Apparent Dough Stickiness of Selected 1BL/1RS Translocated Soft Wheat Flours

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ABSTRACT

A new method, called the Schwarzlaff-Shephard Dough Stripping Method, was used to determine apparent dough stickiness in seven 1BL/1RS translocated soft, red, winter wheat (SRWW) lines and five SRWW lines without the translocation. Pairwise comparisons of all 1BL/1RS versus all non-1BL/1RS lines indicated that doughs made from the 1BL/1RS lines were significantly stickier, on average, than doughs made from the non-1BL/1RS lines. However, there was no significant difference in the apparent dough stickiness of one set of sister lines that shared a similar pedigree, 1BL/1RS line VA 93-54-18 versus its non-1BL/1RS sister line VA 94-54-21. Another 1BL/1RS line, VA 92-52-22, ranked last in apparent dough stickiness and was significantly less sticky than two non-1BL/1RS lines. VA 92-52-22 has a distinctly different pedigree from the other 1BL/1RS lines that we evaluated. These findings suggest that there are strong genotypic effects on dough stickiness, making it possible to develop non-sticky cultivars of 1BL/1RS SRWW.

The 1BL/1RS hard and soft wheat lines originated by way of reciprocal translocation events, where the short arm of the 1B chromosome of wheat (*Triticum aestivum* L.) has been replaced by the short arm of the 1R chromosome of rye (*Secale cereale* L.) (Mettin et al 1973). Interest in 1BL/1RS wheat stems primarily from the fact that the short arm of the 1R rye chromosome carries with it linked resistance genes to four major wheat diseases: powdery mildew, stripe rust, leaf rust, and stem rust (Dhaliwal et al 1990; Singh et al 1990). The 1BL/1RS translocation has also been associated with high grain yields (Villareal et al 1991; Moreno-Sevilla et al 1995). This combination of disease resistance and high yields has been attractive to plant breeders and to growers.

However, some of the initial enthusiasm for 1BL/1RS wheat was subdued by a report that a translocated 1BL/1RS hard wheat line from Australia produced doughs that were sticky and broke down quickly when tested in a resistograph (Martin and Stewart 1986). This was followed by other reports of significant increases in dough stickiness of hard wheat due to the presence of the 1BL/1RS translocation (Dhaliwal et al 1990; van Lill et al 1990, Burnett et al 1995; Hussain et al 1997). Dough stickiness was an even greater problem in 1BL/1RS doughs during high-speed mixing (Pena et al 1990), which is commonplace in modern bread factories. Martin and Stewart (1990) also noted in pilot bakery trials that 1BL/1RS dough stickiness was, in some cases, so severe that residues of sticky doughs caused equipment jams.

It is not altogether clear whether there are similar or related problems for soft wheat with 1BL/1RS genotypes. One report indicated that dough stickiness is reduced in low-protein soft wheat flours (Dhaliwal et al 1990). Mild stickiness may or may not be an insurmountable problem in soft wheat flour doughs made into cookies, crackers, and biscuits. Recent work in our department indicates that not all 1BL/1RS soft wheat lines make sticky doughs, and that quality cookies and cakes can be made from 1BL/1RS soft wheat flours (Johnson et al 1999). The objective of the current study, therefore, was to determine whether there are significant differences in the apparent dough stickiness of soft, red, winter wheat (SRWW) lines due to the presence of the 1BL/1RS translocation.

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MATERIALS AND METHODS

Cultivation, Milling, and Chemical Analysis

A total of 12 SRWW lines were evaluated in the current study. Seven of the lines were determined by enzyme-linked immunosorbent assay (ELISA) testing (Howes et al 1989) to be 1BL/1RS wheat, and two experimental lines and three commercial cultivars or checks lacked the 1BL/1RS translocation (Table I). The SRWW lines were planted in October 1995 at Warsaw and Blacksburg, Virginia, and harvested in late June and early July, respectively, of the following year. The two locations represent distinctive growing environments. Warsaw is at a lower elevation (≈240 m) and has a warmer climate and one month shorter growing season than Blacksburg (elevation ≈600 m) (Johnson et al 1999). Wheat lines were grown in randomized complete blocks with three replicates. Standard recommendations were followed for lime, fertilizer, herbicide, and pesticide application. Following harvest, grain from each replicate was composited by location and line, resulting in one composite sample for each line at each location.

Combine-harvested wheat was aged for approximately one month and then tempered overnight to 14% moisture and milled in a Quadramatic Junior laboratory mill (Brabender, Hackensack, NJ). The protein (N × 5.7), moisture, and ash content of experimental flours were determined in triplicate according to Approved Methods 46-12, 44-19, and 08-01, respectively (AACC 2000). The alkaline water retention capacity (AWRC) of flour was determined in triplicate according to Approved Method 56-10.

Dough Stickiness Testing

Apparent dough stickiness was determined by the Schwarzlaff-Shephard Dough Stripping Method. This method was modeled after a similar methodology for peel testing of pressure-sensitive tapes (Skeist 1990). Doughs were prepared immediately before stickiness testing by mixing 50 g of flour with water in a farinograph (Brabender) until each dough reached its peak time. One half of a dough sample was wrapped in plastic and the other half was rolled onto a clean 30.5- × 30.5- × 0.64-cm glass plate with a wooden rolling pin using stainless steel guides (0.16 cm thick). A 2.5- × 17.8-cm precut fiberglass mesh screen strip of 16 squares per inch was placed on top of the rolled out dough (center of dough). The second dough half was rolled out on top of the first dough layer plus fiberglass strip, again using stainless steel guides, to make a dough-fiberglass mesh strip-dough sample (Fig. 1). For testing purposes, the dough-fiberglass strip-dough sample was cut into a 2.5- × 17.8-cm strip using a knife and one of the fiberglass mesh strips as a guide.

The glass plate was then transferred to the top of a Nalgene Schwarzlaff-Shephard dough stickiness testing box so that the dough-fiberglass mesh-dough strip affixed to the glass plate was now inside the box (Fig. 2). A constant relative humidity of 97% was maintained inside for dough stickiness testing by inserting a tray filled with a supersaturated aqueous solution of potassium sulfate into the bottom of box. Humidified air was circulated inside the box by means of a small fan. A clear plastic ruler was taped to the outside of the glass plate to measure a peel distance of 0.5 in. (1.27 cm). Plastic gloves were used to attach a 50-g weight to the dough-free end of the fiberglass mesh strip. Once the weight was hung onto the mesh strip, timing began. When the dough had peeled 1.27 cm, the timer was stopped and the peel time recorded in seconds.

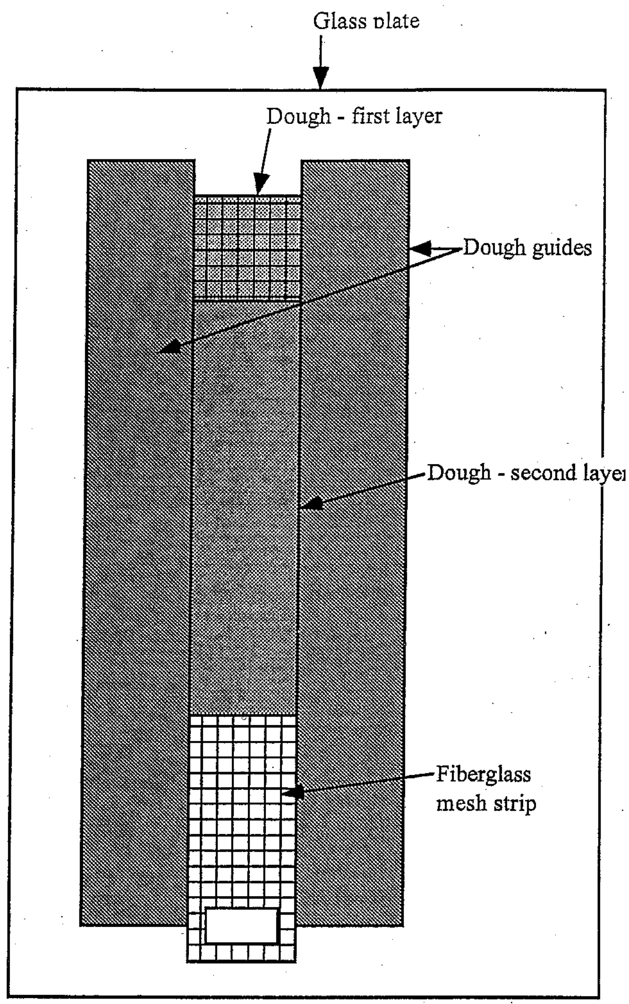

Fig. 1. Dough-fiberglass mesh-dough strip layout on a glass plate.

Statistical Analysis

The general linear model procedure was used to determine significant differences in apparent dough stickiness due to the 1B/1R translocation. Analysis of variance and a Tukey HSD test were performed to determine significant differences in the apparent stickiness of experimental SRWW doughs. The Microsoft Excel program (Microsoft Office 97) was used to determine correlations of apparent dough stickiness (peel times) with protein, moisture, and ash content and AWRC of SRWW flours. A critical values of r* table (Freund 1970) was consulted to determine whether any of the correlations were significant at the $P \leq 0.05$ or 0.01 level.

RESULTS

The P values for the pairwise comparisons of all 1BL/1RS lines versus all non-1BL/1RS lines indicate that 1BL/1RS doughs were significantly stickier, on average, than non-1BL/1RS doughs (Table II). 1BL/1RS line VA 93-54-211 was significantly stickier than its non-1BL/1RS sister line VA 93-54-209 across both locations and for Blacksburg, but not when the two lines were grown in Warsaw. There were no significant differences in the apparent dough stickiness of a second set of sister lines, 1BL/1RS lines VA 94-54-18 and VA 94-54-19 versus a non-1BL/1RS line, VA 94-54-21.

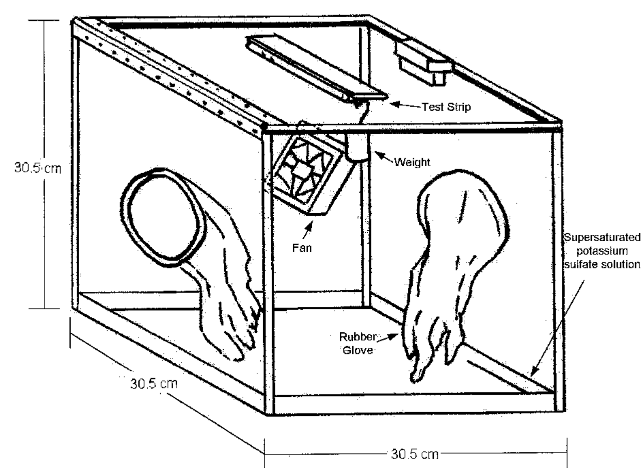

Fig. 2. Schwarzlaff-Shephard dough stickiness testing box.

TABLE I
Pedigrees of 1BL/1RS and Non-1BL/1RS Soft Red Winter Wheat Lines

Wheat Group and Line[a,b]	Abbreviation	Pedigree
1BL/1RS		
VA 93-54-211 (a)	211	Massey/3/Massey*3/Balkan//Saluda
VA 94-54-18 (b)	18	Massey*3/Balkan//2*Saluda
VA 94-54-19 (b)	19	Massey*3/Balkan//2*Saluda
VA 93-54-418	418	Saluda*2/SC822290(Nainari60/Arthur71/Kavkaz)
VA 93-54-185	185	Wheeler/3/Massey*3/Balkan//Saluda
VA 92-52-22	22	Tyler//Wheeler/Balkan
VA 93-54-258	258	VA 82-54-330 (Saluda SIB)/8/Cl13836/9*Chancellor// Wheeler/3/ Severn/4/Coker 916/5/ST1-25// ASII/9*Chancellor/6/Tyler/7/ Massey
Non-1BL/1RS		
VA 93-54-209 (a)	209	Massey/3/Massey*3/Balkan//Saluda
VA 94-54-21 (b)	21	Massey*3/Balkan//2*Saluda
Massey	Massey	Blueboy/Knox62
FFR555W	FFR	Coker 76-35/Unknown Parent
Saluda	…	VA 71-54-147(C117449)/Coker 68-15

[a] Balkan, kavkaz, and ST1-25 are the donors of 1BL/1RS.
[b] Sister lines with (a) and without (b) 1BL/1RS.

Mean peel times for each of the 1BL/1RS and non-1BL/1RS lines are presented in Table III. The higher the peel time in seconds, the stickier the dough. When the data were combined across both locations, doughs made from the 1BL/1RS line VA 93-54-211 were significantly stickier than any of the other soft wheat flour doughs tested in this study. Seventy-two percent of the genetic composition of VA 93-54-211 was derived from two crosses with Massey (Table I), which ranked highest in apparent dough stickiness among non-1BL/1RS lines. Again, when the data were combined, there were no significant differences in the peel times of four 1BL/1RS and four non-1BL/1RS lines. The 1BL/1RS line VA 92-52-22 ranked last in peel time and, hence, in apparent dough stickiness, and was significantly less sticky than two non-1BL/1RS lines, Massey and FFR555W. VA 92-52-22 was derived from crosses with Tyler and Wheeler rather than with Massey.

Correlation coefficients were determined for correlations between mean peel times and percent moisture, ash, and protein content and AWRC of milled flours from 1BL/1RS and non-1BL/1RS SRWW lines grown in 1995–96 in Blacksburg and in Warsaw (data not shown). None of these correlations were statistically significant except for a positive correlation $r = 0.526$, significant at $P < 0.01$, between mean peel times of all SRWW lines (combined data cross both locations) and the protein content of the milled flours.

DISCUSSION

Dobraszczyk (1997) is, to our knowledge, the only other investigator to use a peel test to determine apparent dough stickiness. Using an Instron testing machine to measure the peel force required to separate a dough layer from a stainless steel strip, Dobraszczyk found distinct differences in the behavior of sticky versus nonsticky doughs. Sticky doughs had higher peel energies and higher bakery stickiness scores than nonsticky doughs. According to Dobraszczyk, the peel energy of a viscoelastic dough is a combination of the surface energy bonding the dough to some substrate and cohesive energy that gets dissipated within the bulk of the dough as it peels away from the substrate. Because no significant differences in surface tension of sticky and nonsticky doughs were found, he concluded that differences in peel energy are primarily a reflection of differences in the bulk rheological behavior of doughs.

The Schwarzlaff-Shephard Dough Stripping Method was modeled after a standard test procedure used by the Pressure Sensitive Tape Council (PSTC) for determining the shear adhesion forces of pressure-sensitive tapes. In the PSTC test procedure, a weight is hung from one end of a pressure-sensitive tape causing the tape to come loose from a vertical panel to which it has been affixed. Sheer adhesion forces are measured in terms of the time it takes for the tape to peel away from the panel (Skeist 1990). Dough peeling was initiated in much the same way in our study by hanging a 50-g weight, at the same location each time, from the dough-free end of a fiberglass mesh strip. Thus, each dough strip was subjected to nearly the same initial force. The peel time of each of the doughs was recorded instead of the peel force. Rye flour doughs are notoriously sticky (Henry et al 1989); therefore, they were used as a standard for peel time testing. The mean peel time of a commercial rye flour dough was three times that of the stickiest 1BL/1RS soft wheat flour dough (Table III).

In addition to the 1BL/1RS translocation, dough stickiness is affected by a number of parameters including dough thickness and dough moisture content (Dobraszczyk 1997), temperature and relative humidity (Heddleson et al 1994), the amount of compressive force used to bond a dough to its adherend and the surface contact area (Chen and Hoseney 1995), and ash and free sulfhydryl content and proteinase activity (Noguchi et al 1976). Some of these factors were reasonably well controlled in our experiments and some were not. Doughs were rolled out to a uniform thickness using a rolling pin and pastry guides. The farinograph and dough stickiness testing box were housed in an air-conditioned laboratory at 24 ± 1°C. The relative humidity of the testing box was controlled by inserting a tray of a supersaturated solution of potassium sulfate into the bottom of the box and circulating the humidified air (97% rh) with a fan. Surface area between the dough and the fiberglass mesh strips was held constant by cutting the strips to the same dimensions each time.

Other parameters were not controlled, most notably dough moisture content. For each dough to reach its peak time in the farinograph, different amounts of water were added to each flour; thus,

TABLE III
Mean Peel Times of 1BL/1RS and Non-1BL/1RS Soft Red Winter Wheat Lines

	Peel Time (sec)[a]		
Wheat Line	**Both[b]**	**Blacksburg**	**Warsaw**
1BL/1RS			
VA 93-54-211	45.9b	51.6a	40.1ab
VA 94-54-18	19.8cde	16.8cd	22.8bc
VA 94-54-19	18.7de	15.0cd	22.3bc
VA 93-54-418	25.7cde	24.9bcd	26.4bc
VA 93-54-185	23.2cde	18.9bcd	27.4bc
VA 92-52-22	16.6e	12.5cd	20.7c
VA 93-54-258	20.1cde	21.0bcd	19.1c
Non-1BL/1RS			
VA 93-54-209	25.8cde	21.2bcd	30.3abc
VA 94-54-21	19.0de	18.1bcd	19.9c
Massey	29.5c	25.4bc	33.6ab
FFR55W	28.2cd	30.3b	26.1bc
Saluda	23.6cde	21.2bcd	26.0bc
Commercial rye flour	155a	…	…

[a] Means of nine determinations (triplicate measurements on three individually prepared doughs). Values followed by the same letter in the same column are not significantly different ($P < 0.05$).
[b] Combined data for Blacksburg and Warsaw.

TABLE II
***P* Values for Pairwise Comparisons of the Dough Stickiness of 1BL/1RS and Non-1BL/1RS Lines**

	P Value at Location		
Pairwise Comparison	**Both[a]**	**Blacksburg**	**Warsaw**
All 1BL/1RS lines versus all non-1BL/1RS lines	0.0006	…	…
All 1BL/1RS lines versus all non-1BL/1RS lines	…	0.0024	…
All 1BL/1RS lines versus all non-1BL/1RS lines	…	…	0.0114
1BL/1RS line VA 93-54-211 versus its non-1BL/1RS sister line VA 93-54-209	0.0012	…	…
1BL/1RS line VA 93-54-211 versus its non-1BL/1RS sister line VA 93-54-209	…	0.0064	…
1BL/1RS line VA 93-54-211 versus its non-1BL/1RS sister line VA 93-54-209	…	…	0.0625
1BL/1RS line VA 94-54-18 versus its non-1BL/1RS sister line VA 94-54-21	0.7928	…	…
1BL/1RS line VA 94-54-18 versus its non-1BL/1RS sister line VA 94-54-21	…	0.5586	…
1BL/1RS line VA 94-54-18 versus its non-1BL/1RS sister line VA 94-54-21	…	…	0.6230
1BL/1RS line VA 94-54-19 versus its non-1BL/1RS sister line VA 94-54-21	0.7079	…	…
1BL/1RS line VA 94-54-19 versus its non-1BL/1RS sister line VA 94-54-21	…	0.4398	…
1BL/1RS line VA 94-54-19 versus its non-1BL/1RS sister line VA 94-54-21	…	…	0.5630

[a] Combined data for Blacksburg and Warsaw.

each dough had a different moisture content. Dough stickiness is highly dependent on dough moisture (Heddleson et al 1994; Dobraszczyk 1997). Our results might have been different, therefore, if we had carefully controlled the moisture levels of the doughs and tested doughs with identical moisture contents.

Dough stickiness in 1BL/1RS wheats has been attributed to rye secalins, water-soluble, possibly sticky proteins encoded by genes on the short arm of the 1R chromosome of rye (Dhaliwal et al 1988) and, also, to the unknown effects of trans-ferulic acid moieties that are reported to be covalently linked to β-glucans of 1BL/1RS wheats (Huang and Hoseney 1999). Sidhu et al (1980) found that ferulic acid reduced the mixing tolerance of hard wheat flour doughs, presumably through reaction with, and attachment to, free-sulfhydryl groups of gluten proteins. After forming covalent linkages with β-glucan-bound ferulic acid moieties, the free-sulfhydryl groups of gluten proteins would no longer be able to form intermolecular disulfide bonds. This might upset the balance between free –SH groups and S-S linkages in gluten proteins, which is believed to be critical to dough viscoelasticity (Tanaka and Bushuk 1973). Reactions between ferulic acid and gluten proteins may occur more frequently in doughs made from high protein flours, which might explain why dough stickiness appears to be more of a problem in 1BL/1RS hard wheat than in 1BL/1RS soft wheat (Dhaliwal et al 1990). This also may explain why we found a positive correlation in this study between apparent dough stickiness of 1BL/1RS and non-1BL/1RS lines and flour protein content.

Dough stickiness in hard wheat is reportedly a function not just of the presence or absence of the 1BL/1RS translocation but also of genotype. Martin and Stewart (1990) noted that one of the 1BL/1RS hard wheat lines they tested, a cultivar named Disponent from West Germany, had no propensity whatsoever for dough stickiness. Burnett et al (1995) found wide variation in the dough stickiness of 1BL/1RS hard wheat lines and found that the stickiness of two lines was only slightly higher than that of a control wheat without the 1BL/1RS translocation. Chen and Hoseney (1995) tested the dough stickiness of 15 1BL/1RS wheat lines and found that three of the lines produced nonsticky doughs. In the current study, six out of seven doughs made from 1BL/1RS lines were found, from a statistical standpoint, to be equal to or less sticky than that of five non-1BL/1RS lines grown in the same crop year and location (Table III). Similarly, both McKendry et al (1996) and Johnson et al (1999) found that genetic background was a more important determinant of soft wheat baking quality than the presence or absence of the 1BL/1RS translocation. These findings suggest that it may be possible to produce 1BL/1RS SRWW lines that have excellent baking quality and no problems with dough stickiness.

CONCLUSIONS

Apparent dough stickiness was measured in 1BL/1RS and non-1BL/1RS soft wheat doughs using a new dough stripping method. Significant differences in apparent dough stickiness were attributed not only to the 1BL/1RS translocation but also to the effects of genotype. Results of apparent dough stickiness testing on seven 1BL/1RS and five non-1BL/1RS lines suggest that it may be possible to develop 1BL/1RS SRWW lines where dough stickiness is no longer considered an impediment to potential use in baked products.

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