1166	1202	1150	1051	1123
15	1337	1176	1214	1276	1172	1188	1162	1009	1050
17	1387	1181	1218	1281	1123	1198	1133	997	1032
BFP									
1 h	1327	1163	1143	1350	1268	1182	1276	1201	1199
3 h	1301	1149	1091	1300	1117	1098	1281	1154	1149
SMM									
0 min fermentation									
Mixing									
2/4	1309	1179	1105	1380	1229	1261	1250	1226	1221
2/6	1418	1256	1249	1306	1217	1273	1261	1177	1234
20 min fermentation									
Mixing									
2/4	1406	1220	1099	1398	1252	1236	1319	1253	1245
2/6	1414	1249	1231	1351	1262	1247	1301	1185	1256

TABLE 7

Crumb structure score: wholemeal strong flours and blends compared in breadmaking (max 10 points)

	100% strong			Blends					
				2/3 strong:1/3 weak			1/3 strong:2/3 weak		
	CWRS	T1	T2	CWRS	T1	T2	CWRS	T1	T2
CBP									
Wh/kg									
9	8	6	6	8	4	6	5	2	4
11	7	5	7	8	4	6	4	1	3
13	7	5	7	8	3	5	4	1	2
15	6	4	7	6	2	5	3	1	2
17	7	5	7	6	2	5	2	1	1
BFP									
1 h	8	4	4	8	8	5	6	3	5
3 h	8	5	3	8	4	2	5	3	4
SMM									
0 min fermentation									
Mixing									
2/4	8	6	4	6	5	4	5	4	3
2/6	7	6	5	6	5	7	4	2	4
20 min fermentation									
Mixing									
2/4	8	5	3	7	4	6	5	3	5
2/6	7	5	5	5	3	3	3	2	3

TABLE 8

Gel-protein breakdown of white flours from CWRS, Torfrida and Fresco after mixing using a Simon Majorpin machine, g/5g

	Gel-protein breakdown			
	CWRS	T1	T2	Fresco
Flour gel-protein	11.24	8.39	9.29	10.90
Dough gel-protein				
Mixing time, min				
1	9.40	7.00	8.79	8.31
2	7.95	5.89	8.09	7.98
3	5.89	5.43	7.81	8.14
4	5.80	4.39	7.32	7.48
5	3.88	4.58	7.31	NA
6	1.91	3.61	7.33	NA
7	NA	NA	NA	7.30
8	1.36	1.66	7.29	NA
10	2.30	1.53	6.65	NA
12	1.12	1.69	5.74	NA

NA = not available

TABLE 9

Gel-protein breakdown after mixing and fermentation for white strong flours and blends, g/5g

	100% strong			Blends					
				2/3 strong:1/3 weak			1/3 strong:2/3 weak		
	CWRS	T1	T2	CWRS	T1	T2	CWRS	T1	T2
Flour gel-prot.	11.20	8.40	9.30	8.10	6.70	7.60	6.60	5.20	5.30
CBP, Wh/kg									
9	0.52	0.56	1.03	0.27	0.20	0.26	0.34	0.18	0.26
11	0.26	0.36	0.40	0.34	0.23	0.18	0.34	0.26	0.28
13	0.67	0.54	0.57	0.34	0.18	0.21	0.33	0.40	0.25
15	0.40	0.34	0.31	0.46	0.42	0.27	0.32	0.25	0.34
17	0.31	0.54	0.34	0.30	0.30	0.29	0.35	0.29	0.30
1 h BFP									
End of mixing	6.06	2.35	8.90	1.90	0.82	4.24	0.92	0.39	0.50
After 1 h	4.86	2.75	7.62	1.90	1.79	4.44	1.33	0.88	1.27
3 h BFP									
End of mixing	8.16	2.78	8.62	3.24	0.68	3.05	0.62	0.62	0.37
After 3 h	6.40	3.13	10.22	4.00	2.04	5.31	2.29	1.40	1.73
SMM 2/4 mixing									
End of mixing	0.80	0.37	1.80	0.72	0.55	0.56	0.43	0.44	0.44
After 20 min	4.23	1.03	7.32	1.80	1.03	2.10	0.64	0.59	0.49
SMM 2/6 mixing									
End of mixing	0.52	0.73	0.81	0.42	0.65	0.44	0.57	0.83	0.60
After 20 min	4.04	0.68	2.55	1.97	1.00	1.03	0.72	2.54	0.48

TABLE 10

Gel-protein breakdown after mixing and fermentation for wholemeal strong flours and blends, g/5g

				Blends					
	100% strong			2/3 strong:1/3 weak			1/3 strong:2/3 weak		
	CWRS	T1	T2	CWRS	T1	T2	CWRS	T1	T2
Flour gel-prot.	9.75	6.65	7.81	7.5	5.6	6.1	5.1	4.6	4.0
CBP									
Wh/kg									
9	0.30	0.24	0.14	0.37	0.23	0.47	0.27	0.11	0.30
11	0.27	0.17	0.29	0.30	0.15	0.28	0.33	0.11	0.22
13	0.23	0.15	0.19	0.24	0.32	0.24	0.22	0.13	0.21
15	0.28	0.14	0.20	0.87	0.17	0.46	0.25	0.12	0.30
17	0.55	0.20	0.45	0.28	0.31	0.38	0.32	0.37	0.36
1 h BFP									
End of mixing	0.38	0.84	2.04	0.48	0.44	0.75	0.33	0.80	0.47
After 1 h	0.39	0.84	0.84	0.48	0.32	0.48	0.36	0.59	0.27
3 h BFP									
End of mixing	0.91	0.76	4.72	0.49	0.50	1.26	0.40	0.37	0.30
After 3 h	0.75	0.69	1.60	0.49	0.60	0.52	0.35	0.24	0.30
SMM 2/4 mixing									
End of mixing	0.44	0.48	2.11	0.24	0.21	0.39	0.23	0.24	0.18
After 20 min	0.39	0.93	3.73	0.32	0.46	0.51	0.39	0.32	0.30
SMM 2/6 mixing									
End of mixing	0.40	0.21	0.49	0.30	0.28	0.21	0.23	0.18	0.28
After 20 min	0.38	0.20	1.61	0.39	0.30	0.40	NA	0.32	0.17

NA = not available

TABLE 11

Rheological characteristics of gel-protein, Bohlin rheometer

	Elastic modulus G 1 (Pa)		
	CWRS	T1	T2
Flour gel-protein	50.3	52.0	40.5
Dough Mixing time, min			
1	34.6	28.3	NA
2	21.8	24.4	30.3
3	12.8	13.1	NA
4	7.0	9.0	16.2
5	5.9	NA	NA
6	NA	NA	8.5
8	NA	NA	7.0
10	NA	NA	2.6
	Viscosity from Bohlin (Pas)		
	CWRS	T1	T2
Flour gel-protein	4.32	4.48	4.60
Dough Mixing time, min			
1	2.32	2.03	NA
2	1.58	1.95	2.41
3	1.00	1.19	NA
4	0.60	0.79	1.24
5	0.59	NA	NA
6	NA	NA	0.75
8	NA	NA	0.61
10	NA	NA	0.30

go3450

APPENDIX 1

Wheat storage and milling procedure

Storage

Wheat samples were checked to ensure moisture contents were below 14.5% before storage at ambient temperature and humidity of 53% until required for milling.

Conditioning and milling

18 to 25 hours before milling samples were conditioned by adjusting moisture content to 15.5%.

Milling was carried out using a laboratory Buhler mill, model 202, in a room at controlled temperature of 20^{o}C and a relative humidity of 65%. First and third roll gaps were set at 0.6 and 0.4 mm and first and third reduction roll gaps 0.3 and 0.2 mm respectively. The scalpers from the first and second reduction roll sifters were removed. These roll gap settings and the sifter cloth sizes employed are such that the flour meets requirements of EEC Regulation No. 1628/77 (Gundelach 1977). A feed setting of 2 was used during milling to obtain a flow rate of approximately 6kg/h.

Bran and offal were retreated twice on a Buhler 302 laboratory impact finisher.

Using different wheats these milling conditions have previously given flours with commercial levels of starch damage and extraction (Osborne et al, 1991).

Extraction rate was calculated on a total product basis, with a requirement that 98.0% of feed was recovered from the mill.

For wholemeal flours the bran was ground in a Christy Norris 8" laboratory hammer mill with 1.6 mm screen.

All flours were blended for 30 minutes in a ribbon blender to ensure uniformity before entry into the test programme.

APPENDIX 2

Recipes and processing for white and wholemeal breadmaking

	% of flour weight			
	CBP	1h	3h	SMM
Flour	100	100	100	100
Yeast (compressed)	2.5	2.5	1.5	2.5
Salt	2.0	2.0	2.0	2.0
Water	As determined by Simon Extrusion Meter			
Fat (Ambrex, slip point c.45°C)	1.0	1.0	1.0	1.0
Ascorbic acid	0.01	0.002	0.0015	0.0125
Addition of fungal alpha-amylase (FU)	80	5	15	80

Fat addition was increased to 2.0% for all wholemeal recipes.

Dough processing:

Differences between doughs

Flour weight of mix White g	1400	1400	1400	2500
Wholemeal g	1400	1400	1400	3000
Mixing machine	Morton	Artofex	Artofex	Spiral
Beater speed, rev/min	300	47 lifts	47 lifts	sl/fast 130/260
Work input or time	9-17Wh/kg	10 min	10 min	sl 2min f4 or 6
Dough temperature +/- 1° C	30.5	27	27	30.5
Bulk fermentation temp °C	NA	27	27	27

All doughs

Scaling weight g	454
First moulding	Cylinder using Mono moulder
First proof	10 min at ambient temperature
Final moulding	Single-piece cylinder using Sorensen
Pan size	Top 160mm x 98mm, 83mm deep
Shape	Unlidded
Proving conditions	43°C humidity to prevent skinning
Proving height	10 cm
Baking temperature	244°C
Oven type	Direct gas-fired reel
Baking time	25 min
Baking humidity	No steam injected
Cooling	Open rack at room temperature
Storage	Closed cupboard overnight at 21°C

NA = not applicable

APPENDIX 3

Estimation of gel-protein (Glutenin 1) from flour and dough and its rheological assessment

Laboratory assessment of gel-protein breakdown during mixing

280 g flour + 5 g sodium chloride and water level appropriate for flour water absorption (Simon Extrusion Meter 10 min method) were mixed in a Simon Majorpin. 20 g samples of dough were removed after time intervals up to 12 min, immediately frozen and subsequently freeze-dried.

Bread dough assessment of gel-protein

Immediately after mixing in each of the machines used for breadmaking, see Appendix 2, a sample of dough was frozen and subsequently freeze-dried. For BFP and SMM doughs were also sampled after bulk fermentation periods.

Processing of freeze dried dough

Freeze-dried dough was milled to pass through a 250 micron sieve before defatting for one hour with 40:60 petroleum ether, (20 g to 50 ml). Flours were also defatted.

5 g of defatted dough, or flour, were sprinkled into 90 ml 1.5% sodium dodecyl-sulphate solution at 10°C with magnetic stirring. After 10 minutes extraction time under gentle agitation, the mixture was centrifuged at 63,000 x g for 40 minutes.

Gel-protein was determined by the weight of the gel layer between the supernatant SDS soluble material and the starch pellet. The weight was recorded as weight of gel per 5 g flour or dough.

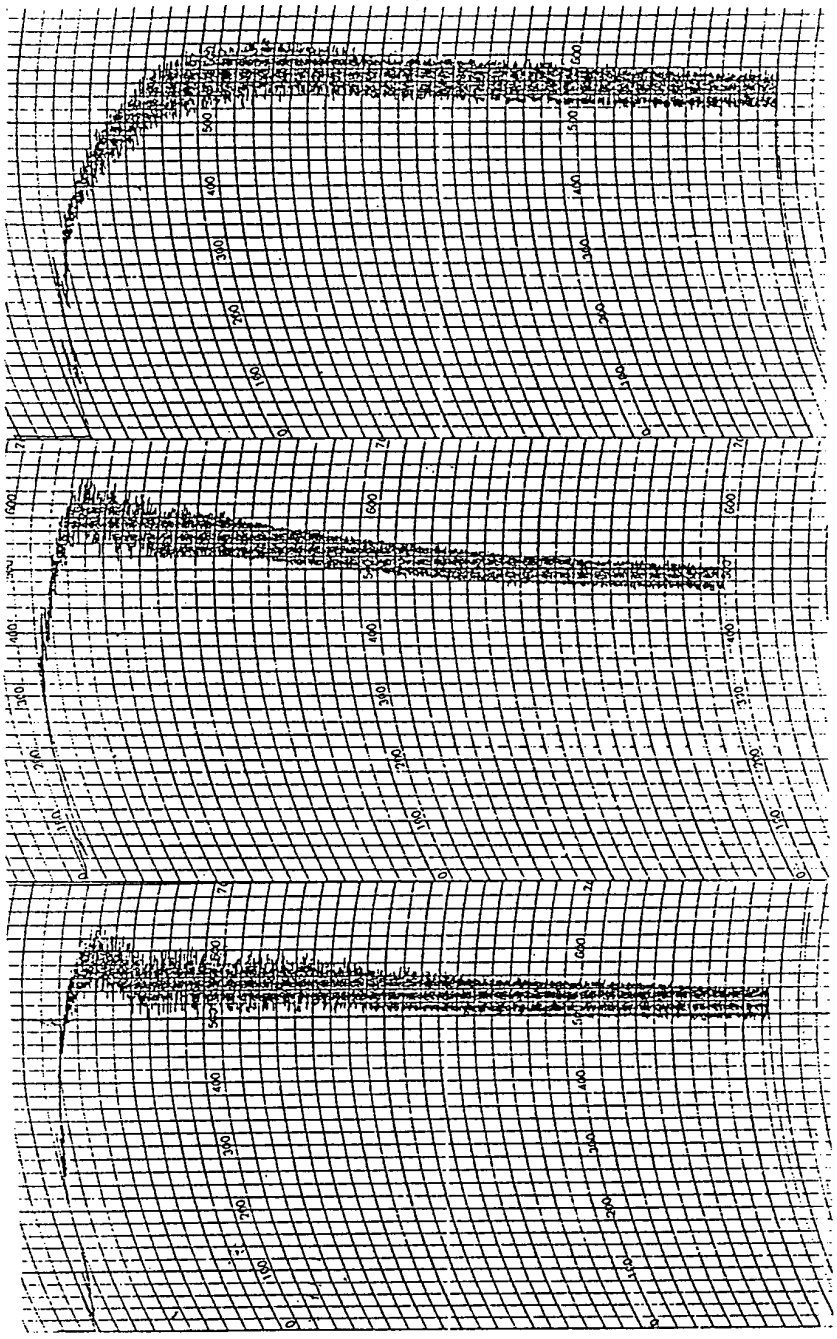
The method is based upon Graveland, et al, 1979.

Rheological assessment of gel-protein

Laboratory prepared gel-protein from the Majorpin mixer was separated from the residue starch and supernatant SDS solution and evaluated by oscillatory stress rheometry on the Bohlin VOR rheometer. A frequency sweep from 0.1 to 20 Hz was carried out. Data at 1 Hz for elastic modulus (G^1) and viscosity are given in Table 11. For CWRS and T1 samples there was insufficient gel-protein for rheological testing for times above 5 minutes mixing, due to the rapid breakdown during mixing.

Fig. 1

Farinograph curves for CWRS and Torfrida flours



Farinograph curve parameters

	development time (min)	Stability (min)	Degree of Softening (BU)
CWRS	6.5	11.0	30
T1	2.0	4.5	95
T2	2.0	6.5	65

Fig. 2

Reduction in gel-protein during mixing

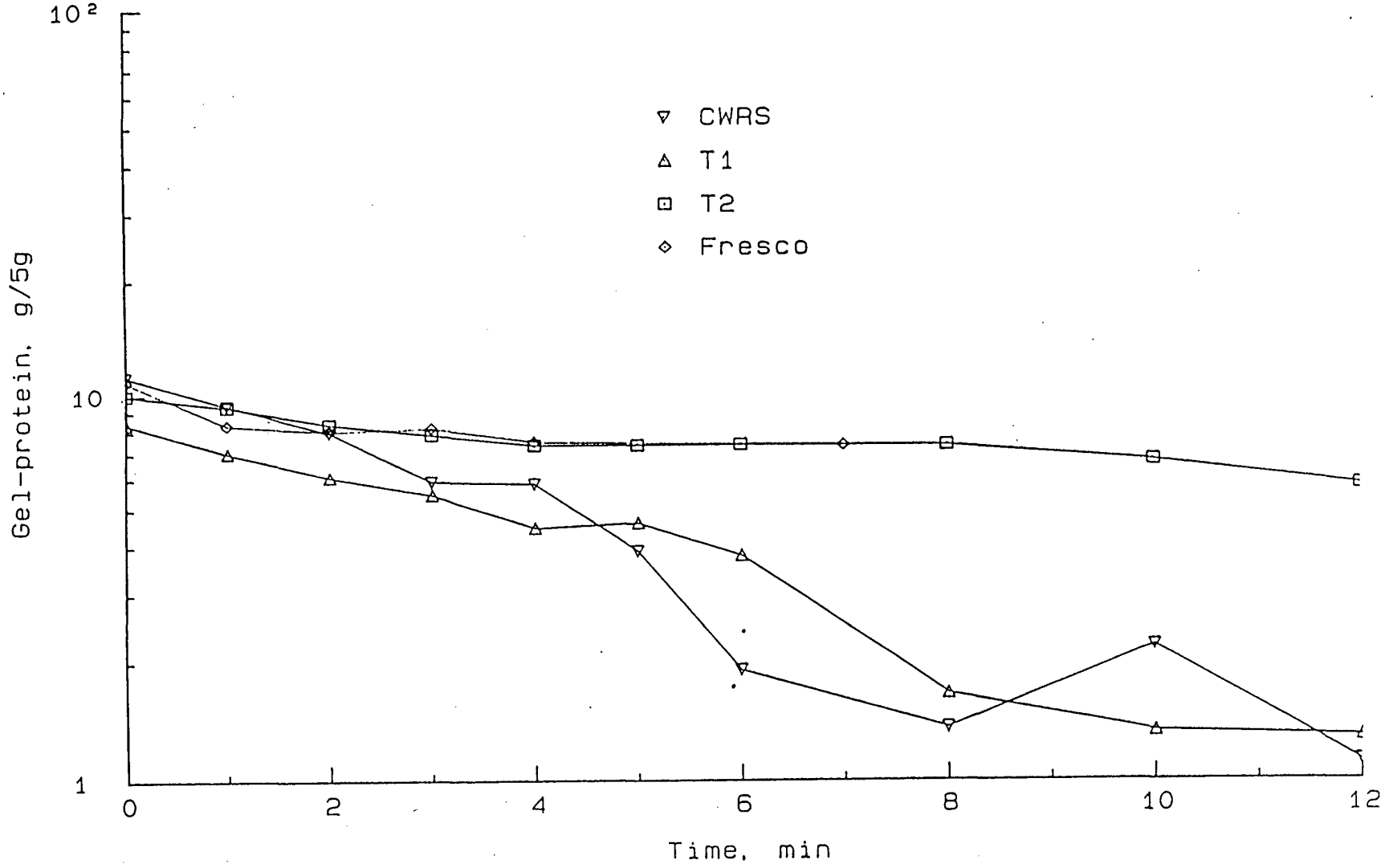
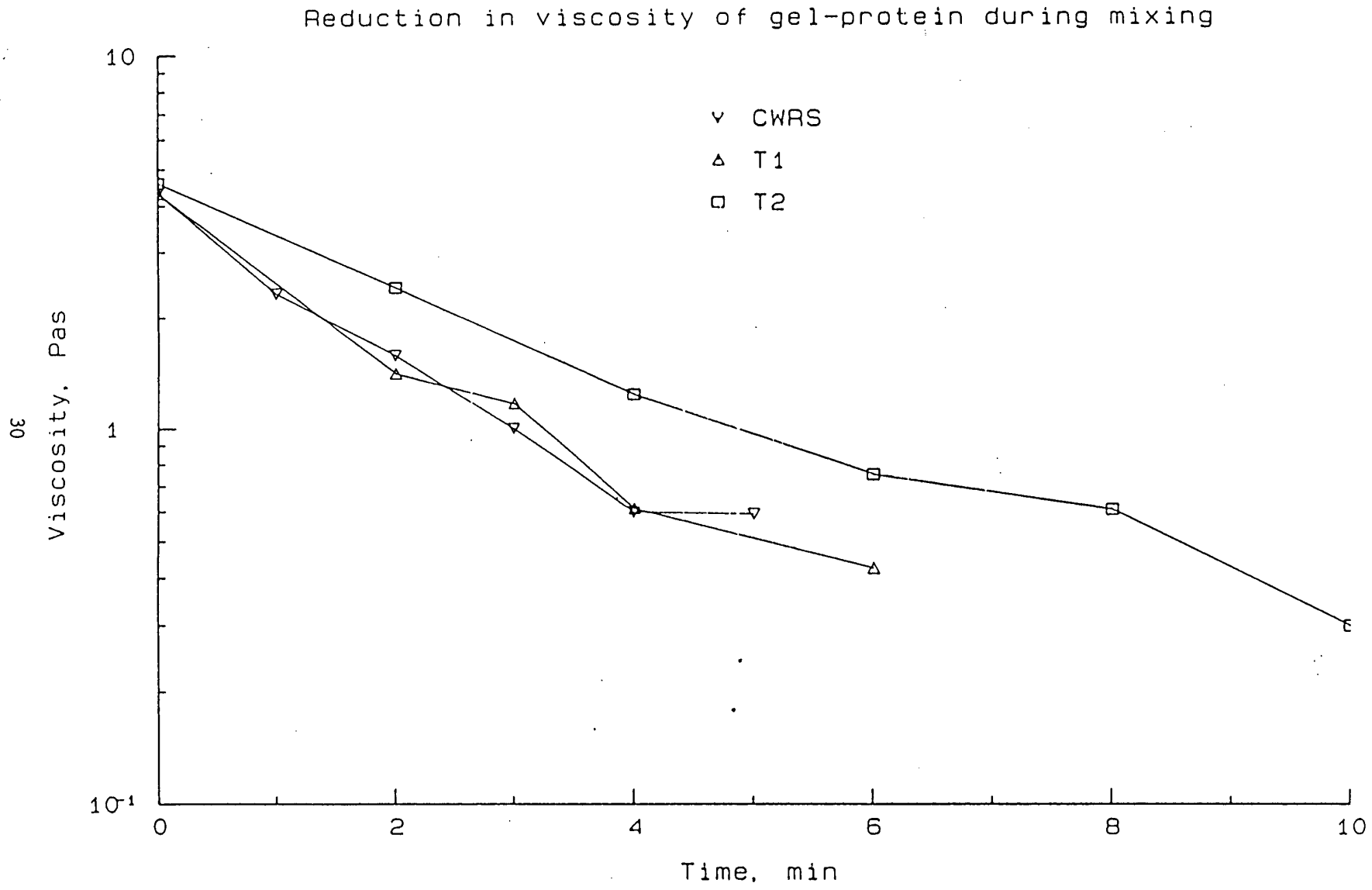


Fig. 3

Reduction in elastic modulus of gel-protein during mixing

Fig. 4


Reduction in viscosity of gel-protein during mixing
CWRS
T1
T2
Viscosity, Pas
10
1
10^{-1}
0
2
4
6
8
10
Time, min