

# Effects of Pearling on Falling Number and $\alpha$ -Amylase Activity of Preharvest Sprouted Spring Wheat

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## ABSTRACT

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Preharvest sprouted wheat is often characterized by the falling number (FN) test. FN decreases in preharvest sprouted wheat as enzymatic degradation of the starchy endosperm increases. Wheat with FN values <250–275 is often discounted at the time of sale. The intent of this investigation was to evaluate the effects of debranning or pearling on the flour quality traits of five samples of wheat rated as low, med-low, medium, med-high, and sound that exhibited a range in FN values of 62–425 sec. Replicates of each sample were pearled for 30, 60, and 120 sec to remove portions of the outer bran layers before milling. FN was highly correlated with  $\alpha$ -amylase activity ( $r > -0.97$ ) in the med-low, medium, and med-high FN sample sets as pearling time increased. FN increased in the med-

low, medium, and med-high FN samples by 128, 123, and 80%, respectively, after 120 sec of pearling. Pearling had no effect on flour FN of the low FN sample but  $\alpha$ -amylase activity was significantly decreased. Pearling had little or no effect on FN and  $\alpha$ -amylase activity of the sound sample. FN was moderately to strongly correlated with Rapid Visco Analyser (RVA), alveograph, and farinograph properties, and poorly correlated with protein content, flour yield, and bread loaf volume. In subsequent breadmaking studies, bread loaf volume, and crumb characteristics of flour from pearled wheat were not significantly different from loaf volume and crumb characteristics of flour from the corresponding nonpearled wheat.

Preharvest sprouting in wheat results in large economic losses throughout the wheat growing regions of the world. Economic losses are unpredictable because the frequency of preharvest sprouting is weather related (Meredith and Pomeranz 1985) and the severity of sprout damage is influenced by the degree of grain ripening and amount of rainfall before harvest (Mares 1993). Sprouted kernels are generally bleached and mealy in appearance, have lower test weight than sound kernels (Meredith and Pomeranz 1985), and are classed as damaged according to U.S. Grain Standards (Halverson and Zeleny 1988).

Preharvest sprouted wheat is reduced in grade and value, depending on the quantity of sprouted kernels present in a sample. In commercial milling industries, a sample of wheat is often discounted at the time of sale when falling number (FN), an indirect measure of sprout damage, is <250–275 sec (*personal communication*). Sound wheat with FN > 350 sec is preferred. Monsalve-Gonzalez and Pomeranz (1993) reported a highly significant negative correlation between wheat FN and  $\alpha$ -amylase enzyme activity. The severity of sprout damage was related to the extent of starchy endosperm degradation caused by the  $\alpha$ -amylase enzyme, but did not preclude other harmful agents that were synthesized in the sprouted kernels (Meredith and Pomeranz 1985).

The biochemical changes that occur in preharvest sprouted wheat have been the focus of several reviews (Meredith and Pomeranz 1985; Hill and MacGregor 1988; Kruger and Reed 1988). Reviewers alluded to the synthesis and movement of the  $\alpha$ -amylase enzyme in sprouted kernels, the discovery of isoenzymes of  $\alpha$ -amylase, and the activity of  $\alpha$ -amylase as a starch-degrading enzyme that specifically hydrolyzes  $\alpha$ -(1,4)-D-glucosidic linkages from starch oligosaccharides. The effects of preharvest sprouting on baking quality are well known (Hwang and Bushuk 1973; Rahnorta et al 1977; Ibrahim and D'Appolonia 1979; Kurger 1980; Kulp et al 1983; Ariyama and Khan 1990; Lorenz et al 1983). However, studies are needed to determine whether  $\alpha$ -amylase activity, relative to FN,

can be reduced in the milling process as a means of increasing the end-use value and baking quality of the flour.

Posner and Hibbs (1997) suggested that debranning wheat to remove the embryo and outer bran layers before milling reduced  $\alpha$ -amylase activity in the flour. Kruger and Hatcher (1993) found that flour milled from wheat with elevated sprout damage, as measured by the FN test, contained increasing amounts of  $\alpha$ -amylase, and that decreasing mill extraction rate reduced the amounts of  $\alpha$ -amylase in the flour.

In this study, cultivars of spring wheat that ranged from low to high FN were obtained. The objective was to investigate the effects of pearling (debranning) on flour and baking quality. The hypotheses is that flour from pearled wheat would contain less residual  $\alpha$ -amylase and have higher FN than corresponding flour from wheat that had not been pearled.

## MATERIALS AND METHODS

### Wheat Samples

Five cultivars of hard spring wheat were selected from the 1999 crop harvested at Crookston, MN. FN was averaged over cultivars, which were rated as low FN, med-low FN, medium FN, med-high FN, and sound wheat (Table I). A complete randomized block design experiment was conducted using 5×4 (FN rating by pearling time) between groups × 3 replicates within groups factors. Whole wheat FN ranged from 62 sec (low FN wheat) to >400 sec (sound wheat). Subsamples (1 kg) of each cultivar were pearled (Strong-Scott Pearler, model 17810, Seedburo Equipment, Chicago, IL) for 30, 60, or 120 sec to remove portions of the bran layers. For comparison, subsamples from each cultivar that were not pearled served as controls.

### Milling

All samples (control and pearled samples) were tempered to 15.5% wb and conditioned for 24 hr at 20°C. Samples of 600–800 g were milled separately in an experimental mill (model MLU-202, Buhler, Minneapolis, MN) at a feed rate of 100 g/min. Flour yield was calculated on a total product basis and adjusted for the loss of bran that resulted from pearling action.

### Dependent Variables

Kernel test weight was measured according to Approved Method 55-10 (AACC 2000). Pound per Winchester bushel (× 1.297) was converted to kilograms per hectoliter (Halverson and Zeleny 1988). Kernel weight was measured by counting the number of seeds

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in a 10-g sample of cleaned wheat using a seed counter (Seedbuco Equipment, Chicago, IL). FN was measured by the Falling Number 1800 Instrument (Perten Instruments, Springfield, IL) by Approved Method 56-81B; moisture by Approved Method 44-15A; protein by Approved Method 46-30; and ash by Approved Method 08-01 (AACC 2000). The Ceralpha Method (Megazyme International, Wicklow, Ireland) was used to measure  $\alpha$ -amylase activity. One Ceralpha unit of activity was defined as the amount of enzyme, in the presence of excess thermostable  $\alpha$ -glucosidase, required to release 1  $\mu$ M of *p*-nitrophenol from blocked *p*-nitrophenyl maltoheptaoside/min under defined assay conditions. Pasting properties of the flour were determined using the Rapid Visco Analyser (RVA) (Newport Scientific, Eden Prairie, MN), Thermocline for Windows software (v. 2.2), and Approved Method 76-21 (AACC 2000). A slurry of 3.5 g flour (14% mb) and 25 mL of water was stirred at 160 rpm and heated according to the following temperature profile: hold 1.0 min at 50°C; ramp temperature 12.5°C/min to 100°C and hold for 2.5 min; and decrease temperature 12.5°C/min for 4 min to 50°C and hold for 4.0 min. Farinograph properties were measured using a 50-g bowl according to Approved Method 54-21 (AACC 2000). Alveograph properties were measured under constant hydration capacity (58% moisture) according to Approved Method 54-30A (AACC 2000). Bread was baked by the straight-dough method using 100 g of flour according to Approved Method 10-09 (AACC 2000). Bread was measured for loaf volume and rated subjectively for internal crumb color, grain, and textural quality.

### Statistical Analysis

The between group combinations of FN rating and pearling time and within group replicates were milled separately. The 5 × 4 factorial was a complete randomized block design. Analysis of variance (ANOVA) of FN and pearling time was conducted using Statistica software (v. 5.1, StatSoft, Tulsa, OK). FN and pearling time fixed effects were compared using the Tukey's honest signi-

ficant difference (HSD) test ( $P = 0.05$ ). Associations between dependent variables were determined by Pearson's correlation coefficients ( $P = 0.001$ ).

## RESULTS AND DISCUSSION

### Pearling Effects on Wheat and Flour Physical Properties

The cultivars that were rated as low, med-low, medium, and med-high had FN values that were low enough to be discounted by a commercial elevator (*personal communication*) and potentially be graded as sample grade according to Official U.S. Grain Standards (Halverson and Zeleny 1988). The effects of pearling

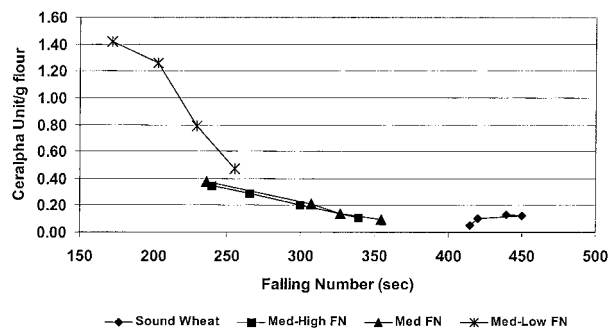


Fig. 1. Relationship between flour falling number and  $\alpha$ -amylase enzyme activity (Ceralpha unit/g of flour) as a function of pearling wheat.

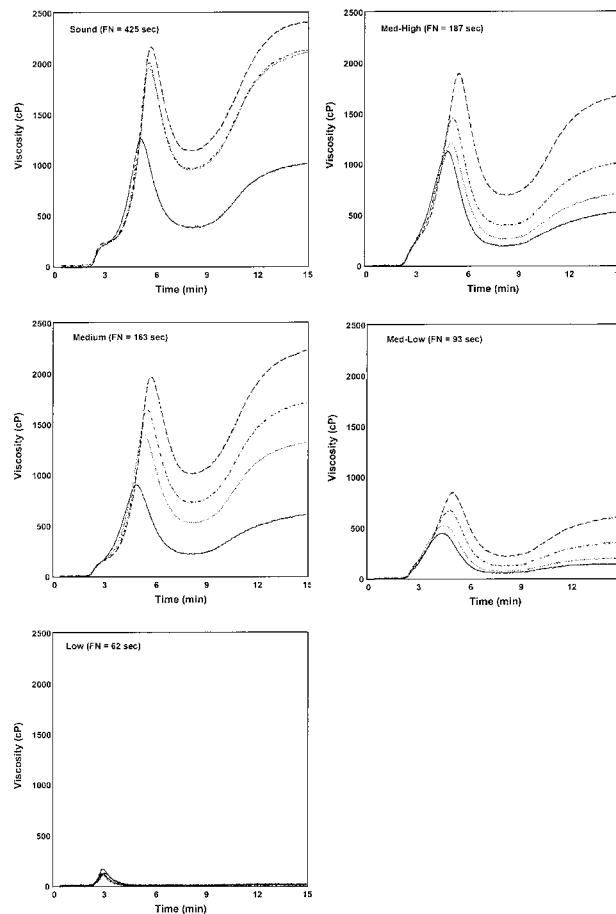


Fig. 2. Effect of pearling on RVA viscosity profiles (Pearling time: control, 30, 60, and 120 sec).

TABLE I  
Treatment and Dependent Response Factors

Treatment			
Wheat FN Rating <sup>a</sup>	Pearling Time (sec)	Replicates (within groups)	Response Factors
Low (FN 62)	0	A	Wheat and flour FN
Med-Low (FN 93)	30	B	Test weight
Medium (FN 163)	60	C	Kernel weight
Med-High (FN 187)	120		Wheat and flour protein
Sound (FN 425)			Wheat and flour ash
			Flour yield
			RVA pasting properties
			Alveograph <i>P/L</i> ratio
			Farinograph properties
			Bread loaf volume
			Crumb color
			Crumb grain
			Crumb texture
			Wheat and flour ash

<sup>a</sup> Falling number (FN) values in parentheses are averages of within-group replicates of control (nonpearled) samples.

the med-low, medium, med-high, and sound samples on  $\alpha$ -amylase enzyme activity (Ceralpha U/g of flour) and flour FN are shown in Fig. 1. The relationship between flour FN and  $\alpha$ -amylase activity was highly significant ( $r > -0.97$ ) in the med-low, medium, and med-high FN samples, but not significant in the sound sample. Flour from the medium and med-high FN samples was increased to FN levels  $> 325$  sec with pearling time of 120 sec, and at these levels, the enzyme activities were similar to that of the pearled sound wheat samples. Enzyme activity in flour milled from low FN wheat (*data not shown*) was reduced from 35 to 10 Ceralpha U/g of flour as pearling time increased, but flour FN was not affected. Thus, some factors that may explain differences in magnitude of FN and  $\alpha$ -amylase activity as a result of pearling include differences in physical properties of the kernels, resistance to abrasion during the pearling process, activity level and rate of diffusion of  $\alpha$ -amylase into the endosperm, and activities of other enzymes that act on other components in the sprouted grain.

Pearling preharvest sprouted wheat resulted in significant changes in starch pasting properties of the milled flour, with the exception of the low FN sample, when measured by the RVA (Fig. 2). RVA measurements were significantly correlated with wheat and flour FN values (Table II). Concomitant increases in RVA peak viscosities occurred in the med-low, medium, and med-high FN samples with increased pearling time. In addition, peak viscosities increased in the sound samples that were pearled (Fig. 2) despite no significant changes in  $\alpha$ -amylase activity. This suggested that other factors besides decreased  $\alpha$ -amylase activity attributed to differences in starch pasting properties. These factors include actions of proteases, cellulases, lipases, oxidases-reductases, and nucleases that are synthesized in wheat (Meredith and Pomeranz 1985). Hence, further studies are needed to ascertain the role of these biochemical constituents on pasting properties. Because all samples were tempered to the same moisture content before milling and despite loss of bran integuments during pearling, higher RVA peak

**TABLE II**  
Correlation Coefficients ( $r$ ) Among Dependent Variables<sup>a</sup>

Dependent Variable <sup>b</sup>	FFN	TW	KW	WPRO	WASH	FPRO	FASH	RVAPK	RVATR	RVASB	FYLD
WFN	0.97*	0.86*	0.46*	-0.22	-0.51*	-0.14	-0.54*	0.94*	0.92*	0.94*	-0.03
FFN		0.86*	0.60*	-0.36	-0.43*	-0.28	-0.43*	0.94*	0.87*	0.92*	0.06
TW			0.47*	-0.27	-0.60*	-0.18	-0.56*	0.80*	0.78*	0.82*	0.10
KW				-0.24	0.26	-0.21	0.28	0.36	0.25	0.30	0.70*
WPRO					0.29	0.98*	0.00	-0.40	-0.20	-0.32	0.23
WASH						0.22	0.75*	-0.56*	-0.64*	-0.63*	0.77*
FPRO							-0.03	-0.34	-0.14	-0.26	0.19
FASH								-0.60*	-0.70*	-0.68*	0.56*
RVAPK									0.95*	0.98*	-0.14
RVATR										0.98*	-0.20
RVASB											-0.20
FYLD											
APL											
AW											
FGABS											
FGPT											
FGDS											
FGMTI											
FGTTB											

<sup>a</sup> Marked correlations (\*) were significant at  $P < 0.001$ ,  $n = 60$ .

<sup>b</sup> WFN = wheat falling number, FFN = flour falling number, TW = test weight, KW = kernel weight, WPRO = wheat protein, WASH = wheat ash, FPRO = flour protein, FASH = flour ash, RVAPK = RVA peak time viscosity, RVATR = RVA trough viscosity, RVASB = RVA setback viscosity, FYLD = flour yield, APL = alveograph  $P/L$  ratio, AW = alveograph  $W$  value, FGABS = farinograph water absorption, FGPT = farinograph peak time, FGDS = farinograph dough stability, FGMTI = farinograph mechanical tolerance index, FGTTB = farinograph time to breakdown, LV = bread loaf volume.

**TABLE II (continued)**  
Correlation Coefficients ( $r$ ) Among Dependent Variables<sup>a</sup>

Dependent Variable <sup>b</sup>	APL	AW	FGABS	FGPT	FGDS	FGMTI	FGTTB	LV
WFN	0.71*	0.76*	0.72*	0.52*	0.72*	-0.67*	0.59*	0.02
FFN	0.72*	0.71*	0.67*	0.41	0.65*	-0.66*	0.51*	-0.07
TW	0.61*	0.69*	0.67*	0.39	0.59*	-0.66*	0.49*	0.05
KW	0.12	0.46*	0.47*	0.23	0.33	-0.55*	0.34	0.13
WPRO	-0.68*	0.29	0.32	0.62*	0.33	-0.10	0.52*	0.80*
WASH	-0.66*	-0.26	-0.33	-0.11	-0.25	0.24	-0.16	0.09
FPRO	-0.64*	0.35	0.41	0.69*	0.41	-0.20	0.61*	0.85*
FASH	-0.54*	-0.46*	-0.38	-0.24	-0.35	0.13	-0.22	0.01
RVAPK	0.85*	0.63*	0.54*	0.32	0.58*	-0.51*	0.39	-0.22
RVATR	0.76*	0.71*	0.67*	0.46*	0.64*	-0.53*	0.50*	-0.03
RVASB	0.82*	0.67*	0.61*	0.36	0.59*	-0.51*	0.42*	-0.14
FYLD	-0.44*	0.25	0.16	0.20	0.10	-0.17	0.20	0.26
APL		0.21	0.17	-0.08	0.20	-0.20	-0.01	-0.52*
AW			0.90*	0.78*	0.83*	-0.70*	0.82*	0.50*
FGABS				0.83*	0.84*	-0.77*	0.89*	0.64*
FGPT					0.85*	-0.67*	0.95*	0.73*
FGDS						-0.81*	0.92*	0.50*
FGMTI							-0.82*	-0.41
FGTTB								0.72*

<sup>a</sup> Marked correlations (\*) were significant at  $P < 0.001$ ,  $n = 60$ .

<sup>b</sup> WFN = wheat falling number, FFN = flour falling number, TW = test weight, KW = kernel weight, WPRO = wheat protein, WASH = wheat ash, FPRO = flour protein, FASH = flour ash, RVAPK = RVA peak time viscosity, RVATR = RVA trough viscosity, RVASB = RVA setback viscosity, FYLD = flour yield, APL = alveograph  $P/L$  ratio, AW = alveograph  $W$  value, FGABS = farinograph water absorption, FGPT = farinograph peak time, FGDS = farinograph dough stability, FGMTI = farinograph mechanical tolerance index, FGTTB = farinograph time to breakdown, LV = bread loaf volume.

viscosities in pearled samples may be related to a combination of reduced  $\alpha$ -amylase activity and lower starch damage, which needs to be confirmed in future studies. The RVA profiles of the low FN subsamples were not affected by pearling.

The effects of pearling on test weight and kernel weight are shown in Fig. 3. Pearling caused significant increases in test weights of the low, med-low, medium, and med-high FN samples, especially after 30 sec of pearling, but had no effect on test weight of the sound sample. In the med-low, medium, and med-high FN samples, degradation of protein and starch in the bran and aleurone layers likely preceded degradation of the starchy endosperm. In that case, greater differential would occur between bran layer density and endosperm density. Dronzek et al (1972) reported that enzymatically degraded starch granules were visible near the aleurone layer in sprouted wheat, indicating the movement of  $\alpha$ -amylase in the kernel. By pearling off the less dense bran and aleurone layers of these wheat samples, the higher density endosperm portion of the kernels would remain and contribute to higher test weight. Also, the polishing effect by pearling action would tend to increase packing efficiency and uniformity in kernel size, thereby resulting in higher test weight (Hlynka and Bushuk 1959). Pearling resulted in decreased kernel weight and size of all samples, as expected. However, pearling had the least effect on kernel weight of the low FN sample, which decreased slightly from 21 g/1,000 kernels to 19 g/1,000 kernels. This suggested that the density of the bran, aleurone, and endosperm components in the low FN sample was similar throughout the kernels. However, FN of the low FN sample remained the same despite pearling, whereas  $\alpha$ -amylase activity decreased significantly with respect to pearling as mentioned previously. Pearling had the greatest effect on kernel weight of the sound sample,

which decreased from 38 g/1,000 kernels to 27 g/1,000 kernels. This suggested that the bran layers of sound wheat contribute substantially more to kernel density than bran of sprouted wheat.

### Pearling Effects on Protein, Ash, and Flour Yield

Pearling action caused slight decreases in wheat protein and significant decreases in ash content in all samples (Fig. 3). Flour protein was not affected by pearling, but flour ash was significantly reduced in the med-low, medium, and med-high FN samples (*data not shown*). Flour yield decreased significantly in all samples when factoring in the weight of bran that was removed in the pearling process (Fig. 3). Typically, the bran and aleurone, which remains attached to the bran during milling, represent  $\approx 14.5\%$  of the kernel and contain 10–20 $\times$  the ash content as the endosperm (Posner and Hibbs 1997). By comparison, ash has the highest specific gravity of all the components in wheat. Among all samples, kernel weight was decreased by 6.5 to 8.5% after 30 sec of pearling, 12 to 16% after 60 sec of pearling, and 22 to 29% after 120 sec of pearling. These results suggested that  $\approx 30$ –60 sec of pearling would be optimum under these laboratory conditions to remove the bran layers that are highest in  $\alpha$ -amylase activity without removing large portions of the endosperm.

Overall, flour yield decreased by 1.3 to 3.3 percentage points when wheat samples were pearled for 30 sec. Therefore, the medium and med-high FN samples, as opposed to the low and med-low FN samples, could potentially be milled into flour exhibiting a higher FN without dramatic loss in flour yield than if the samples were not pearled. Hence, a trade-off between flour yield and increase in FN should be considered when evaluating the economic impact of pearling wheat before conventional milling.

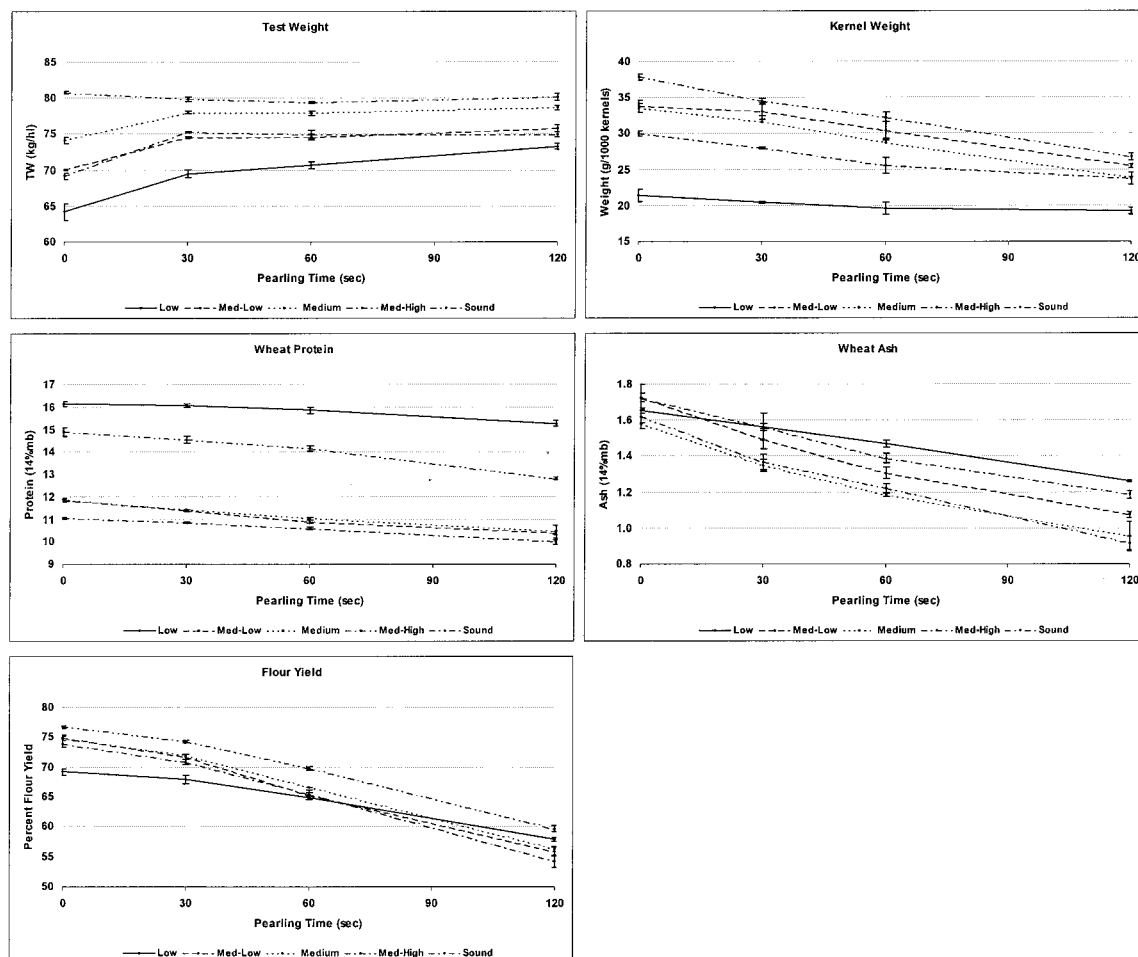


Fig. 3. Effect of pearling on test weight, kernel weight, wheat protein and ash content, and flour yield ( $n = 3$ ,  $\pm$  standard deviation of within-group replicates).

## Pearling Effects on Dough and Bread Properties

Pearling resulted in significant increases in alveograph  $P/L$  ratios of the med-low, medium, med-high, and sound wheat samples, but had no effect on  $P/L$  ratio of the low FN sample (Fig. 4). The increases in  $P/L$  ratio could be attributable to wheat tempering conditions, differences in starch damage and particle size of the flour, or differences in gluten quality. Alveograph  $P/L$  ratios were significantly correlated with FN and RVA measurements (Table II). Unlike alveograph  $P/L$  ratios, farinograph properties were not significantly affected by the increase in FN that accompanied pearling (Fig. 4). Wheat FN and RVA properties were significantly correlated with farinograph water absorption (Table II). Ibrahim and D'Appolonia (1979) reported a decrease in water absorption and dough development time as levels of sprouting increased in cultivars with different levels of sprout damage. Hwang and Bushuk (1973) reported that both quantitative and qualitative changes occurred in the endosperm protein during sprouting. In this study, the sound sample had higher farinograph water absorption, peak time, dough stability, and time to breakdown than the other samples. Therefore, any changes in farinograph measurements are likely related to other factors such as protease activity on the gluten structure.

Bread loaf volume was not significantly affected by pearling wheat (Fig. 4). These results are in agreement with Ibrahim and D'Appolonia (1979), who reported that no detrimental effects occurred in loaf volume when comparing the increase in sprouting among different wheat cultivars. However, Ariyama and Khan (1990) reported significantly higher loaf volumes than controls because of higher  $\alpha$ -amylase activity in sprouted wheat. Lorenz et al (1983) reported that high levels of protease caused expanded loaf volume

and poor internal crumb characteristics. In this study, loaf volume of each control sample represented a baseline from which to compare loaf volume of flour from pearled wheat. Wheat protein content appeared to have the greatest effect on loaf volume rather than FN and  $\alpha$ -amylase activity. The low FN and sound samples contained the highest protein levels and yielded greater loaf volumes than the other samples.

Bread crumb color, grain, and texture remained statistically the same ( $P = 0.05$ ) in the pearled samples as in the corresponding control sample of each cultivar (*data not shown*). However, when comparing bread characteristics across different cultivars and pearling times, the sound wheat exhibited better crumb color, grain, and texture than the other wheat samples. Ranhotra et al (1977), Ibrahim and D'Appolonia (1979), and Lorenz et al (1983) reported that low FN wheat resulted in gradual deterioration of bread quality.

## CONCLUSIONS

Pretreating low FN wheat by pearling before milling into flour increased flour FN, peak viscosity of the flour slurry, kernel test weight, and alveograph  $P/L$  ratio. Pearling had a negative effect on wheat and flour protein content and flour yield, and a positive effect on reducing wheat and flour ash content. Pearling had no effect on farinograph properties. Bread loaf volume and crumb characteristics were not affected by the pearling treatments.

## ACKNOWLEDGMENTS

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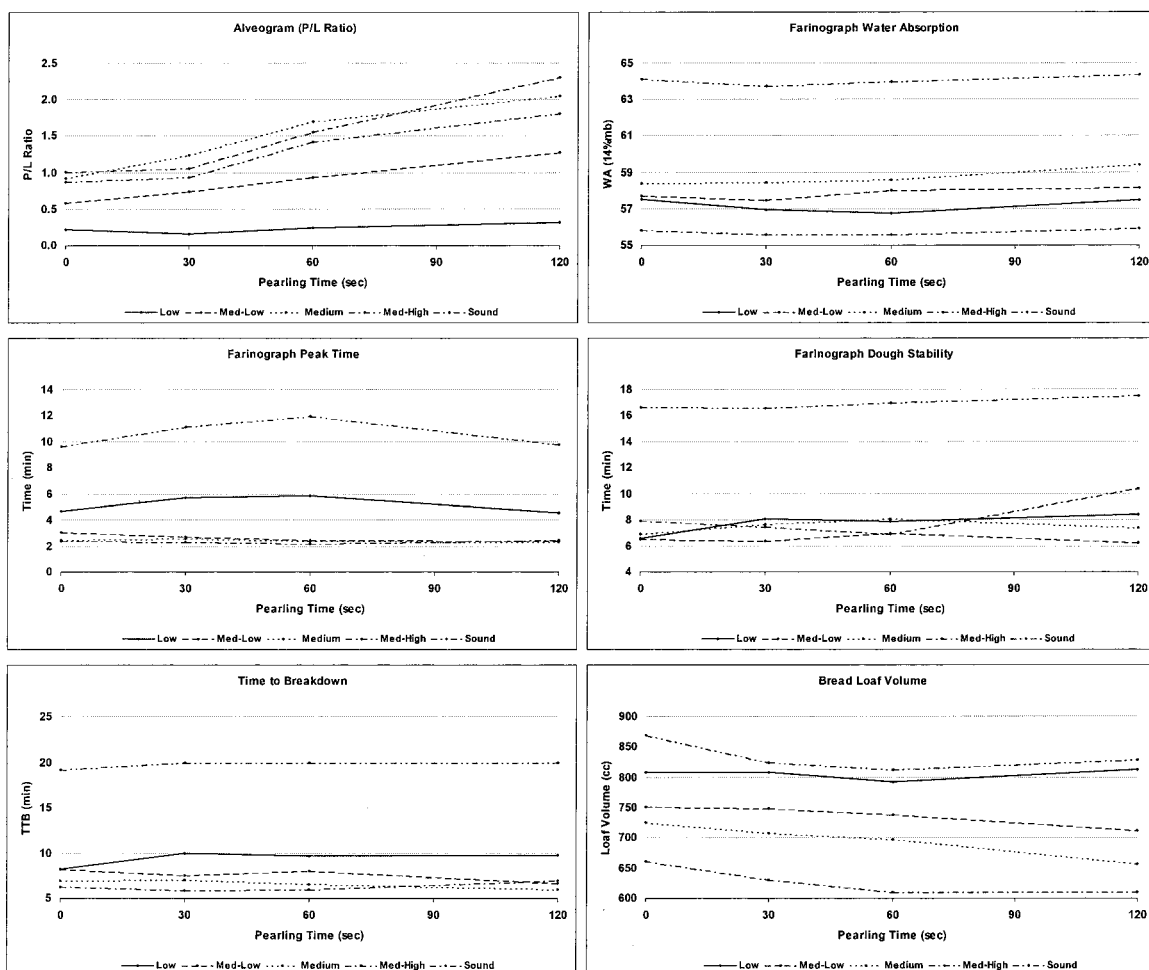


Fig. 4. Effect of pearling on dough and bread loaf volume. Alveogram  $P/L$  ratio = maximum overpressure or resistance to dough deformation/abscissa at dough rupture; farinograph water absorption, peak time, dough stability, and time to breakdown; and bread loaf volume ( $n = 3$ ).

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